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INDUSTRIAL ENGINEERING STUDY OF HAZARDS ASSOCIATED WITH UNDERGROUND COAL MINE PRODUCTION

VOLUME I

THEODORE BARRY AND ASSOCIATES

USBM CONTRACT REPORT S0110601

DECEMBER 10, 1971

THEODORE BARRY
AND ASSOCIATES
MANAGEMENT CONSULTANTS

DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
WASHINGTON, D. C.

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VOLUME I

ANALYSIS OF UNDERGROUND HAZARDS AND FATAL ACCIDENTS

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DECEMBER 10, 1971

Department of the Interior
Bureau of Mines
Washington, D. C.

FOREWORD

This report was prepared by Theodore Barry and Associates, 1151 West Sixth Street, Los Angeles, California under USBM Contract No. S0110601. The contract was initiated under the Coal Mine Health and Safety Program. It was administered under the technical direction of the Spokane Mining Research Center with Mr. Thomas W. Martin acting as the technical project officer. Mr. Frank M. Naughton was the administrator for the Bureau of Mines.

This report is a summary of the work recently completed as part of this contract during the period December 10, 1970 to December 10, 1971. This report was submitted by the authors for final approval on November 30.

Per contractual requirement, all raw data and the card deck of the computerized fatality accident data base have been submitted to the technical project officer.

This technical report has been reviewed and approved.

Theodore Barry and Associates

PREFACE

During this study, Theodore Barry and Associates has visited and worked in over 50 underground coal mines in all parts of the United States. Throughout the entire effort we were extremely impressed by the depth of commitment and the sincerity of the men who comprise our country's coal industry. Almost without exception, we received strong support and cooperation from every sub-group within the industry -- owners, management, union officials, and mine workers. We believe that the interest and enthusiasm of these individuals and groups was a function of their genuine concern for the improvement of safety in the mines, and an honest desire to improve the quality of the industry's image in the eyes of the American people. It is the dedication that we saw and felt which leads us to be sincerely optimistic about the prospects for continuing improvements in the industry's safety records.

We would like to thank all of those throughout the coal industry who assisted not only as representatives of various groups, but also as individuals in contributing the information, ideas, and insights which served as the foundation for this report. We hope their reward can be measured in lives saved.

ABSTRACT

In 1970, the U. S. Bureau of Mines contracted with Theodore Barry and Associates, a management consulting firm, to perform a one-year industrial engineering study of working-face hazards in underground bituminous coal mines. The field data was accumulated from industrial engineering observations in fifty underground mines. Supporting data for the analysis was derived primarily from the Bureau's fatal accident reports for the years 1966 through 1970.

This report, Industrial Engineering Study of Hazards Associated with Underground Coal Mine Production, consists of three main parts: 1) The Fatal Accident Reports Analysis, 2) The Industrial Engineering Analysis, and 3) Multiflow Process Charts and Standard Time Data.

The Fatal Accident Reports Analysis (Volume I, Section II) is based upon individual USBM fatal accident reports for 1966-1970. These were read, coded and computerized in terms of 84 significant variables. Cross-tabulations of these variables have been used to identify major underground hazards and to quantify significant causal factors.

A very strong relationship was found to exist between fatal accident occurrences and low task experience. This led to a recommendation for formalized training, certification and supervision programs for miners. Victim compliance with federal regulations, mine regulations and supervisor instructions was analyzed, indicating that supervisors provide the most crucial communication link to workers. Thus, every attempt should be made to ensure the competence of immediate supervisors in the industry.

Analysis of roof fall variables revealed a fatal propensity on the part of the miners to work under unsupported roof or under support conditions that are marginal. The technical approach to the problem is to make it physically impossible for a miner to work under these conditions; the behavioral approach is to ensure adequate training and develop proper safety attitudes among the miners.

The Fatal Accident Reports Analysis revealed a need for normalizing data to interpret the results more accurately.

The Industrial Engineering Analysis (Volume I, Section III) is primarily represented by twelve Fatality Reduction Projects (Chapters 7-18). These projects focus upon highly hazardous areas identified through the Fatal Accident Reports Analysis and through underground industrial engineering observations. Recommendations are evaluated in terms of estimated annual cost to the industry and estimated potential lives saved.

The recommendations developed in Chapters 7 and 8 on temporary and permanent support are mainly concerned with low-cost truss support systems and improved support installation procedures which can substantially reduce fatal accidents. The reduction of maintenance accidents, discussed in Chapter 9, can be accomplished through improved training and certification programs. Chapters 10 and 12, concerning protection for face equipment operators, develops major recommendations in the areas of operator cages and equipment matching.

Chapter 11, which discusses shuttle haulage accidents, points out that the articulated, center-seated shuttle could substantially reduce haulage fatalities if employed on an industry-wide basis. However, since this is not a practical near-term solution, cage protection for side and corner-seated shuttles is recommended as a workable compromise. Chapter 14 discusses auger mining hazards and develops recommendations regarding improved winch jacks, crew-sized canopies, and retractable auger guards.

Brattice cloth is involved in two types of major underground hazards: maintaining the brattice near the face, and tramming through line brattice. These problems are discussed in Chapters 15 and 18. A simple, automatic brattice-advance is proposed as a solution to the brattice maintenance problem. Specific, improved procedures and low-cost equipment accessories are recommended to reduce the hazards generated by tramming through check curtains. As Chapter 17 shows, the few surveying fatalities expected during the early 1970's can be substantially reduced through a number of procedural changes.

Chapter 20 discusses the additional research needed in certain areas for which the optimal solution was not identifiable, or for which sufficient data was not available to make a useful judgement. The top priority areas of new research include: development of a USBM internal technical consulting group, development of a mine classification system, and development of a system for computing the real costs of roof control.

The Multiflow Process Charts (Volume II, Chapter 2) illustrate, in diagrammatic form, the time-related interaction between all job elements. These charts have been construed so as to be interpretable by a layman with limited mining knowledge. The Standard Time Data (Volume II, Chapters 3 and 4) represents typical cycle element times for all activities associated with the working face. Hazardous exposure times have been noted. The time study data forms part of the empirical basis upon which the Fatality Reduction Projects have been developed.

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INTRODUCTION AND DESCRIPTION OF THE STUDY

CHAPTER 1

INTRODUCTION

I. BACKGROUND AND OBJECTIVES OF THE STUDY

Falls of roof, rib, and face account for approximately 60% of the fatalities in the underground bituminous coal mines (100 men/year). Seventy percent of these occur within 25 feet of the active face in unsupported or inadequately supported areas. Haulage accidents, machinery accidents, and explosions account for the majority of the remaining fatalities.

Fatal accident reports normally contain extensive detail on the conditions surrounding these accidents. However, very little data is available on the relation between hazardous work elements in jobs and the flow process of jobs at typical faces in the industry. In addition, available fatality statistics are not normalized with respect to the total manhours of certain kinds of hazardous exposure in related jobs throughout the industry. All of these factors make it difficult to assess the significance of the conditions contributing to each fatality and to make recommendations that could reduce fatality frequency.

The U.S. Bureau of Mines saw the need for information regarding not only job elements subjected to hazardous exposure, but also the nature of the hazard and the time of exposure. Therefore, the Bureau of Mines decided that an industrial engineering study of all jobs related to underground coal mine production would prove useful.

Consequently, in April of 1970 a Request for Proposal (RFP) was released by the USBM to conduct an "Industrial Engineering Study of Hazards Associated with Underground Coal Production". Theodore Barry and Associates successfully competed for this study, and in December, 1970 was awarded a one-year contract to complete the work.

The provisions of this contract included the following:

> "The Contractor shall analyze existing accident data pertaining to roof-fall fatalities in underground coal mines. Primary source of the data will be the Bureau of Mines' files; however, supplementary information concerning details not reported on the official accident report forms will be obtained from other sources such as mine

> operators. These data will be arrayed in matrix form to determine what kind of sampling would be truly representative of the whole field study.
>
> "The Contractor shall analyze all available data on underground coal mines now operating in the United States in terms of seam thickness, production level, mining method, type of overburden, type of roof support, type of mine plan, and other factors deemed germane to complete characterization of mining operations.
>
> "The Contractor will establish a work-element breakdown for each operation and face work station in sufficient detail to permit the study of all variables which could possibly affect operational safety. The form of the data summary log into which all of the observations will be registered will be developed."

The essential products of this research effort were outlined in the contract as follows:

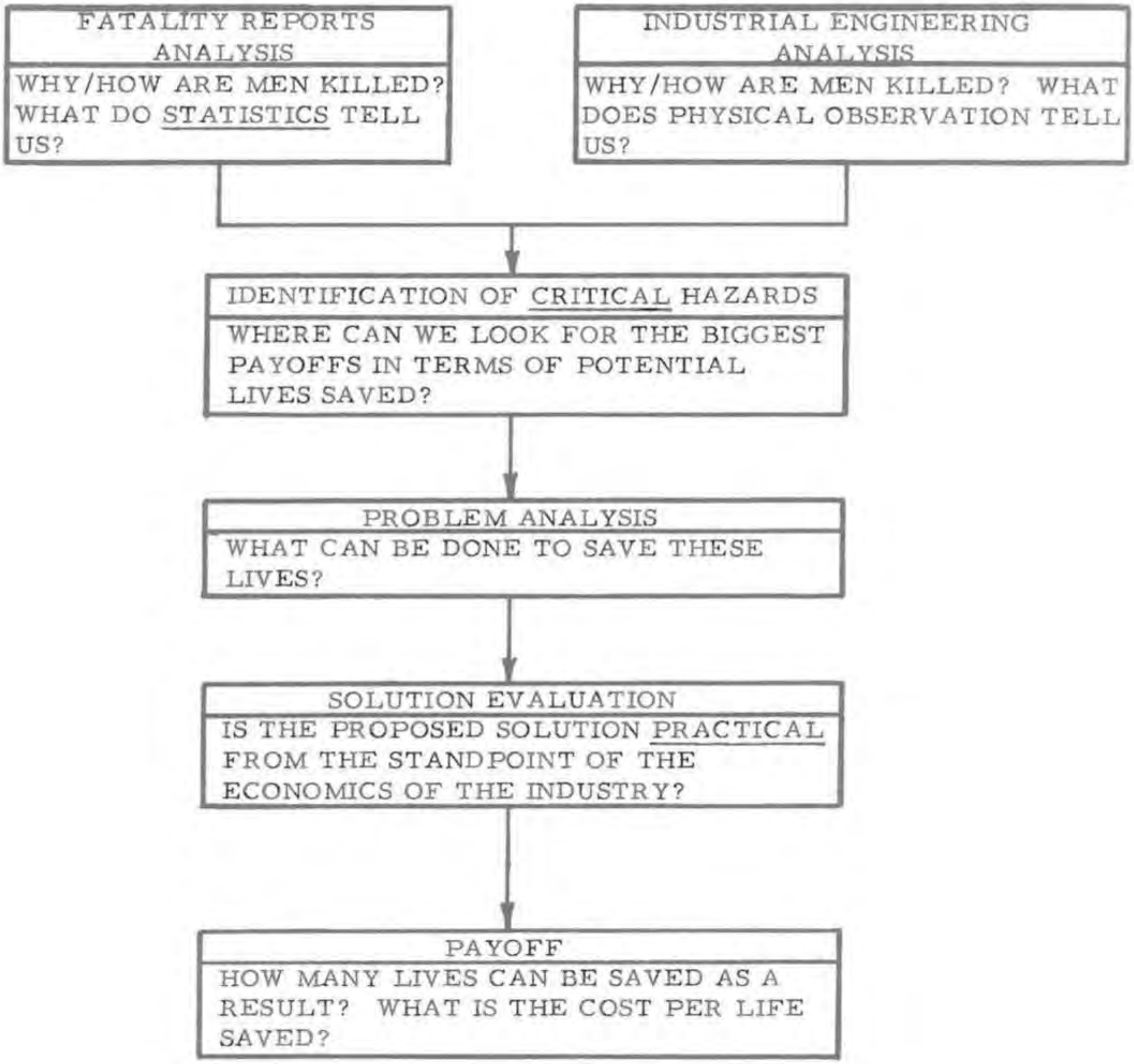
> "In each of the mines selected for study, the Contractor shall analyze all production operations from the face out to the main-line haulage point. This will include mining of entries, crosscuts, rooms and pillars, and temporary and permanent timber and roof-bolt support. All phases of the production cycle for both continuous and conventional mining operations shall be analyzed. The mining operation will be treated as a total system comprised of such factors as mining pattern, mining methods, water and roof control, methane control, dust control, ventilation, and subsidence control.
>
> "The Contractor shall explore ways of changing the work elements in ways which would reduce accident exposure from rib and roof falls. These would include eliminating hazardous work elements by substituting other less hazardous elements and reducing the degree of hazards by the adoption of different

> safety practices, work patterns, or crew assignments. Improvements in present safety codes will be considered, and the implications of such changes will be evaluated. Equipment modifications and changes in work practices and mining methods will also be considered.
>
> "Based upon his extensive analyses, the Contractor will recommend those changes in work practices, mining methods, equipment, and safety practices which can effectively reduce the fatality rate from rib and roof falls. In addition, the contractor will identify additional research areas which could potentially reduce fatality frequency.
>
> "The Contractor shall prepare multiflow process charts which will illustrate in diagrammatic form the time-related interaction between all job elements. They will be constructed in a manner such that they are interpretable by plan view sketches; the charts will depict all job elements of the production cycle as they are time-and-space related to each other. They would, if photographed in sequence, produce an animation depicting the combined performance of all components in the operation."

II. APPROACH TO THE PROBLEM

Theodore Barry and Associates approached the underground safety problem from a systems viewpoint in order to consider all the variables affecting fatal accidents. This approach is diagrammed on the following pages.

APPROACH TO STUDY OF UNDERGROUND HAZARDS



FATALITY REPORTS ANALYSIS

WHY/HOW ARE MEN KILLED? WHAT DO STATISTICS TELL US?

INDUSTRIAL ENGINEERING ANALYSIS

WHY/HOW ARE MEN KILLED? WHAT DOES PHYSICAL OBSERVATION TELL US?

IDENTIFICATION OF CRITICAL HAZARDS

WHERE CAN WE LOOK FOR THE BIGGEST PAYOFFS IN TERMS OF POTENTIAL LIVES SAVED?

PROBLEM ANALYSIS

WHAT CAN BE DONE TO SAVE THESE LIVES?

SOLUTION EVALUATION

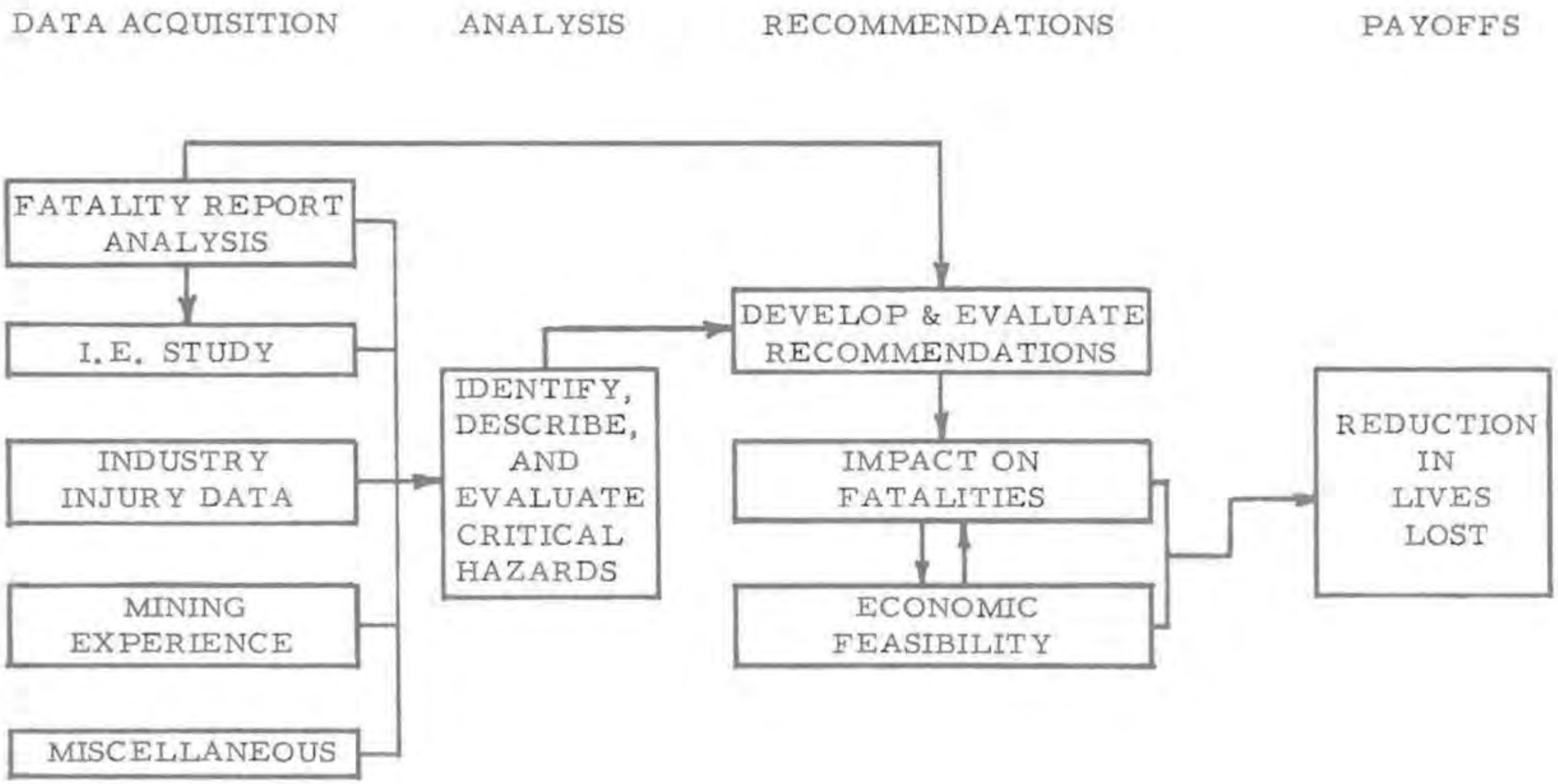
IS THE PROPOSED SOLUTION PRACTICAL FROM THE STANDPOINT OF THE ECONOMICS OF THE INDUSTRY?

PAYOFF

HOW MANY LIVES CAN BE SAVED AS A RESULT? WHAT IS THE COST PER LIFE SAVED?

A more detailed flow diagram of the actual methodology used in this study is shown here.

STUDY METHODOLOGY



The two principal data sources for this study were the Fatality Report Analysis (Section II) and the Industrial Engineering Study field data. As can be seen from the figures on the previous pages, these two sources are related. The Fatality Report Analysis (FRA) alerted us to direct our underground observations toward certain key situations and environments; it allowed us to focus our analytical energies upon those areas responsible for the majority of lost lives. The field industrial engineering study included both objective time-motion observations of actions associated with potentially hazardous situations, and subjective opinions of management and labor concerning major hazards.

The flow diagram indicates that these two data sources -- the fatality report analysis and underground industrial engineering observations -- have been supplemented by several additional sources -- company injury data encountered during the course of the study, the mining consulting experience of our own firm, and a variety of miscellaneous data sources (insurance actuarial data, equipment manufacturers' data, etc.). This data enabled us to identify major underground hazards, to describe those hazards in detail, and to evaluate their significance in terms of their contribution to annual fatalities.

Based upon our analysis of major underground hazards, we developed and critically evaluated a range of recommendations in terms of their impact upon fatality reduction and their economic feasibility. Reference was again made at this stage to the original Fatality Report Analysis. The result is a series of recommendations, each of which provides an estimated number of lives saved and estimated cost of implementation.

We recognize that the development of "ideal" solutions and recommendations without a proposed plan of implementation can be a sterile excercise. "Ideal" solutions may take a long time to sell to the industry, and may take a long time to implement. The what and who of less ideal, but more attainable alternative solutions therefore become important. In our discussion of recommendations in this study we believe we have kept the objective of practical attainability in focus.

III. SCOPE OF THE REPORT

It became clear early in the Industrial Engineering Study that two areas were significant and warranted expanded and independent analysis. As a result, Theodore Barry and Associates is currently involved in two other related studies for the Bureau of Mines: Fatality Report Analysis and Equipment Operations Safety Study.

IV. ORGANIZATION OF THE REPORT

The Industrial Engineering Study of Underground Coal Mine Hazards is a two volume report. Each volume is briefly outlined and discussed below.

Volume I FATALITY REPORTS AND INDUSTRIAL ENGINEERING ANALYSIS

Volume I consists of four sections:

Section I Introduction and Description of the Study

The Introduction defines the study problem and objectives, provides the necessary background information, describes the scope and approach of the study, and explains the study methodology.

The Description of the Field Study describes the physical conduct of the study: how the consulting team prepared for the assignment; how the mine sample was selected; how contact was made with subject mines and interviews with management scheduled; how underground observations were made; and how the various data forms were used.

Section II Fatality Reports Analysis

The chapters in this section represent a partial statistical analysis of all of the fatality reports collected from the Bureau of Mines for the period 1966-1970. The data in this section is the basis for the estimates of potential lives saved which accompany the various recommendations in Section III.

Section III Fatality Reduction Projects

Section III contains the substance of the results of the Industrial Engineering Study. As the study progressed, TB & A consultants developed or were exposed to a wide range of observations, insights, opinions, comments, and thoughtful, well reasoned proposals relating to safety. These differed in character as well as in subject matter. Some were "one-liners" -- brief, difficult to document, but nevertheless potentially valuable insights into certain safety problems. Others were well documented, well reasoned improvements in areas in which fatalities simply are not a major problem (e.g., improvements in face drill procedure). Still others were both well supported and significant in terms of their potential contribution to fatality reduction. Finally, there were some areas in which the problem could be clearly defined and the importance of a potential solution shown, but for which no immediate solution was apparent. (The necessary recommendation in this latter case is a call for new research.)

We believe each of these kinds of information can be valuable and useful to the Bureau of Mines. Consequently we have sought to sift through and categorize these data according to their primary focus.

The first such grouping developed by Theodore Barry and Associates consists of twelve Major Fatality Reduction Projects. Each of these projects 1) presents a significant problem area in terms of fatalities, 2) has been the subject of observation and in-depth empirical research during the course of this study, and 3) offers an opportunity to reduce fatalities through the implementation of practical recommendations.

Each project is organized according to the following outline:

I STATEMENT OF THE PROBLEM

Brief capsule statement of the problem in terms of fatalities.

II ANALYSIS OF THE PROBLEM

Complete discussion and analysis of the problem and possible solution.

III SUMMARY OF RECOMMENDATIONS

A brief summary of the possible solutions discussed in the previous section.

IV POTENTIAL LIVES SAVED ANNUALLY

A discussion of the effect of recommendations upon annual underground fatalities.

V COST TO IMPLEMENT SOLUTIONS

Estimates of the industry-wide cost of implementing the recommendations.

Section IV Areas of New Research and Comments

The chapter entitled "Areas of New Research" describes major safety hazards for which no immediate or clear-cut solution can presently be proposed. The problem may be technical, procedural, or managerial; but, in any case, it requires further study before action can be taken. We have attempted to assign priorities to these suggested areas of new research roughly according to their significance in terms of the number of lives potentially saved. While these priorities are only estimates, they represent the collective opinion of the TB & A consultants who have performed the data collection and analysis for this study. The rating scale used is:

1 — Top priority - A breakthrough could have a significant impact on fatality reduction; or, a useful contribution could be made for a minimum expenditure of time and research funds.

2 — Second priority - Less significant research in terms of potential payoff (lives saved), but still useful; research benefits still some distance "downstream".

3 — Low priority - These projects should be considered if extra funds are available.

In the final chapter of Section IV, "Insights, Observations, and Comments", we have collected and edited a number of ideas which lack either the empirical support or the significance of the Major Fatality Reduction Projects and the Areas of New Research. We offer them not as TB & A-supported conclusions, but as stimuli to further thought and creative analysis.

Volume II DATA AND CHARTS

Volume II introduces the essential minimum of technical mining terminology to facilitate understanding of the report by non-technical individuals; describes and illustrates the primary mining techniques through the use of multiflow process charts; and presents typical work-cycle times and the means and standard deviations of basic work element times.

CHAPTER 2

DESCRIPTION OF THE FIELD STUDY

This chapter provides an overview of the conduct of the field study. It describes the selection of the consulting team, the team's preparation for the assignment, the selection of the mines and the arrangement of the mine visits. It also includes a discussion of the kinds of observations made and the data collected while in the mines.

I. CONSULTING TEAM ORIENTATION

It is difficult to generalize about the caliber of the staff selected to perform this study, since a wide range of academic and work experience was represented by the team members. Most have one or more advanced degrees in business administration, engineering, or science. All staff members have expertise in more than one discipline in addition to the required Industrial Engineering background. In addition, all possess the ability to communicate effectively with all levels of personnel within the mining industry. Without exception, the personnel assigned to this project were enthusiastic volunteers, well aware of the conditions they would be asked to accept in order to gather data and develop inputs essential to the missions.

Despite working in an underground environment that is often uncomfortable, the staff members found the assignment both stimulating and rewarding. The variety of contacts with people, changing geographic and physical conditions, the importance of the project goals, and the opportunity to make a significant contribution to the solution of a serious national problem contributed greatly to the satisfaction experienced by the participants.

TB & A consultants prepared for this assignment in several ways:

A. First, the consultants reviewed the final reports of all commercial coal mine studies conducted by Theodore Barry and Associates during the 17-year history of the firm. This review familiarized them with typical industrial engineering problems encountered in production operations, with typical work-element breakdowns and production cycle times, with management and employee attitudes regarding such topics as production and safety, and with the overall economic characteristics and constraints of the coal industry.

B. All USBM fatality reports generated since 1966 (over 700) were examined in order to gain some preliminary familiarity with and understanding of the physical characteristics and situations associated with fatal accidents.

This review proved an invaluable aid as it enabled our consultants to associate particular underground situations observed during the study with similar circumstances recalled from the fatality reports. This fatality report review also served as the initial step in the coding of fatality data for computerized analysis.

C. The 1969 Coal Mine Health and Safety Act was studied and discussed in detail among the members of the consulting team. This review allowed the individual consultants to more effectively interview operators and local USBM personnel concerning the problems and advantages associated with the law.

D. The consulting team also reviewed appropriate trade journals and house organs -- e.g., Coal Age, UMW Journal, etc. -- to become acquainted with the technological issues and innovations of current major concern to the industry and to compile a reference file of articles relating to safety.

II. SELECTION OF MINES

Selection of mines was undertaken within the expressed parameters of the RFP and basic contract. The tentative mine sample plan outlined in the RFP consisted of mines having the following characteristics.

1. Mining Method
    - a. Conventional mining, mechanical loading
    - b. Continuous mining
2. Seam Thickness
    - a. Under 3 feet
    - b. 3 to 5 feet
    - c. Over 5 feet
3. Production Class
    - a. Under 50,000 tons/year
    - b. 50,000 to 250,000 tons/year
    - c. Over 250,000 tons/year

Taken factorially, a total of 18 mines would require study-(2 mining methods) x (3 seam thicknesses) x (3 production classes).

A further condition was that the mines in each category must produce a significant proportion of the nation's bituminous coal supply or contribute significantly to the total number of roof fall fatalities. An additional restriction limited the study to room-and-pillar type mining as opposed to longwall mining, since approximately 98% of underground bituminous coal is produced by this technique.

Initial study revealed that many of the 18 types of mines did not contribute significantly to either the nation's bituminous coal supply or to the total number of roof fall fatalities. An example of this situation would be a conventional mine producing over 250,000 tons/year with a seam thickness of less than 3 feet. It is physically possible to have a mine in this category, but highly unlikely that this type of operation would exist widely for economic reasons. Conversely, a continuous operation producing less than 50,000 tons/year would be uncommon because the annual production of a single miner in normal use is usually greater than 50,000 tons. In addition, the cost of the machine makes it an impractical system in other than high production uses. Of the 18 theoretically possible categories, 7 were eliminated as irrelevant for study purposes. The excluded categories and the 11 remaining categories are discussed in more detail in Chapter 3, Volume II, "Typical Work Cycle Times".

The concept of using a single mine to represent each category raised the question of statistical validity. Since extremely small samples are best measured by non-parametric methods, we decided to include the maximum possible number of mines in each category. After concluding the preliminary work-element breakdowns for the actual study, and using our experience and the experience of others in the industrial engineering and coal industries, we decided that 50 mines would be optimal for the study. Most of the 50 mines would provide time study data, with the remainder providing sample selection information.

The next step in the sample selection was to structure a desirable sample. Random selection among the almost 3,000 mines would have depicted the industry but not by category and would have ignored the wealth of information available from especially high and low fatality mines.

To more completely satisfy the study's information requirements, therefore, it was decided to select two stratified samples representing 1) mines with poor safety records and 2) mines known to place great emphasis on employee safety. Also, because of the somewhat random nature of accidents, it was expected that some mines with poor safety records would exhibit the characteristics of well operated non-fatality mines. This situation occurred frequently.

The high fatality sample was selected from the fatality reports covering the period from 1966 through 1970. These reports were assembled, coded, and reviewed to isolate individual mines and mine ownerships. A sample of 50 high fatality mines was selected based on the number and type of fatalities and the circumstances surrounding the accidents. In addition, an effort was made to attain geographical dispersion in order to be able to evaluate state and regional differences. In all cases, the selection was oriented toward mines most likely to display adverse physical or safety conditions. This condition was not consistently attained by the process, especially in the small mine categories, since many mines had only a single fatality during the five-year sample period.

In addition to these fifty high fatality mines, a slightly smaller sample of well operated mines was selected to provide examples and information on the methods used in lower fatality mines. A premium was placed on those mines which were operating safely under adverse physical conditions. Particular emphasis was also placed on mines with safety records that had drastically improved as a result of new management or application of better management techniques. This sample was selected through personal consultation with USBM inspection personnel, ranging from inspectors to district managers. In all cases, their nominations were based on personal knowledge and contact with the mine and its management. The selection was made from USBM districts on a weighted basis which approximated the high fatality sample.

The objective of selecting stratified samples at supposedly opposite ends of the safety spectrum was twofold. The mines nominated by inspection personnel provided information on the latest management techniques and equipment in use and served as a model to help evaluate other mines. These model mines also provided invaluable training in safety engineering for the industrial engineers who performed the study. The high fatality sample was intended to depict the worst possible safety conditions and provide key information on the frequencies of hazardous procedures or physical conditions.

Paradoxically, a large percentage of the fatality mines displayed characteristics equal to or better than the "control" sample. There were a number of reasons for this situation: 1) a great many of the fatality mines were closed before the study was started, particularly the smaller mines, and substitutions were required that were not equal in our rating system; 2) many of these mines had been improved since the time of the fatality (fatalities), which could have taken place as early as 1966, although greater weight was placed on more recent years; 3) more safety consciousness on the part of mine management as a result of fatalities or for other reasons might have influenced this condition; and 4) most certainly, the 1969 Act has had a profound influence on mine conditions.

The average safety conditions, however, between the two samples were significantly different. This was the result of uniformly high standards in the model sample. On the other hand, it is reasonable to assume that the high fatality sample is more representative of the total mine population.

We should also note that the names of the specific mines cooperating in this study have been and will continue to be treated as confidential information. The design of the total sample provided the inputs necessary to identify hazards and formulate proposed solutions. With the benefit of hindsight, it is obvious that the structure of this sample contributed significantly to the development of information.

III. MINE CONTACTS AND VISITS

After designing the sample and selecting candidate mines based upon their ability to fulfill the requirements of particular categories, TB & A consultants contacted owners and operators by letter and telephone to make arrangements for mine visits. The overwhelming majority of operators responded positively to our initial inquiry. Overall, approximately 90% of the operators contacted granted our consultants permission to enter their mines and record data. Alternate sample mines were substituted for those for which entry permission could not be obtained.

A major factor in the success of TB & A in gaining entry into such a cross-section of mines throughout the country was the enlistment of the operators' enthusiasm and support for the project at the time of the initial contact. Their cooperation was obtained by recording their opinions and judgements with regard to a range of technical and economic mining issues confronting the industry. Operators were particularly vocal in their criticism of certain parts of the 1969 Health and Safety Act.

The field trip began with visits to several large captive mines with reputations for "sparing no expense" and overlooking no potential innovation for improving safety. These initial visits gave us some feel for the operational, tested value of certain approaches to safety under various conditions (e.g., mobile roof trusses for temporary support at the face) and suggested a real-world standard of comparison by which we could evaluate the high fatality mines which we visited next.

A typical mine visit engaged the time of one consultant for an entire work-week. A normal schedule would be represented by the following sequence of events:

- Monday - Arrival at mine, meeting with owner, operator, and/or key management people; explanation of purpose of study to management; interview one or more key management people (owner, operator, superintendent, mine foreman, etc.); tour of mine facility and assessment of special circumstances of mine; contact and possible meeting with local USBM officials.

- Tuesday - Industrial engineering analysis (underground).
- Wednesday - Industrial engineering analysis (underground).
- Thursday - Industrial engineering analysis (underground).
- Friday - Summarize raw data; ask questions generated as a result of underground observations.

TB&A consultants normally spent four weeks in the field (i. e., four mine visits), before returning to Los Angeles for one to two weeks to meet, exchange experiences and observations, perform a general analysis of data, and develop recommendations.

During underground data collection, consultants normally observed a different working section each day (8-hour shift) in order to gain an overview of the mine's entire operation. Swing and midnight production shifts were also observed whenever possible.

Consultants normally worked without special escort, entering the mine with the crew at the beginning of the shift. Crews were briefed that we were neither their company's time study men nor USBM officials, but rather representatives of a private company under contract to USBM for the purpose of improving underground safety. Without exception, underground supervisors and crews rendered the fullest cooperation and support to TB&A consultants in data gathering.

IV. DATA COLLECTION

The data collection forms used by TB & A consultants are shown as Exhibits 1 through 7 presented at the end of this chapter.

Exhibit 1 is the questionnaire used by our consultants to interview mine management personnel. The questionnaire was not given to the interviewee, but was instead used as a guide and promptor by the consultant in engaging the interviewee in informal conversation. Quite often, the interviewee had so much to say in response to a particular question that all questions could not be covered. The questionnaire's primary value was in channeling the interviewee's comments, within broad boundaries, toward a discussion of mine safety.

The operator interviews resulted in two significant benefits to the study: 1) They provided a wealth of technical background information, examples, insights anecdotes, and even quantitative data regarding safety. This interview information increased the technical competence of the consulting team, gave them an important historical perspective concerning trends and issues in mine safety, and, most of all, provided the team with a frank and honest sounding board for testing tentative ideas and recommendations developed during the course of the study. 2) The interviews "broke-the-ice" with a number of owners and operators, allowing TB & A consultants to get to know them and their managers as people, and consequently led to greater mine accessibility and greater support for the study. The interview responses are not presented here as a single body of data; instead, the significant data derived from these unstructured interviews have been absorbed into the body of this report as they relate to a particular subject. Various recommendations, observations modifications of time study data, etc. have been influenced by the interviews where appropriate.

Exhibit 2 shows the data sheet used to record general information concerning the mine visited. Most of the data required to complete this form was obtained during the interview sessions.

Exhibit 3 is the Section Data Sheet, normally taken underground by the consultant and completed with the assistance of the section foreman during the working shift.

Exhibit 4, the Sketch Sheet, was used underground as a tool for making graphic notes concerning unique operations, hazardous incidents, or work element deviations. This form was originally intended to record work element pictures for multiflow process charts. Standard mining operations became so familiar to our consultants that the use of the form for this purpose proved unnecessary. It was, however, especially useful in recording complex man-machine interactions such as crew and machine position and movement in low seam, auger mining.

Exhibit 5, Time Study Observation Sheet, served as the primary underground data collection sheet for recording work element breakdowns and cycle times. During a normal shift, the consultant might complete 6-10 of these forms containing complete and partial work cycle times on various operations -- continuous mining, roof bolting, undercutting, shot firing, etc.

Exhibits 6 and 7 are the forms used to recap raw field data. Exhibit 6, Time Study Recap Sheet, is merely a summary sheet for developing averages for each work element such as "change bit" (CB), "insert and tighten bolt" (IB), etc. Work element times varied over an extremely wide range, depending upon conditions (see "Typical Work Cycles", Chapter 4, Volume III), and average times did not always prove to be representative. Nevertheless, averages provided a starting point from which typical or representative work cycles could be reconstructed. Exhibit 7, Cycle Recap Sheet, was used to record the chronology and sequence of work elements for each work cycle observed, along with the average times for the various elements in the cycle.

EXHIBIT I

MINE OPERATORS' QUESTIONNAIRE

1. What new state or federal laws do you have most difficulty complying with?

    a. What specific problems do you have because of these laws?

    b. What are the contradictions that exist between the state and federal laws?

    c. How would you modify or change these laws so they can help you?

    d. What kind of additional costs do you incur by these new laws?

    e. What effect do these new laws have on safety, if any?

2. What kind of relationship do you have with the inspectors? Do you work together?

    a. How comfortable are you with their judgement or with criticisms they may have about your mine?

    b. What happens when you protest the inspector's judgement? Have you ever gone over his head? What do you do?

    c. What is the inspector's role and what type of relationship does he have with foremen and workers?

    d. Would you object to being rated by a mine inspector?

    e. If you were director of USBM how would you manage and direct the inspectors?

EXHIBIT 1

AREA DIMENSIONS:

3. What type of beam and/or bolt roof plan do you use?

   a. How was this present plan derived?

   b. What kind of a relationship does it have to roof falls?

   c. Do you use trusses, metal strips, screens, etc?

   d. When can you have too much support?

4. What is your standard face width?

   a. How did you arrive at that width? Does it fall within the law? Are you satisfied with it?

   b. Is this working face width safe?

5. What is the standard size of your entries and intersections?

   a. How did you arrive at that width?

   b. Are you satisfied? Is it safe?

6. How do you establish a work or production pace? Do you measure performance? How?

a. Which rate, a slow or quick pace, creates a more hazardous condition?

b. What common problems cause the production rate to vary?

c. What type of incentives do you use?

7. How can you measure a worker's judgement? Can it be measured?

8. What are some unusual activities you have observed in the mine?

a. Are they, in general, more hazardous?

b. What positions in the mine tend to be more hazardous than others?

c. How many accidents have you heard of that relate to unusual activities performed by the miners?

9. Given this grid, where are the roof falls most likely to occur, under a supported roof and under a non-supported roof?

EXHIBIT 1

10. What are some of the danger signals that indicate a roof fall, a rib burst, etc?

    a. Can you teach these signals to the miners?

    b. Can you also learn to spot other events such as, cracks, slips, etc.?

    c. How do you handle faults? Cracks? Outbursts? Etc.?

11. How do you keep your men working under safe conditions? (e.g., supports)

    a. Are they safety conscious?

    b. What type of safety program do you have? Do you give training? How long and how often?

    c. Does the foreman enforce safety conditions? What type of pressure is placed on him by management to enforce safe conditions?

    d. What type of pressure does management give to create safer working conditions? Who gives criticisms?

12. What type of training program do you conduct for your employees (foremen included)?

    a. What does it consist of? Where is it held? When? Are employees paid for it?

    b. How new is the information given? Where is it obtained?

EXHIBIT 1

13. What types of equipment do you use in your mining process? Are they safe?

    a. Are you satisfied with them? Problems?

    b. What kind of relationships do you have with manufacturers?

    c. Do the new federal requirements cause you grief? New accessories? Additional costs?

    d. How would you design or modify these machines to increase safety and production?

    e. What kind of maintenance problems do you have?

14. What kind of relationship do you have with the unions?

    a. Do you work together?

    b. What rules bother you the most?

MINE DATA SHEET

Company____________________ Mine____________________ Location____________________

Daily Tons Produced: Gross______ Net______ No. Shifts______ No. Sections______ No. Sections/Day__________

Elapsed Hours/Man-Shift______

Total Employment:	Above	Below	Maint.	Total
First Shift				
Second Shift				
Third Shift				
Total				

Coal Seam____________________ Mine Depth and Dimensions (Developed)____________________

EXHIBIT 2

DATA SECTION SHEET

Date ____________ Mine ____________ Section ____________ Foreman ____________ I. E. ____________

Mining Method (A, CT, CV) ________ O. B.' ________ Seam Ht. ________ Roof Ht. ________ Support Plan ________

Face Grade: Decline L____°, R____°, F____°, A____°, Level ( )____ Support Deviations ____________

Lithology: ________________________________ Anomalies: ________________________________

Miners by Job Titles: ____ Total: ________

Equip. by Model # & Qty: ____

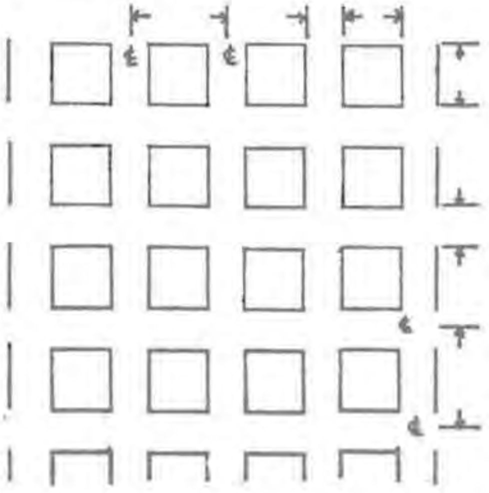
Shuttle Cap. ____ Tons RR Cap. ____ Tons SC Ld. ____ Tons RR Ld. ____ Tons # Cuts/Shift ____________

Depth of Cut ____' Ft^3/Cut ____ Tons/Cut ____ Tons/Man-Shift ____ Length SC Run ________ to ________'

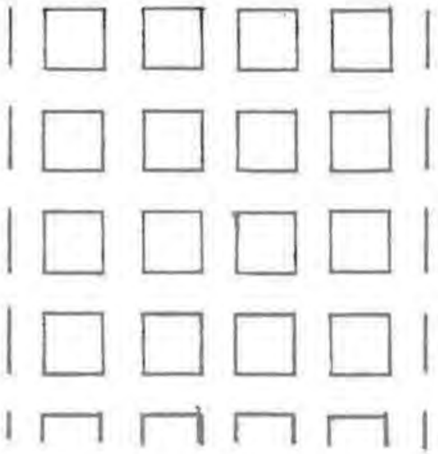
Man-Trip In ____ Minutes Man-Trip Out ____ Minutes Lunch Period Yes/No Lunch Period ____ Minutes

Highest Methane ________% Ventilation Quality ____________ Escape Routes ____________ Known? ____________

Comments: ____



Start of Shift



End of Shift

Show:
1. Tram routes including shuttle car
2. Faces
3. Dimensions
4. Equipment positions

Do above for start and end of shift only.

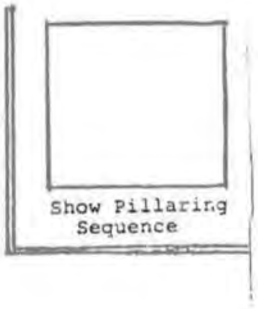
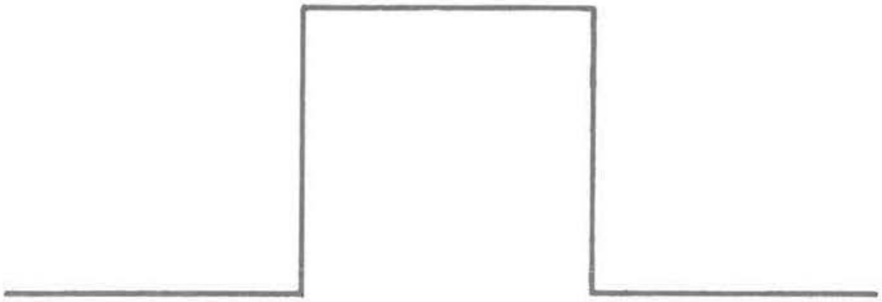


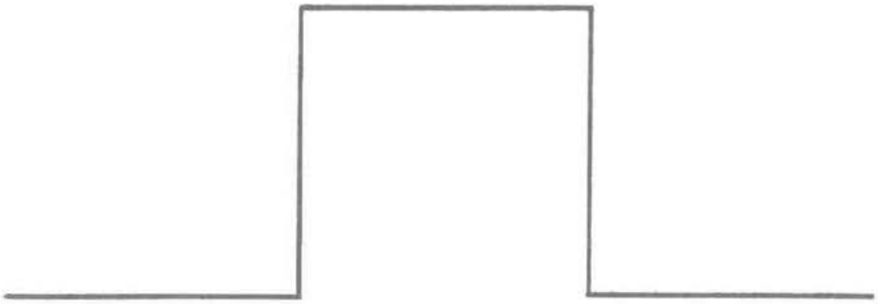
EXHIBIT 3

EXHIBIT 4

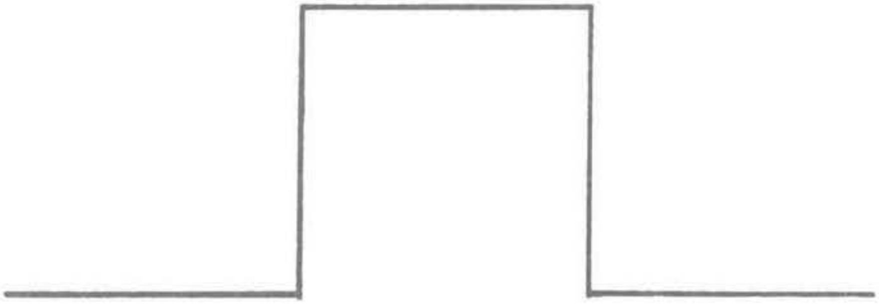
SKETCH SHEET



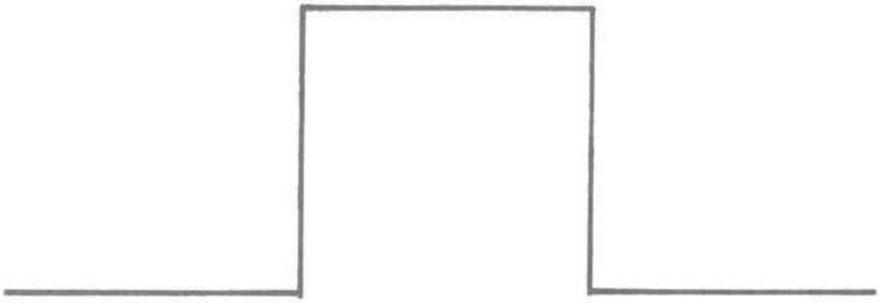
Average Time________



Average Time________



Average Time________



Average Time________

EXHIBIT 5

TIME STUDY OBSERVATION SHEET

Shift________________ I. E.________________

Mine________________________ Sheet________________

Section________________________ Date________________

Operation Equipment

Element Description	Cont. Time	Subtr. Time	Element Description	Cont. Time	Subtr. Time

TIME STUDY RECAP SHEET

I. E. ____________________

Mine ____________________ Coal Co. ____________________ Date ____________________

CT/CV Section ____________ Operation ____________________ Equipment ____________________

#Men/Machine Crew ______ Entries=Black Totals=Red Averages=Green

EXHIBIT 6

EXHIBIT 7

CYCLE RECAP SHEET

I. E.________________

Mine________________ Coal Co.________________ Date________________

Operation________________ Equipment________________ #Men/Machine Crew_____

Element	Element Time	Subcycles	Subcycle Time	Subcycle Freq.

SECTION II

FATALITY REPORT ANALYSIS

CHAPTER 3

THE FATAL ACCIDENT REPORT DATA BASE

I. PURPOSE OF FATALITY REPORT ANALYSIS CONTRACT

A. Original Purpose of FRA

The objectives of performing fatality analysis as part of the Industrial Engineering Study have evolved considerably during the course of the study. The study's original Statement of Work for fatal or non-fatal injury accident analysis read:

> "To obtain existing Bureau of Mines accident fatality data, attempt to normalize the data with respect to manhours exposure or production and assess the principle causes of these accidents."

The focus of the original Industrial Engineering Study (and hence fatality analysis) was roof fall accidents. A Bureau research group in Spokane performed a preliminary analysis of 1966, 1967 and 1968 roof fall accidents and found a disproportionate number of roof fall fatal accidents occurring in mines having certain seam heights and using certain production methods. The study also documented a need to normalize the number of accidents occurring under particular circumstances by the frequency with which those conditions occur in the industry.

In the first phase of the Industrial Engineering Study, the fatality reports were hand tabulated along such dimensions as seam height, style of mining, production class, etc. These tabulations assisted in determining what types of mine conditions were relevant to roof fall fatalities. Work cycle variables were also coded to indicate the more dangerous work cycle elements. These fatality reports were then used to help select representative mines to visit and to emphasize critical work cycle elements to be observed during the field study phase of the I. E. Study.

As the field study progressed, it became necessary to analyze the fatality reports in greater detail. The field observation team needed to know more about the production operations which were most commonly associated with the highest number of accident fatalities in order to perform a more precise analysis of potential accident situations. Such factors included lithology of the roof and floor, seam thickness, depth and dimensions of the mine, the mining method, the coal bed, the worker job classification, the dimensions of the work place, the kind of support used, the type of equipment, and the roof support plan. Hence, while the number of variables of interest grew quickly, no such detailed data was available from the Bureau except in the narrative fatality reports.

Many variables chosen for coding from the fatality reports were suggested by the field engineers who had made industrial engineering studies of work cycles in mines, observed lengths of hazardous roof exposure, or spotted work elements that seemed especially dangerous. In order to determine the relative degree of hazard of the observed conditions, the team needed to know how many fatalities had occurred in similar situations. This information was also needed in order to evaluate the potential benefits of a specific improvement proposal in terms of decreased fatalities.

B. Expanded Purpose of FRA

By the start of the second phase of the field study, our analysts had established a primitive computerized data base composed of those variables thought to be related to fatalities. The advantage of the computerized data base was the capability it gave us to instantaneously combine several coded factors and determine that combination's resulting fatality frequency. Hence, this "live" data base became increasingly important in analyzing the relative significance of phenomena observed underground.

Based on the initial success of the computer data base, the first modification to the basic I. E. Study contract included a small add-on contract for accident analysis. The scope of the new study included:

1) Analysis of new fatality variables on the computer.
2) Suggestions for revising the accident reporting process.
3) New accident analysis concepts or models which would be relevant to the Bureau of Mines' research efforts.

The data and statistics which will be illustrated in this volume are based upon coded fatality variables that have been revised several times. Each time the industrial engineers returned from a field study of a new safety problem, they suggested expanding or revising the existing fatality variable coding. As new variables were coded and tabulated the results often indicated that the interval scale for the variable needed revision. Many variables had to be recoded because the scale did not extend far enough, was not sufficiently sensitive, or because certain important factors were omitted. Thus, through trial and error the data base was improved, but the reader may also see opportunities to further refine and significantly improve the variables shown in this report. Hopefully, these variables will be revised in future work on this data base.

It should be emphasized that most of the variables coded for the data base were influenced by previous Bureau studies and by classifications used by the Department of Accident Analysis in the Bureau. However, several new variables were also tested. Some of these have not produced satisfactory or reliable information and will be dropped; others need revision to furnish more accurate information. Many of these new variables, we believe, provided valuable insights into the reasons for the occurrence of fatal accidents.

Since the Spokane report ('66-'68 roof falls) was not made available to us until July, the coding and analysis of the two studies were almost completely independent of each other. The roof fall variables analyzed in our study basically agree with all of the observations made in the Spokane roof fall study, with the exception of roof fall size. Both studies confirm the fact that without normalizing data of industry roof control plans and/or actual roof control practices, much of the data cannot be made meaningful.

II. DESCRIPTION OF THE FATAL ACCIDENT DATA BASE

A. Fatality Report Source Document

The source document for the data base established under this contract is a narrative accident investigation report. A Bureau of Mines inspector investigates the accident and prepares this valuable report, usually with the assistance of a union safety committee and representatives of the company management. It is a requirement by law that all fatalities be reported to the U.S. Bureau of Mines.

The data base consists of 84 coded variables, emphasizing roof fall accidents. Of course, not every variable applies to a single accident as many of the variables are mutually exclusive. There are approximately 48 general questions (30 objective and 18 subjective), 21 roof fall questions and 15 miscellaneous questions applying to equipment and other factors.

Most of the variables are restricted to 12 values simply because there are 12 single punches available per column on a Hollerith card. However, there are some variables for which multiple columns were allocated. Each single-column question was given a code number from 0 through 9, or a coded 11 or 12. In the case of double columns the codes would range from 00 to 99, or 000 to 999 for three column questions. Exhibit 1 is an index to question topics and Exhibit 2 is the actual fatality report analysis questionnaire used to code the fatality reports.

B. Data Base Computer Software

The data base was prepared as specified for a commercial software package called "QPAK" which is offered by the International Timesharing Corporation of Minneapolis. The data file physically resides on a disc of a computer in Minneapolis and is available virtually all over the country by way of the telephone system and a teletype terminal.

The software is a combination of a cross-tabulation program with Boolean logic capability, a formatted report writer, plus a convenient statistical analysis library. The software permits a person to determine the frequency of occurrence for any variable and a sub-category by typing its label or name. With a few typed commands, either a tabulation of individual variables or a cross-tabulation table between one or more variables can be easily developed. These tabulation tables can be made more complex by restricting the tabulation tables to Boolean combinations of cases in which a third or fourth or fifth variable must have occurred. These restrictive variables are called "limiters" and provide an enormous range of tabulating possibilities to the user.

The general capability of the computer in this kind of analysis cannot be underestimated. For instance, consider the amount of time required to manually scan the coding sheets for 700 accidents and tally the simultaneous occurrences of certain codes within five columns. Such a task would take a considerable amount of time and is subject to a high error rate. On the computer this process can be performed in a few seconds without errors (assuming no coding errors) and the results cost less than $1.00 per table.

An important aspect of the computer tabulation versus the manual tabulation is the reluctance of engineers to submit themselves to the drudgery of manual tabulation. Quite a number of research personnel in the Bureau who have heard about our data base have shown us partial manual tabulations they have abandoned. With a computer, the investigator will be able to obtain more information in greater detail than with manual tabulation.

C. Data Base Description

The data base developed by Theodore Barry and Associates consists of 731 fatal underground bituminous coal mining accidents, representing 831 victims, which occurred from January 1966 through December 1970. This is not the total official number of fatal accidents or victims over the five-year period because we had not received several reports when the data was coded and processed. We also did not code explosion accidents, including two explosion disasters totaling 87 victims. Thus, the 731 coded accidents, plus the two explosion disasters with 87 victims, represent 918 of the 966 official fatal underground victims, or approximately 95% of the official total.

In each multiple victim accident, the data base currently contains the information on the one victim who we felt was either the most responsible for the accident or most involved. For instance, in a mantrip accident with 9 fatalities, the age, occupation, and experience of each victim is not especially meaningful for analysis purposes. Biographical information on victims who had little to do with the accident occurrence could be misleading if included in the data base. On the other hand, information about the driver of the mantrip locomotive who was careless and caused the accident is important and is in the data base. One shortcoming of the present data base is that if the person causing the accident was not a victim, no information is recorded for him; this will be corrected in future work on the data base.

All frequencies in the exhibits shown in this report represent the number of fatal incidents rather than the number of victims involved in accidents. Our analysis assumes the circumstances surrounding a fatal accident are of more importance in reconstructing fatal accident patterns than the number of lives lost. The data, however, can be used to approximate the number of deaths as the ratio of accident incidents to accident victims is very close to a one-to-one ratio. In fact, the ratio of incidents to victims for the data base is 1 to 1. 14.

A more exact figure for the number of fatalities can also be obtained, if desired, as the number of fatalities per accident have been coded and can be tabulated against any combination of factors which simulate the pattern of accidents. For example, if there were 145 accident incidents in intersections, we can determine the total number of victims killed in intersections.

In summary, the data base has been constructed in terms of number of incidents to most significantly reconstruct the circumstances leading to a fatal incident. Information on the one victim judged most relevant to the accident is included in the data base to avoid irrelevant information and misleading conclusions. When desired, the exact number of fatalities can be determined from the data base for any set of accidents. Exhibit 3 provides a complete tabulation of all coded variables in the data base.

III. LIMITATIONS OF THE PRESENT FATAL ACCIDENT DATA BASE

A. Lack of Normalized Fatality Data

The biggest handicap in using the current computerized fatal accident data base is the lack of knowledge or information about the industry as a whole that would permit one to normalize the frequency data of certain important variables. For example, while knowing the number of men killed in various seam heights is valuable, knowing the number killed relative to manhours worked or tonnage produced in those seam heights is more meaningful. This is especially true if certain seam heights have a disproportionate number of accidents. Other examples of the kind of industry data needed to normalize our present data base are:

- Production manhours in given mine categories: by seams, seam heights, geological roof classifications, etc.
- Roof control plans for all mines, including room and intersection geometries and dimensions, bolt types and dimensions, and pillar recovery sequences and dimensions.
- Equipment configurations, crew assignments, and manhours of operation.

Obviously obtaining industry-wide data on certain variables is essential if the data base thus far established is to be utilized to its greatest potential.

B. Non-Fatal Injury Accidents

Analyzing only fatal accidents ignores the problems associated with certain types of non-fatal injury accidents which, in dollar amounts, cost the industry far more than fatal accidents. The causes of the two types of accidents may or may not be related. For example, certain non-fatal injuries to the hand or foot are not likely to be closely related to fatal accident occurrences; however, fatal and non-fatal roof fall injuries are probably closely correlated. Thus reporting and analyzing circumstantial accident variables for non-fatal injury accidents is important and independent of fatality accident data.

Moreover, the annual fatal accident frequencies in various categories are often too small for meaningful analysis. One way to expand the fatal accident data base is by grouping fatality frequencies for several years. This, however, tends to create an obsolete data base and can lead to erroneous interpretation of the causes of today's accidents. This is a serious drawback of the current TB & A fatal accident data base utilizing data from 1966-1970.

The number of mines in that time period have decreased from over 5,000 to about 2,500 and the effect of the 1969 law is almost totally obscured. However, detailed information on fatal accidents is virtually all that is available to the Bureau for analysis, and without grouping the five years (1966-1970) the frequencies are too small for reasonable statistical analysis.

Another way to expand the data base, presently comprised of fatal accident information, is to add data on non-fatal injury accidents. This would have the effect of greatly increasing the size of the data base as there are approximately 40 times as many non-fatal accidents as fatal accidents.

This non-fatal injury data is readily available. It is provided by companies to the Bureau of Mines who sends it to the Accident Analysis Department. The Bureau requires the data within 30 days of the accident, except for small mines. The accident report presently consists of either a one page report with standard questions, or a state workmen compensation form.

Unfortunately very little circumstantial data is reported on the non-fatal injury data forms. In addition, the information reputedly is not always reported faithfully by the companies. Furthermore, the Bureau does not usually conduct an investigation of the accident.

Despite these problems a far more powerful and up-to-date data base could be developed by improving the non-fatal accident reports -- for example, increasing the number of reported variables on a simple easy-to-use coded form.

We have been told again and again by Bureau research personnel that many of their research projects seriously suffer from the lack of detailed statistical data on the circumstantial data associated with accidents. We believe an urgent need exists within the Bureau to report important key variables associated with non-fatal injury accidents.

Equally important, we are convinced that the data base needs to be in a user-oriented form such as the computerized data base built as part of this contract for fatality data. Only when Bureau personnel can quickly and easily test large numbers of variable combinations can they adequately discover critical relationships, define problems, set research and inspection priorities, and monitor accident suppression progress.

C. Lack of Non-Fatal Accident Report Format

The major problems with the narrative accident reports are that:

1. The preparation and reading time is slow because of the narrative form.
2. The data is not now consistently or precisely reported.
3. Subsequent coding introduces bias, time delay, and high cost.

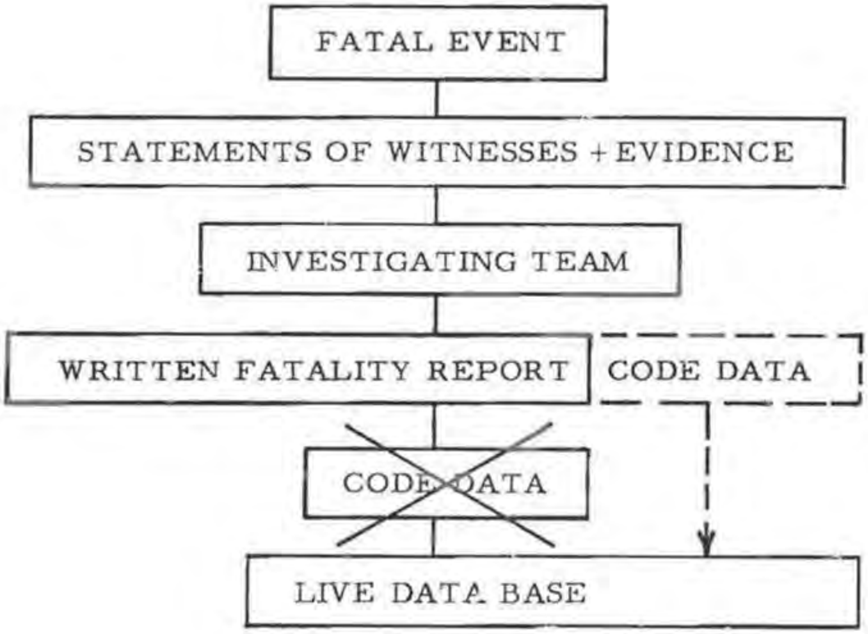
The narrative reports, each describing a fatal coal mining accident, were not really designed to provide data for a detailed research data base such as the one established under this contract. Rather, they were merely to serve as a convenient way to disseminate a description of an accident to a large number of people both in and out of the Bureau, including union officials, company officials and research centers. While the narrative description, especially the description of events preceding the accident, fulfills many important needs, all subsequent analytical accident analysis must also be derived from the narrative descriptions.

Under the present process, Theodore Barry and Associates analysts as well as the Bureau analysts are forced to go through the narrative reports trying to find certain data variables. In the 1966-1970 reports, data was not consistently reported. In many cases it was very hard to interpret the narrative description of certain data variables of interest. Consequently a degree of reader bias may have been introduced. In other cases important data was not reported at all, and it was almost impossible to obtain missing data for 1966 accidents.

Fortunately, the 1970 fatal injury accident reports were significantly better than previous reports, and the 1971 reports that we have read are better still. Nevertheless, we feel the fatal accident reporting process is still inefficient, inexact, and inconsistent.

The most inefficient part of the narrative fatality report is the requirement that the accident investigator compose long narrative sentences for countless quantitative facts that are routinely required for every report: victim age, mining experience of victim, seam height, etc. In our opinion, both the report preparation time and the report reading time could be drastically shortened by a tabular presentation of routine data as shown in Exhibit 4.

Tabular or coded data would also remove a needless level of abstraction and opportunity for bias as illustrated in the following diagram:



As you can see an effective way to reduce this level of abstraction would be to have important routine variables coded directly by the inspector investigating the accident. This direct coding would be particularly advantageous in the cases of questions that involve expert judgement. Moreover, the investigator is less likely to omit vital data if he is using a coding form.

Direct coding was adopted with great success in Germany in 1954 and was computerized there in 1964 and 1965. The German government not only investigates fatal accidents with coded forms but also trains, authorizes and requires a company official to investigate and code serious injury accidents (i. e., those accidents involving more than 3-days lost time from the job). Their report preparation takes less time than in the U. S. and their reports often contain more helpful information.

The major reasons for directly coding certain parts of the accident report in the field are:

- To guide the investigation.
- To reduce preparation time of report.
- To reduce report reading time.
- To enable key punching directly from the code form thereby eliminating costly time delays and thousands of subsequent tedious coding hours.

- To obtain more consistent, precise reporting of data.
- To eliminate opportunity for subsequent coding bias.

We feel that the Accident Analysis Department should assume the responsibility for developing uniform codes compatible with a computerized data base. The new coding form should be prepared with great care after consulting with all the research centers and the Inspection Department. Finally, it should be field tested and debugged before complete adoption.

IV. PROPOSED FATAL ACCIDENT REPORT FORMAT

While the proposed format for reporting fatality information would be more structured than the present system, it would not eliminate valuable narrative sections. The proposed concept resembles the roof control plans where routine questions are listed with spaces for answers. This ensures that routine factual information is not lost through inadvertent omission. The new forms would also permit direct coding of answers by the inspector. A wide left margin would contain squares for the numerical codes, and listed below each question would be all possible responses with their appropriate code. The inspector could write the answer in the space provided after the question and then either scan the list for the corresponding code or have all the coding completed at his office.

In either case, the report itself would be used directly for keypunching or optical scanning, thus eliminating the present operation of reading the report, referring to a master coding index and filling out a separate keypunch coding sheet. With the proposed format, the keypuncher would read down the left margin and keypunch the appropriate columns.

Use of a structured reporting form which permits direct translation from investigation to computer has numerous advantages.

1. It will permit standardized and more precise questioning.

2. It will guide the inspector's investigation time and reduce his report preparation time.

3. It will reduce the inadvertent omission of information.

4. The reader will be able to scan the report more quickly to locate items of interest.

5. The fatal accident data bank can be directly updated without delay.

6. Summary statistical reports can be generated via the computer rather than time-consuming manual write-ups.

The proposed reporting format would consist of several sections -- introduction, narrative, sketch, and an appropriately coded data section. The introduction would include a short summary of the accident, the details on Bureau notification, and the investigating committee. The narrative section would describe the events leading up to the accident, any special circumstances or observations, and recommendations. The data section would consist of the following sections:

a. Mine data (if not captured by new planned Bureau mine data bank)

b. General accident data

c. Victim data

d. Supervision data

e. One of the following types of accident data sections

    1) Roof fall
    2) Haulage
    3) Machinery
    4) Electrical
    5) Explosion

Hopefully a similar, although possibly less detailed, form could be developed and adopted for non-fatal accidents.

We foresee the following possible chain of events when a fatal accident is reported to a subdistrict office:

1. The inspector would key into a remote terminal the USBM serial # for the mine involved (taken from a master list) and generate:

    a. The mine data section

    b. The history of the mine (violations, abatements, past accidents)

2. The inspector could also, if desired, key in a code corresponding to the general mine characteristics (seam height, roof composition, etc.) and receive a profile of accident frequency for conditions surrounding the type

of accident that occurred. (For instance, code "D" mines with three-foot seams and laminated shale roofs generally have roof falls averaging 140 square feet and need special roof control plans). The "accident profile" would then guide the inspector as to mine condition combinations to investigate, especially if the inspector were not intimately familiar with that particular mine.

3. At the mine, the inspector would briefly review the mine data section with management, noting any changes, and proceed to fill out the appropriate accident forms.

4. Back at the office, the inspector could then write up the narrative from his notes while the coding was being completed, checked, and entered into the terminal by his secretary or clerk.

The above sequence of events may seem exotic to some readers, but the ideas involve current technology at reasonable costs.

An example of the proposed coding sheet format is presented in Exhibit 4. The questions and codes illustrated in this exhibit are not necessarily those questions or codes that we would recommend for the actual code form to be used.

Some of the new variables analyzed by our staff may be a useful place to start when designing the questions. However, so many Bureau personnel will have to use the data from the fatality reports and so many inspectors are involved in preparing these reports, that we feel it would be presumptuous to design the coded forms without consultation with a reasonable representation of these Bureau personnel.

The design of the questions should also involve consultation with all the research centers, inspection offices, Department of Accident Analysis and representatives from the Data Processing Department to formulate a set of useful, simple, reliable, standardized variables or questions.

If the Bureau were to adopt the coded accident form idea, we would further advise that the forms be pilot tested before adoption. Moreover, the temptation of designing unwieldy, long and complicated forms must be avoided, otherwise the inspectors will be likely to resist and resent the new system.

V. RELEVANCE OF THE EXISTING DATA BASE TO FUTURE BUREAU RESEARCH AND ANALYSIS

Some Bureau personnel have expressed doubt that either the existing data base or a revision of the existing data base will be valuable to the Bureau except for comparison purposes. They argue that the full impact of the 1969 legislation did not occur in 1970 and that one cannot validly compare roof-plan deviations in fatal accidents which occurred in 1966 versus 1970 or 1971.

Certainly this doubt is well founded for certain variables whose definitions have changed directly or indirectly because of the 1969 legislation. The meaning and implication of the common phrase "violation of the existing roof control plan was a major causal factor in this roof fall accident" have changed dramatically between the writing of the 1966-69 and the 1970-71 fatal accident reports. Obviously, the definition and importance of other factors have also changed.

It is not obvious, however, that certain accident factors were profoundly affected by the law. Many factors showed no significant rate occurrence trends over the five years. It is not clear from the fatality reports that certain types of accidents occurred any differently in 1970 than in 1966, nor is it clear that these accident types will occur any differently in the near future because of an anticipated impact of the 1969 law or changes in inspection procedures. For example, training methods, job turnover, job substitution practices, and proliferation of non-standardized equipment controls are likely to remain roughly the same in the industry in 1972 or 1973 as they were in 1969 unless something drastic occurs. If these factors are linked to the occurrence of equipment accidents, as suspected, then the current data base capturing these accident factors will be helpful only until these factors are no longer important. Moreover, how will the Bureau know that certain accident factor combinations have changed in importance unless the Bureau builds a detailed historic accident data base for comparative analysis?

We hope that accident rates decline dramatically and that the existing data base of accident factors becomes obsolete very quickly. But in the meantime, we feel that this data base has continuing value to the Bureau, especially if it is modified and revised. We discovered many opportunities for improvement as we utilized the data base to fulfill this contract, and many new opportunities will undoubtedly be discovered by future users.

The potential users of a data base similar to the one created by this contract should not be confined to those personnel in an accident analysis section. We feel many potential users could profit by direct access to the data base. Some examples might be Bureau research program managers desiring to assess priorities, research personnel desiring to formulate more precise research accident problem definitions, inspection personnel desiring to assess enforcement priorities or effectiveness, etc. Each of the above potential users has a particular need that cannot possibly be anticipated by the analyst who maintains the data base. Hence, it is important that the accident data be retained on a case-by-case basis so that unique accident factor combinations can be reconstructed almost instantaneously by the computer. Direct access to the data base via timesharing or remote-batch processing facilities by the personnel in the Accident Analysis Department would cut down unnecessary and expensive delay and encourage a greatly expanded use of such a data base.

VI. SUMMARY OF RECOMMENDATIONS

A. Short-Range: Can Be Implemented In The Next Year

1. Make the current Fatality Report Analysis (FRA) data base available to interested Bureau analysts via timesharing computer services. We believe that the accident analysis group, inspection offices and various research centers would profit from the opportunity to use the data base for reference in their own projects. A less desirable but feasible short-range alternative is for Bureau analysts to request desired tabulation runs from our firm or a service bureau. The long-range alternative to timesharing is the development or purchase of cross-tabulating software for the Bureau computation center.

2. Update the current data base for 1971 fatal accidents.

3. Revise the current FRA data base variables. Those most needed are equipment variables and more precise roof fall accident variables.

4. Develop an interim normalizing data base on the industry in order to estimate rates (per man or per manhour) on key parameters and thus be able to assess the significance of many accident factors. Industry data is needed on job task turnover, training, roof control plans, equipment census, etc.

5. Begin development of a new set of variables to be recorded for fatal and non-fatal injury accidents. This should be a coordinated project between the various research centers, inspection personnel, and the accident analysis group. We believe that we have demonstrated the need and advantage of certain new variables; other Bureau analysts have similarly tabulated various variables. We believe that much duplication of effort can be eliminated by a carefully coordinated study and development of a new set of standard accident variables.

6. Develop a streamlined fatal accident report with code sheets for routine variables to enable direct keypunching from the field, thus reducing much of the report preparation time, reading time, and hopefully eliminating most of the coding time. Development of this program should follow recommendation 5 above and be pilot tested before adoption.

7. Develop a standard non-fatal injury accident data form with a few key coded circumstantial variables. This form should also be a direct keypunch document. Eliminate all state workmen compensation forms.

8. Develop interim data processing resources for handling the three new data bases created in the above recommendations: fatal accidents, non-fatal accidents and mine census for normalization. The ideal data processing resources should have efficient cross-tabulation software for rapid analysis of all three data bases, separately and in combination.

B. Long-Range Proposals

9. Develop a permanent mine census data base system suitable for normalizing data from the accident data bases. (The Bureau is presently developing a mine census data base but it is not designed to normalize the accident data bases described above.)

10. Develop computer programs to process routine accident reports complete with tables and text. Minor text revisions could be made manually on any really significant observation before publishing such reports.

11. Make the three accident data bases conveniently available to Bureau analysts in a user-oriented computerized form. Analysts from Research, Inspection, and Accident Analysis should be able to manipulate accident data at will in any conceivable combination for maximum utility in defining problems, monitoring problems, setting priorities or assessing cost/benefit relationships.

EXHIBIT 1

FATALITY REPORT ANALYSIS

INDEX OF QUESTIONS

GENERAL	QUESTIONNAIRE Page #
Mine	
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Daily Tons	1
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No. Injured	2
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ROOF/RIB FALLS	QUESTIONNAIRE Page #
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EXHIBIT 2

THEODORE BARRY AND ASSOCIATES
U. S. BUREAU OF MINES
COAL MINE SAFETY STUDY
FATALITY ANALYSIS QUESTIONNAIRE

QUESTION LABEL (VARIABLE)	RESPONSE LABEL	QUESTION/RESPONSE EXPLANATION
STATE	ALABAMA ALASKA ARIZONA ARKANSAS COLORADO GEORGIA ILLINOIS INDIANA IOWA KANSAS KENTUCKY MARYLAND MISSOURI MONTANA NEW MEX N DAKOTA OHIO OKLAHOMA OREGON PA S DAKOTA TENN UTAH VIRGINIA WASHINGT W VIRGIN WYOMING	State in which accident occurred
MONTH	JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC	Month in which accident occurred
YEAR	1963 1964 1965 1966 1967 1968 1969 1970 1971	Year in which accident occurred
DALYTONS	0-50 51-100 101-200 201-400 401-700 701-1000 1001-140 1401-180 1801-230 2301-300 3001-400 >4000	Daily coal output of mine (tons/day)
# EMPLYD	0-3 4-7 8-15 16-19 20-40 41-65 66-100 101-130 131-160 161-200 201-260 >260	Number of workers employed underground
MINESTYL		Mining style/phase at scene of accident
	HAND	--small mine where development, loading, etc. done by hand (may include blasting off the solid)
	CONV DEV	--conventional mining method in development of new areas (rooms, entries; includes hand and machine loading)
	CONV PIL	--conventional mining on retreat (pillaring)

EXHIBIT 2

Question Label	Response Label		Question/Response Explanation
MINESTYL (Cont)	CONT DEV		--Continuous mining method in development of new areas (rooms, entries, crosscuts)
	CONT PIL		--Continuous retreat mining - extraction of pillars
	LONGWALL		--Development/Retreat by longwall versus room and pillar method
WET?	YES, NO		Was mine considered wet (Water on floor, seeping from roof, ribs, etc.)
SEAM HT.	0-3°	7+-8°	What was average height of seam (feet)
	3+-4°	8+-9°	
	4+-5°	9+-11°	
	5+-6°	11+-14°	
	6+-7°	>14°	
ROOF HGT	0-3°	7+-8°	What was height of roof in accident area (feet)
	3+-4°	8+-9°	
	4+-5°	9+-11°	
	5+-6°	11+-14°	
	6+-7°	>14°	
S.S. &VAR	0-2&NO	0-2&YES	What was the average seam slope (degrees) Was there a variability of equal to or more than 3 degrees (**no**, yes)
	2+-5&NO	2+-5&YES	
	5+-8&NO	5+-8&YES	
	8+-11&NO	8+-11&YE	
	11+-14&N	11+-14&Y	
	>14&NO	>14&YES	
FATALS	1	7	Number of fatalities from the accident
	2	8	
	3	9-15	
	4	16-50	
	5	>50	
	6		
INJURED	0	6	Number of workers injured in accident
	1	7	
	2	8	
	3	9-15	
	4	16-50	
	5	>50	
NONFATAL	0	6	Number of lucky nonfatalities (man under fall but protected by canopy; in fall area but not killed, etc.): includes injuries from above as well as noninjuries
	1	7	
	2	8	
	3	9-15	
	4	16-50	
	5	>50	

EXHIBIT 2

Question Label	Response Label	Question/Response Explanation
TYPE ACC		Type of accident
	EXPLOSON	--Natural combustion explosion (gas, coal dust, etc.); does not include dynamite or shot firing explosives accidents
	RF<25FAC	--Roof fall within 25' of working face includes intersections if working face is present
	RF<10INT	--Roof fall within 10' of intersection. Mainly intersections completed some time in past
	ROOF OTH	--Roof fall not inby face or intersection (mainhaulageway, long crosscut, etc.)
	RIB<25'	--Rib fall within 25' of working face
	RIB>25'	--Rib fall greater than 25' from working face
	OTHER	--Accident not falling in other categories (explosives, man falls, fires, etc.)
	HAULSHUT	--Haulage accident involving shuttle cars, battery-operated tractors, jitneys, etc.
	HAULMAIN	--Haulage accident involving mainline hauls-locomotives, mantrips, etc.
	BUMP	--Burst or bump of face or rib
	ELECT'CL	--Accident involving electrical cause
	EQUIP--	--Accident involving equipment other than haulage (loading machines, continuous miners, belt conveyors)
VIC AGE	<=20YRS 21-25YRS 26-30 31-35 36-40 41-45 46-50 51-55 56-60 61-65 66-70 >70YRS	Age of victim
VIC EXPR	0-.5YR .5-1 YR 1-2YR 2+ -5YR 5.1-8YR 8.1-11YR 11.1-14 14.1-17 17.1-20 20.1-25 25.1-30 >30YRS	Total mining experience of victim
TASK EXP	0-.25MO. .25-.5MO .5-1 MO 1+ -3MO 3+ - 6MO 6+-12MO 12+-24MO 24+-36MO >36MO	Victim's experience at task being performed at time of accident (not necessarily his regular job assignment experience)
TIME	8-10 AM 10-12 AM 12-2 PM 2-4 PM 4-6 PM 6-8 PM 8-10 PM 10-12 PM 12-2 AM 2-4 AM 4-6 AM 6-8 AM	Time of day at which accident occurred

EXHIBIT 2

Question Label	Response Label	Question/Response Explanation
SHIFT #	OTHER 1-1 1-2 1-3 2-2 2-3 3-3 1-? 2-?	Shift number (only coal producing shifts; maintenance = "other") 1-1 = first of one shift; 1-2 = first of two coal-producing shifts
WHO PREV	BUR MINE MANAGEMT FOREMAN VICTIM OTH WKR OTH PER NO ONE	Who might have best prevented the accident (not necessarily to blame but in best position to have prevented)
MACH DEF		What machinery deficiency may have contributed to the accident
	MAINT	--Was maintenance needed
	DESIGN	--Could improved design have prevented
	OPERATON	--Was operation of equipment improper
EQPFEATR	CONTROLS COMMUNIC FLASHBEL CANOPY EXPLOSPF MOVCANPY METH DET ROOFTEST LIGHTING OTHER BRAKES GUARDS	What added or improved equipment feature might have prevented the accident (Improved equipment could be design or maintenance, depending on which was applicable in "machinery deficiency" above)
IMMEDROF		What was composition of immediate roof
	SHALEHRD	--Hard shale (firm; consolidated)
	DRAWROCK	--Drawslate/rock;fragile shale
	SHALELAM	--Laminated shale
	SHLEFRAC	--Fractured shale (loose, unconsolidated, faulted)
	SHLEWKSF	--Weak/soft shale (sandy)
	COAL	--Top coal left
	SDSNSHL	--Sandstone/shale mix or laminate
	SANDSLAM	--Laminated sandstone
	SANDNORM	--Normal sandstone
	BONECOAL	--Rash roof; coal mixture
	ROCKCOAL	--Rock/coal mixture
	SHALNORM	--Normal shale
FALTHKNS	1-4" 5-7" 8-11" 12-17" 18-24" 25-32" 33-42" 43-52" 53-64" 65-74" 75-114" >114"	Average thickness of fall (inches)
FAL SQFT	0-10' 11-20' 21-30' 31-50' 51-70' 71-100' 101-130' 131-180' 181-230' 231-330' 331-630' >630'	Average square footage of fall (feet)

EXHIBIT 2

Question Label	Response Label		Question/Response Explanation
RIB DIST	0-1'	6+-7'	Shortest distance from nearest rib to fall (feet)
	1+-2'	7+-8'	
	2+-3'	8+-10'	
	3+-4'	10+-12'	
	4+-5'	12+-15'	
	5+-6'	>15'	
FACE DIS	0-1'	12+-13'	Shortest distance from face to fall (feet)
	1+-2'	13+-14'	
	2+-3'	14+-15'	
	3+-4'	15+-16'	
	4+-5'	16+-17'	
	5+-6'	17+-18'	
	6+-7'	18+-19'	
	7+-8'	19+-20'	
	8+-9'	20+-21'	
	9+-10'	21+-22'	
	10+-11'	22+-23'	
	11+-12'	23+	
FAIL NAT			Nature of roof fall and support failure
	BV ANCHR		--Broke above anchor line of bolts
	LW ANCHR		--Broke below anchor line of bolts
	BTW SUPT		--Spall fall between bolts
	OVERHANG		--Fall of rib roof overhang
	TO SUPLN		--Break occurred right up to permanent support line
	INBY<2'		--Broke within 2' but not up to support line
	INBY 3-5		--Broke 3 to 5' from support line (inby)
	INBY 6-7		--Broke 6 to 7' from support line (")
	INBY 8-9		--Broke 8 to 9' from support line (")
	INBY 10>		--Broke equal to or over 10' inby support line
	OVER SPT		--Broke over posts used as permanent support
F ENT WD	0-5'	19+-20	Width of entry from rib to rib at accident site (feet)
	5+-8'	20+-21	
	8+-12'	21+-22	
	12+-15	22+-23	
	15+-17	23+-25	
	17+-19	>25	
F ENT DE	0-5'	19+-20	Depth of entry from last crosscut to face (feet)
	5+-10'	20+-21	
	10+-15	21+-22	
	15+-17	22+-24	
	17+-18	24+-26	
	18+-19	>26	
VIC TO S	0-1'	6+-7	Distance from victim to permanent support line (only if working inby supported roof) (feet)
	1+-2'	7+-9	
	2+-3	9+-12	
	3+-4	12+-15	
	4+-5	15+-20	
	5+-6	>20	

Question Label	Response Label	Question/Response Explanation
EXPOSURE		Under what roof condition was victim
	UNSP UNC	--Under unsupported roof unnecessarily (repairing equipment there, etc.) Note: victim under unsupported roof unless surrounded by props (rib counts as support)
	UNSP NEC	--Job necessitated victim being under unsupported roof (setting temporary support)
	<TMP VIO	--Inadequate temporary support in violation of roof plan (called for 3, only used 1 prop)
	<TMP OK	--Inadequate temporary support in concurrence with plan
	FL PM VI	--Failure of permanent support in violation of plan (exceeded center distances, etc.)
	FL PM OK	--Failure of permanent support in concurrenc with plan
CIR DIAM	0-10" 10+-14" 14+-16 16+-18 18+-20 20+-23 23+-27 27+-34 34+-42 42+-50 >50"	Diameter of largest circle between ribs at point of accident, using a center which would approximate victim's location or which would encompass as many victims and as much of the fall as possible
%CIR SUP	0% E 1-10% 11-20% 21-30 31-40 41-50 51-60 61-70 71-80 81-90 91-100%	Percentage of the circle above that is adequately supported by permanent or temporary supports
SUP-CIRC		Type of support, if any, in circle above
	NONE	
	P-T-B	--Posts, trusses, bolts
	POST-TRU	--Posts, trusses
	POST-JAC	--Temporary posts, hydraulic jacks
	BL-ST-CR	--Bolts, straps, cribs
	BOL-STRA	--Bolts, straps
	BOL-CRIB	--Bolts, cribs
	BL-ST-RP	--Bolts, straps, rib posts
	BOL-RIBP	--Bolts, rib posts
	BOLTS	--Bolts only
	RIB POST	--Rib posts only
	POST+RP	--Posts, rib posts
F TO PRM	0-5' 5+-8' 8+-12' 12+-15' 15+-17' 17+-19' 19+-20' 20+-21' 21+-22' 22+-23' 23+-25' >25'	Distance from face to permanent support line (feet)

Question Label	Response Label	Question/Response Explanation
PROP*SQ'	0 .2PROP .4 .6 .8 1. 2+-3 3+-4 4+-5 5+-6' 6+-7' >7'	Number of safety props per 100 sq. ft. in area from last permanent support line to face
PATT-SUP	3' CENTR 4' CENTR 5 6 2X3'CENT 3X4CENT 4X5 5X6 >6'CENT <20SF-SU 21-40SF >40SF-SU	What pattern of permanent support was used in area or adjacent to accident (excluding rib posts) (Usually refers to bolts, crossbars)
BLT LENG	0-30" 31-42" 43-54 55-66 67-78 79-90 91-102 >102"	What length of bolts were used as permanent support (inches)
RIB PATN	0-2'RX3C " X4'CEN " X5'CEN " X6'CEN 2+-R3RX3 " X4'CEN 2 X5'CEN " X6'CEN >3RX4CEN " 5'CEN " 6'CEN "X>6'CEN	What pattern of rib posts were used near scene
VIC LOC		In what area of mine was victim located.
	MAIN ENT	--Haulageway, main air passage, etc. Area more supported and larger than development areas
	DEV AREA	--Room, crosscut, etc. being mined (working face area)
	T INTER	--T or ┐ intersection
	4 INTER	--Four-way intersection
	X INTER	--X-shaped intersection
	Y INTER	--Y-shaped intersection
	PIL POCK	--Pocket area of pillar
	PIL SPLT	--Split area of pillar
	PIL WING	--Wing/fender area of pillar
	PIL STMP	--Stump/push area of pillar
	PIL LIFT	--Lift from pillar
	OTHER	Note: Area refers to place being worked; ie., if victim doing pillar removal and is in passage way while working on pillar stump, he is considered as being in pillar stump area. If in intersection while starting to drive new face, he is in intersection.

EXHIBIT 2

Question Label	Response Label	Question/Response Explanation
%PIL RMV	0-10% 11-20% 21-30% 31-40% 41-50% 51-60% 61-70% 71-80% 81-90% 90-100%	If in pillaring area, what percent of the pillar had already been removed
MAJ CAUS	N ENF SP	What was the major cause of the accident --Not enough support, either in violation of temporary or permanent support plan; can be centers or number of supports
	EXCES WD	--Excessive cut width in violation of plan
	EXCES DP	--Excessive cut depth in violation of plan
	TESTING	--Improper or lack of testing (roof)
	CONDAJUS	--Did not adjust for changed conditions in violation of plan (called for crossbars in areas with slips or cracks - did not use)
	SCALTOOL	--Used improper tool for scaling roof/rib
	NO SCALE	--Did not scale down loose roof/ribs
	PILR RMV	--Improper sequence of pillar removal
	RPL SUPT	--Did not replace dislodged supports
	RMV SUPT	--Removed temporary or permanent supports
	RMV BOLT	--Removed bolts upon retreat
	DEL TEMP	--Excessive time lag in installing temporary supports under newly exposed roof, leading to excessive sagging and fall
	EQP OPER	--Faulty equipment operation leading to dislodging of supports
	EQP FAUL	--Use of equipment in need of maintenance
	NOT OBEY	--Knowingly violated company regulations (proceeded under unsupported roof) or did not heed warnings from men
	(Supports) OK, INADQ	--Plan was being followed but was inadequate for conditions
	LRG AREA	--Support not good - large area involved
	LOOSROOF	--Support not good - loose roof not supported
	CLAYVEIN	--Support not good - clay veins/cracks in area
	SLIP-FLT	--Support not good - slips/line faults in area
	OTHR FLT	--Support not good - other faults (horsebacks, kettlebottoms, etc.) in area
	NEARGOBS	--Support not good - near gob areas
	INTERSEC	--Support not good - near intersections
	PASTFALS	--Support not good - in area with past falls
	DIFFROOF	--Support not good - roof composition changed
	PROC DEV	--Victim deviated from established procedure (bolted out of sequence, etc.)
	OTHER	
	NO SUPV	--Serious lack of supervision (no certified official at mine; foreman not around for excessive amount of time)
	NO PLAN	--No established plan or policy for event

EXHIBIT 2

Question Label	Response Label	Question/Response Explanation
CONTFAC1 CONTFAC2	same as major cause	Of previous list for major cause, what were 2 contributing factors
VIC JOB	CUTTING DRILLING SHOOT TOP CREW DRILLBOL CONTLOAD HANDLOBD CONTMINR genl lbr SHUTTLE TRAKHAUL REPAIRMN	What were the victim's regular job duties (top crew is a timberman)
VIC LEVL	HELPER OPR-WKR AS'T FOR FOREMAN MINE FOR SUPINT OWNER ENGR OTHER	What was victim's duty or organizational level (Foremen and above had no job classifications assigned.)
VIC DO	HAND MIN CONT MIN CUTTING DRIL FAC SHOOTING HANDLOAD MACHLOAD SHUTTLE ROOFTEST RFSCALE SET TIMB RF DR&BT CLEANUP TRAMMING REM FALL REM SUPT REPAIR TRK HAUL SUPERVIS OBSERVIN INSPECT NOTHING OTHER SURVEY LONGWALL	What was victim doing when accident occurred --RFSCALE is scaling roof --RF DR&BT is drilling or bolting roof --CLEANUP is hand shoveling loose coal around ribs/face--not the same as hand-loading --REM SUPT is removing support
CREW DO	same as vic do	What was crew doing when accident occurred
MEN WARN	NO, YES	Was there a warning from other men which, if heeded, would have avoided the victim's death ("Don't go in there as roof's about to fall.")
MIN WARN	NO, YES	Was there an observable/audible warning from the mine; i.e., working roof, prior fall, dummy sound, crack, etc.
SUPVWARN	NO, YES	Did management (especially the foreman) fail to properly inform victim of dangerous situation
POORCOMM	NO, YES	Was poor communication to victim a factor; i.e., foreman did not explain situation fully or clearly enough
SUP'VISD	NO, YES	Was victim under direct supervision; i.e., was supervisor aware of and approve victim's actions (supervisor need not be present
LASTTEST	NO YES<1HR 1-4 HRS 4-8HRS PREVSHIF YES>1DAY UNKNOWN	When was roof in accident area last tested (hours)

EXHIBIT 2

Question Label	Response Label	Question/Response Explanation
JOB DEV	NO, YES	Was victim involved in task other than his normal duties - in a new practice, or a variation from normal practice (different pillar sequence; new machine, new technique, new job)
WKR JUDG	NO, YES	Did victim use poor judgment (proceed under unsupported roof unnecessarily)
WK EXPED	NO, YES	Was victim involved in expedient procedures at expense of own safety (did not put up enough props to save time or to maneuver machine more easily)
WK ALONE	NO, YES	Was victim working alone
PCAR POS	NO, YES	Was victim in apparent precarious position (under unsupported roof; riding belt conveyor)
LIGHT	NO, YES PROB NO, PROB YES	Was vision obscured or was insufficient light a factor
FORE DEC	GOOD O.K. POOR BAD NOT MADE	How was foreman's decision relative to accident
MGT POLI	same	How was management's policy relative to event
MGTTRAIN	same	How was management training relative to accident (what were the results of the training)
MGT ATTI	same	What was management's attitude toward risk and/or safety as exhibited by their practices
FEDRULES	NO, YES	Were federal regulations being followed
MINE REG	NO, YES	Were mine regulations being followed
FORE REG	NO, YES	Were foreman's instructions being followed
LST INSP	0-3 MO. 3+-6 MO. 6+-9 9+-12 12+-18 18+-24 >24 NEVER	How recent was the last regular Bureau of Mines inspection (or PBR) (Months)

EXHIBIT 2

Question Label	Response Label		Question/Response Explanation
OVERBURD	0-199' 200-499' 500-799' 800-1299	1300-19C 1900-26C 2600-32C >3200'	What was the overburden in accident area (feet) (Answered for bumps/bursts and explosions onl
EXPLOSIONS			
GASSY	NO YES-TEST YES-NT		Was mine classified as gassy --Yes but was tested regularly --Yes but was not tested regularly
COALDUST	NO 0-.1PPM .11-.14 .15-.18 .19-.21 .22-.24	.25-.29 .30-.35 .36-.40 >.40PPM NOT SPEC	Coal dust level, ppm
ROCKDUST	NO YES-ADQT YES-NA		Was rock dust used for coal dust control --Yes and was adequately applied --Yes but was not adequately applied
XPOSDIGN	NO YESWIRES YES MACH YES CIG	YES SPK CIG-MATC COMBINAT OTHER	What was the source of exposed ignition, if any
VENTILAT	GOOD O.K. POOR	BAD NONE	To what degree was the ventilation adequate
HUM&BAR	LOW & LO LOW & OK OK & LOW OK & OK	LOW & - OK & - - & LOW - & OK	What were the humidity and barometer readings
% METH.	0-.5% .6-.7% .8-.9% 1.0-1.2% 1.3-1.6%	1.7-2.2% 2.3-3.0% 3.1-4.0% >4.0% EXCESSIV	What was the average percentage of methane emission
HAULAGE			
HAUL CLR	0-5" 5+-7" 7+-9 9+-11 11+-13 13+-15	15+-18 18+-21 21+-24 24+-30 30+-36 >36"	What was the haulage clearance measured to the closest immovable object pertinent to accident (rib or roof versus car side or height, respectively; normal minimum clearance)
TRK COND	GOOD, OK POOR, BAD		What were track conditions relative to maintenance or design of haulage tracks (rails, etc.)
COM EQP	same		To what degree was communication equipment present in area of accident or on vehicle

Question Label	Response Label	Question/Response Explanation
EQP LITE	GOOD, OK POOR, BAD NONE, ONLY RFL	Equipment lighting on vehicle (only reflectors)
BRKS-ROL	GOOD, OK POOR, BAD FAILED, NONE	What was the condition of the brakes or anti-roll (or automatic derailer) that might have affected the accident (refers to any mechanism designed to stop vehicles)
P-SELF R	NO, YES	Did the power switches and controls automatically return to neutral or off
HAULGRAD	0-1% 1+-2% 2+-3 3+-4 4+-5 5+-6 6+-7 7+-8 8+-9 9+-10 >10%	What was the grade of the haulage slope in the area of the accident

ALL RESPONSES

EXHIBIT 3

731 FATAL ACCIDENTS, 1966-1970

STATE	TOTAL SAMPLE	% TOTAL
ALABAMA	20	2.74
ALASKA	0	0.00
ARIZONA	0	0.00
ARKANSAS	0	0.00
COLORADO	12	1.64
GEORGIA	0	0.00
ILLINOIS	34	4.65
INDIANA	3	.41
IOWA	1	.14
KANSAS	0	0.00
KENTUCKY	166	22.71
MARYLAND	1	.14
MISSOURI	0	0.00
MONTANA	1	.14
NEW MEX	0	0.00
N DAKOTA	0	0.00
OHIO	23	3.15
OKLAHOMA	3	.41
OREGON	0	0.00
PA	99	13.54
S DAKOTA	0	0.00
TENN	16	2.19
UTAH	11	1.50
VIRGINIA	87	11.90
WASHINGT	0	0.00
W VIRGIN	253	34.61
WYOMING	1	.14
	731	100.01

MONTH	TOTAL SAMPLE	% TOTAL
JAN	74	10.12
FEB	42	5.75
MAR	63	8.62
APR	60	8.21
MAY	61	8.34
JUN	67	9.17
JUL	58	7.93
AUG	72	9.85
SEP	63	8.62
OCT	58	7.93
NOV	51	6.98
DEC	62	8.48
	731	100.00

YEAR	TOTAL SAMPLE	% TOTAL
1963	0	0.00
1964	0	0.00
1965	0	0.00
1966	157	21.48
1967	146	19.97
1968	157	21.48
1969	129	17.65
1970	142	19.43
1971	0	0.00
	731	100.01

DALYTONS	TOTAL SAMPLE	% TOTAL
0-50	50	6.87
51-100	40	5.49
101-200	65	8.93
201-400	60	8.24
401-700	54	7.42
701-1000	46	6.32
1001-140	33	4.53
1401-180	34	4.67
1801-230	37	5.08
2301-300	63	8.65
3001-400	68	9.34
>4000	178	24.45
	728	99.99

# EMPLYD	TOTAL SAMPLE	% TOTAL
0-3	19	2.60
4-7	63	8.63
8-15	90	12.33
16-19	25	3.42
20-40	75	10.27
41-65	45	6.16
66-100	62	8.49
101-130	50	6.85
131-160	52	7.12
161-200	76	10.41
201-260	46	6.30
>260	127	17.40
	730	99.98

MINESTYL	TOTAL SAMPLE	% TOTAL
HAND	21	3.25
CONV DEV	274	42.41
CONV PIL	65	10.06
CONT DEV	218	33.75
CONT PIL	64	9.91
LONGWALL	4	.62
	646	100.00

WET?	TOTAL SAMPLE	% TOTAL
YES	93	77.50
NO	27	22.50
	120	100.00

SEAM HT.	TOTAL SAMPLE	% TOTAL
0-3"	114	15.66
3+-4"	184	25.27
4+-5"	170	23.35
5+-6"	106	14.56
6+-7"	73	10.03
7+-8"	43	5.91
8+-9"	18	2.47
9+-11"	7	.96
11+-14"	6	.82
>14"	7	.96
	728	99.99

ROOF HGT	TOTAL SAMPLE	% TOTAL
0-3"	45	12.89
3+-4"	83	23.78
4+-5"	71	20.34
5+-6"	48	13.75
6+-7"	32	9.17
7+-8"	31	8.88
8+-9"	14	4.01
9+-11"	13	3.72
11+-14"	7	2.01
>14"	5	1.43
	349	99.98

S.S.&VAR	TOTAL SAMPLE	% TOTAL
0-2&NO	4	13.79
2+-5&NO	4	13.79
5+-8&NO	5	17.24
8+-11&NO	1	3.45
11+-14&N	3	10.34
>14&NO	8	27.59
0-2&YES	0	0.00
2+-5&YES	0	0.00
5+-8&YES	2	6.90
8+-11&YE	0	0.00
11+-14&Y	1	3.45
>14&YES	1	3.45
	29	100.00

EXHIBIT 3

FATALS	TOTAL SAMPLE	% TOTAL
1	692	94,66
2	24	3,28
3	7	,96
4	5	,68
5	1	,14
6	0	0,00
7	1	,14
8	0	0,00
9-15	0	0,00
16-50	1	,14
>50	0	0.00
	731	100.00

INJURED	TOTAL SAMPLE	% TOTAL
0	636	87,00
1	74	10,12
2	14	1,92
3	3	,41
4	1	,14
5	2	,27
6	0	0,00
7	0	0,00
8	0	0,00
9-15	1	,14
16-50	0	0,00
>50	0	0.00
	731	100.00

NONFATAL	TOTAL SAMPLE	% TOTAL
0	597	81,78
1	92	12,60
2	28	3,84
3	8	1,10
4	3	,41
5	0	0.00
6	1	,14
7	0	0,00
8	0	0,00
9-15	1	,14
16-50	0	0,00
>50	0	0.00
	730	100.01

TYPE ACC	TOTAL SAMPLE	% TOTAL
EXPLOSON	7	,96
RF<25FAC	287	39,26
RF<10INT	58	7,93
ROOF OTH	43	5,88
RIB<25'	19	2,60
RIB>25'	9	1,23
OTHER	23	3,15
HAULSHUT	74	10,12
HAULMAIN	81	11,08
BUMP	6	,82
ELECT'CL	40	5,47
EQUIP--	84	11.49
	731	99.99

VIC AGE	TOTAL SAMPLE	% TOTAL
<=20YRS	11	1,51
21-25YRS	58	7,96
26-30	52	7,13
31-35	58	7,96
36-40	85	11,66
41-45	121	16,60
46-50	126	17,28
51-55	103	14,13
56-60	85	11,66
61-65	23	3,16
66-70	4	,55
>70YRS	3	.41
	729	100.01

VIC EXPR	TOTAL SAMPLE	% TOTAL
0-.5YR	22	3,10
.5-1 YR	17	2,40
1-2YR	15	2,12
2+ -5YR	45	6,35
5,1-8YR	39	5,50
8,1-11YR	47	6,63
11,1-14	30	4,23
14,1-17	58	8,18
17,1-20	48	6,77
20,1-25	136	19,18
25.1-30	89	12,55
>30YRS	163	22.99
	709	100.00

TASK EXP	TOTAL SAMPLE	% TOTAL
0-.25MO.	23	3,81
,25-.5MO	11	1,82
.5-1 MO	18	2,98
1+ -3MO	42	6,95
3+ - 6MO	59	9,77
6+-12MO	50	8,28
12+-24MO	71	11,75
24+-36MO	50	8,28
>36MO	280	46.36
	604	100.00

TIME	TOTAL SAMPLE	% TOTAL
8-10 AM	82	11,25
10-12 AM	113	15,50
12-2 PM	95	13,03
2-4 PM	85	11,66
4-6 PM	39	5,35
6-8 PM	62	8,50
8-10 PM	56	7,68
10-12 PM	48	6,58
12-2 AM	33	4,53
2-4 AM	29	3,98
4-6 AM	31	4,25
6-8 AM	56	7.68
	729	99.99

SHIFT #	TOTAL SAMPLE	% TOTAL
OTHER	59	8,09
1-1	157	21,54
1-2	128	17,56
1-3	82	11.25
2-2	107	14,68
2-3	75	10,29
3-3	87	11,93
1-?	21	2,88
2-?	13	1.78
	729	100.00

WHO PREV	TOTAL SAMPLE	% TOTAL
BUR MINE	3	,41
MANAGEMT	245	33,56
FOREMAN	114	15,62
VICTIM	309	42,33
OTH WKR	36	4.93
OTH PER	1	,14
NO ONE	19	2,60
UNKNOWN	3	.41
	730	100.00

MACH DEF	TOTAL SAMPLE	% TOTAL
MAINT	64	25,20
DESIGN	96	37,80
OPERATON	94	37.01
	254	100.01

EQPFEATR	TOTAL SAMPLE	% TOTAL
CONTROLS	19	12,26
COMMUNIC	1	,65
FLASHREL	10	6,45
CANOPY	42	27.10
EXPLOSPF	0	0,00
MOVCANPY	0	0,00
METH DET	0	0,00
ROOFTEST	0	0,00
LIGHTING	5	3,23
OTHER	44	28,39
BRAKES	2	1,29
GUARDS	32	20.65
	155	100.02

EXHIBIT 3

IMMEDROF	TOTAL SAMPLE	% TOTAL
SHALEHRD	55	13.19
DRAWROCK	39	9.35
SHALCLAM	48	11.51
SHLEFRAC	63	15.11
SHLEWKSF	34	8.15
COAL	43	10.31
SDSNESHL	34	8.15
SANDSLAM	13	3.12
SANDNORM	26	6.24
BONECOAL	20	4.80
ROCKCOAL	9	2.16
SHALNORM	33	7.91
	417	100.00

FALTHKNS	TOTAL SAMPLE	% TOTAL
1-4"	58	14.22
5-7"	75	18.38
8-11"	76	18.63
12-17"	57	13.97
18-24"	44	10.78
25-32"	21	5.15
33-42"	21	5.15
43-52"	10	2.45
53-64"	9	2.21
65-74"	9	2.21
75-114"	16	3.92
>114"	12	2.94
	408	100.01

FAL SQFT	TOTAL SAMPLE	% TOTAL
0-10'	22	5.33
11-20'	22	5.33
21-30'	29	7.02
31-50'	56	13.56
51-70'	26	6.30
71-100'	35	8.47
101-130'	22	5.33
131-180'	20	4.84
181-230'	20	4.84
231-330'	32	7.75
331-630'	62	15.01
>630'	67	16.22
	413	100.00

RIB DIST	TOTAL SAMPLE	% TOTAL
0-1'	233	58.69
1+-2'	42	10.58
2+-3'	36	9.07
3+-4'	20	5.04
4+-5'	15	3.78
5+-6'	20	5.04
6+-7'	8	2.02
7+-8'	7	1.76
8+-10'	8	2.02
10+-12'	2	.50
12+-15'	4	1.01
>15'	2	.50
	397	100.01

FACE DIS	TOTAL SAMPLE	% TOTAL
0-1'	94	36.86
1+-2'	25	9.80
2+-3'	27	10.59
3+-4'	16	6.27
4+-5'	10	3.92
5+-6'	9	3.53
6+-7'	12	4.71
7+-8'	6	2.35
8+-9'	7	2.75
9+-10'	5	1.96
10+-11'	6	2.35
11+-12'	7	2.75
12+-13'	9	3.53
13+-14'	3	1.18
14+-15'	3	1.18
15+-16'	0	0.00
16+-17'	1	.39
17+-18'	4	1.57
18+-19'	2	.78
19+-20'	3	1.18
20+-21'	1	.39
21+-22'	1	.39
22+-23'	0	0.00
23+	4	1.57
	255	100.00

FAIL NAT	TOTAL SAMPLE	% TOTAL
BV ANCHR	46	12.85
LW ANCHR	15	4.19
BTW SUPT	20	5.59
OVERHANG	31	8.66
TO SUPLN	115	32.12
INBY<2'	30	8.38
INBY 3-5	45	12.57
INBY 6-7	9	2.51
INBY 8-9	1	.28
INBY 10>	16	4.47
OVER SPT	30	8.38
	358	100.00

F ENT DE	TOTAL SAMPLE	% TOTAL
0-5'	4	1.74
5+-10'	25	10.87
10+-15	21	9.13
15+-17	7	3.04
17+-18	8	3.48
18+-19		.43
19+-20	9	3.91
20+-21	7	3.04
21+-22	1	.43
22+-24	3	1.30
24+-26	12	5.22
>26	132	57.39
	230	99.98

F ENT WD	TOTAL SAMPLE	% TOTAL
0-5'	2	.83
5+-8'	1	.42
8+-12'	8	3.33
12+-15	26	10.83
15+-17	37	15.42
17+-19	35	14.58
19+-20	20	8.33
20+-21	9	3.75
21+-22	18	7.50
22+-23	11	4.58
23+-25	28	11.67
>25	45	18.75
	240	99.99

VIC TO S	TOTAL SAMPLE	% TOTAL
0-1'	7	3.41
1+-2'	17	8.29
2+-3	28	13.66
3+-4	21	10.24
4+-5	21	10.24
5+-6	28	13.66
6+-7	15	7.32
7+-9	16	7.80
9+-12	19	9.27
12+-15	9	4.39
15+-20	7	3.41
>20	17	8.29
	205	99.98

EXPOSURE	TOTAL SAMPLE	% TOTAL
UNSP UNC	163	42.78
UNSP NEC	39	10.24
<TMP VIO	54	14.17
<TMP OK	21	5.51
FL PM VI	31	8.14
FL PM OK	73	19.16
	381	100.00

CIR DIAM	TOTAL SAMPLE	% TOTAL
0-10'	3	.77
10+-14'	18	4.62
14+-16	34	8.72
16+-18	43	11.03
18+-20	46	11.79
20+-23	64	16.41
23+-27	70	17.95
27+-34	65	16.67
34+-42	27	6.92
42+-50	6	1.54
>50'	14	3.59
	390	100.01

EXHIBIT 3

%CIR SUP	TOTAL SAMPLE	% TOTAL
0% E	52	13.83
1-10%	61	16.22
11-20%	21	5.59
21-30	32	8.51
31-40	16	4.26
41-50	26	6.91
51-60	24	6.38
61-70	21	5.59
71-80	27	7.18
81-90	35	9.31
91-100%	61	16.22
	376	100.00

SUP-CIRC	TOTAL SAMPLE	% TOTAL
NONE	45	10.92
P-T-B	12	2.91
POST-TRU	26	6.31
POST-JAC	29	7.04
BL-ST-CR	3	.73
BOL-STRA	11	2.67
BOL-CRIB	4	.97
BL-ST-RP	11	2.67
BOL-RIBP	53	12.86
BOLTS	105	25.49
RIB POST	51	12.38
POST+RP	62	15.05
	412	100.00

F TO PRM.	TOTAL SAMPLE	% TOTAL
0-5"	27	12.44
5+-8"	24	11.06
8+-12"	54	24.88
12+-15"	32	14.75
15+-17"	18	8.29
17+-19"	9	4.15
19+-20"	10	4.61
20+-21"	8	3.69
21+-22"	8	3.69
22+-23"	5	2.30
23+-25"	5	2.30
>25"	17	7.83
	217	99.99

PROP*SQ"	TOTAL SAMPLE	% TOTAL
0	167	49.70
.2PROP	35	10.42
.4	14	4.17
.6	12	3.57
.8	6	1.79
1.	41	12.20
2+-3	27	8.04
3+-4	13	3.87
4+-5	6	1.79
5+-6"	3	.89
6+-7"	6	1.79
>7"	6	1.79
	336	100.02

PATT-SUP	TOTAL SAMPLE	% TOTAL
3" CENTR	17	7.30
4" CENTR	106	45.49
5	41	17.60
6	5	2.15
2X3"CENT	2	.86
3X4CENT	9	3.86
4X5	27	11.59
5X6	7	3.00
>6"CENT	4	1.72
<20SF-SU	5	2.15
21-40SF	4	1.72
>40SF-SU	6	2.58
	233	100.02

BLT LENG	TOTAL SAMPLE	% TOTAL
0-30"	28	20.00
31-42"	40	28.57
43-54	24	17.14
55-66	22	15.71
67-78	11	7.86
79-90	4	2.86
91-102	8	5.71
>102"	3	2.14
	140	99.99

RIB PATN	TOTAL SAMPLE	% TOTAL
0-2"RX3C	6	2.96
" X4"CEN	9	4.43
" X5"CEN	8	3.94
" X6"CEN	1	.49
2+-R3RX3	11	5.42
" X4"CEN	35	17.24
" X5"CEN	18	8.87
" X6"CEN	7	3.45
>3RX4CEN	53	26.11
" 5"CEN	39	19.21
" 6"CEN	10	4.93
"X>6"CEN	6	2.96
	203	100.01

VIC LOC	TOTAL SAMPLE	% TOTAL
MAIN ENT	154	26.19
DEV AREA	193	32.82
T INTER	45	7.65
4 INTER	94	15.99
X INTER	0	0.00
Y INTER	10	1.70
PIL POCK	17	2.89
PIL SPLT	35	5.95
PIL WING	3	.51
PIL STMP	19	3.23
PIL LIFT	18	3.06
OTHER	0	0.00
	588	99.99

%PIL RMV	TOTAL SAMPLE	% TOTAL
0-10%	9	13.04
11-20%	13	18.84
21-30%	8	11.59
31-40%	4	5.80
41-50%	5	7.25
51-60%	3	4.35
61-70%	5	7.25
71-80%	6	8.70
81-90%	9	13.04
90-100%	7	10.14
	69	100.00

LASTTEST	TOTAL SAMPLE	% TOTAL
NO	9	2.22
YES<1HR	277	68.40
1-4 HRS	78	19.26
4-8HRS	8	1.98
PREVSHIF	4	.99
YES>1DAY	9	2.22
UNKNOWN	20	4.94
	405	100.01

EXHIBIT 3

MAJ CAUS	TOTAL SAMPLE	% TOTAL
N ENF SP	156	28.68
EXCES WD	1	.18
EXCES DP	0	0.00
TESTING	54	9.93
CONDAJUS	13	2.39
SCALTOOL	1	.18
NO SCALE	12	2.21
PILR RMV	24	4.41
RPL SUPT	6	1.10
RMV SUPT	13	2.39
RMV BOLT	2	.37
DEL TEMP	3	.55
EQP OPER	78	14.34
EQP FAUL	33	6.07
NOT OBEY	42	7.72
OK,INADQ	26	4.78
LRG AREA	3	.55
LOOSROOF	19	3.49
CLAYVEIN	4	.74
SLIP-FLT	11	2.02
OTHR FLT	3	.55
NEARGOBS	2	.37
INTERSEC	1	.18
PASTFALS	8	1.47
DIFFROOF	2	.37
PROC DEV	5	.92
OTHER	0	0.00
NO SUPV	4	.74
NO PLAN	18	3.31
	544	100.01

CONTFAC1	TOTAL SAMPLE	% TOTAL
N ENF SP	34	8.08
EXCES WD	12	2.85
EXCES DP	1	.24
TESTING	106	25.18
CONDAJUS	18	4.28
SCALTOOL	3	.71
NO SCALE	19	4.51
PILR RMV	15	3.56
RPL SUPT	7	1.66
RMV SUPT	10	2.38
RMV BOLT	1	.24
DEL TEMP	5	1.19
EQP OPER	11	2.61
EQP FAUL	15	3.56
NOT OBEY	24	5.70
OK,INADQ	7	1.66
LRG AREA	3	.71
LOOSROOF	23	5.46
CLAYVEIN	9	2.14
SLIP-FLT	18	4.28
OTHR FLT	14	3.33
NEARGOBS	6	1.43
INTERSEC	0	0.00
PASTFALS	11	2.61
DIFFROOF	5	1.19
PROC DEV	10	2.38
OTHER	0	0.00
NO SUPV	24	5.70
NO PLAN	10	2.38
	421	100.02

CONTFAC2	TOTAL SAMPLE	% TOTAL
N ENF SP	9	3.61
EXCES WD	7	2.81
EXCES DP	0	0.00
TESTING	62	24.90
CONDAJUS	8	3.21
SCALTOOL	0	0.00
NO SCALE	6	2.41
PILR RMV	5	2.01
RPL SUPT	4	1.61
RMV SUPT	0	0.00
RMV BOLT	0	0.00
DEL TEMP	0	0.00
EQP OPER	2	.80
EDP FAUL	1	.40
NOT OBEY	14	5.62
OK,INADQ	1	.40
LRG AREA	2	.80
LOOSROOF	20	8.03
CLAYVEIN	4	1.61
SLIP-FLT	15	6.02
OTHER FL	12	4.82
NEARGOBS	12	4.82
INTERSEC	4	1.61
PASTFALS	10	4.02
DIFFROOF	1	.40
PROC DEV	8	3.21
OTHER	0	0.00
NO SUPV	35	14.06
NO PLAN	7	2.81
	249	99.99

VIC JOB	TOTAL SAMPLE	% TOTAL
CUTTING	41	6.67
DRILLING	9	1.46
SHOOT	22	3.58
TOP CREW	37	6.02
DRILLROL	71	11.54
MACHLOAD	86	13.98
HANDLOD	35	5.69
CONTMINR	95	15.45
GENL LBR	18	2.93
SHUTTLE	75	12.20
TRAKHAUL	55	8.94
REPAIRMN	71	11.54
	615	100.00

VIC LEVL	TOTAL SAMPLE	% TOTAL
HELPER	86	11.76
OPR-WKR	523	71.55
AS'T FOR	7	.96
FOREMAN	65	8.89
MINE FOR	31	4.24
SUPINT	7	.96
OWNER	10	1.37
ENGR	1	.14
OTHER	1	.14
	731	100.01

VIC DO	TOTAL SAMPLE	% TOTAL
HAND MIN	1	.14
CONT MIN	56	7.68
CUTTING	16	2.19
DRIL FAC	18	2.47
SHOOTING	16	2.19
HANDLOAD	32	4.39
MACHLOAD	51	7.00
SHUTTLE	49	6.72
ROOFTEST	8	1.10
RFSCALE	18	2.47
SET TIMB	43	5.90
RF DR&BT	46	6.31
CLEANUP	34	4.66
TRAMMING	72	9.88
REM FALL	10	1.37
REM SUPT	19	2.61
REPAIR	60	8.23
TRK HAUL	66	9.05
SUPERVIS	17	2.33
OBSERVIN	17	2.33
INSPECT	18	2.47
NOTHING	10	1.37
OTHER	50	6.86
SURVEY	2	.27
LONGWALL	0	0.00
	729	99.99

CREW DO	TOTAL SAMPLE	% TOTAL
HAND MIN	3	.47
CONT MIN	125	19.72
CUTTING	28	4.42
DRIL FAC	17	2.68
SHOOTING	15	2.37
HANDLOAD	31	4.89
MACHLOAD	108	17.03
SHUTTLE	12	1.89
ROOF TES	0	0.00
RF SCALE	2	.32
SETTIMB	28	4.42
RF DR&BT	38	5.99
CLEANUP	18	2.84
TRAMMING	30	4.73
REM FALL	19	3.00
REM SUPT	6	.95
REPAIR	53	8.36
TRK HAUL	76	11.99
SUPERVIS	0	0.00
OBSERVIN	0	0.00
INSPECT	3	.47
NOTHING	6	.95
OTHER	14	2.21
SURVEY	1	.16
LONGWALL	1	.16
	634	100.02

EXHIBIT 3

MEN WARN	TOTAL SAMPLE	% TOTAL
NO	498	81.91
YES	110	18.09
	608	100.00

MIN WARN	TOTAL SAMPLE	% TOTAL
NO	286	63.27
YES	166	36.73
	452	100.00

SUPVWARN	TOTAL SAMPLE	% TOTAL
NO	503	80.22
YES	124	19.78
	627	100.00

SUP'VISD	TOTAL SAMPLE	% TOTAL
NO	327	47.12
YES	367	52.88
	694	100.00

JOB DEV	TOTAL SAMPLE	% TOTAL
NO	625	86.21
YES	100	13.79
	725	100.00

WKR JUDG	TOTAL SAMPLE	% TOTAL
NO	284	39.23
YES	440	60.77
	724	100.00

WK EXPED	TOTAL SAMPLE	% TOTAL
NO	601	83.01
YES	123	16.99
	724	100.00

WK ALONE	TOTAL SAMPLE	% TOTAL
NO	598	82.26
YES	129	17.74
	727	100.00

PCAR PDS	TOTAL SAMPLE	% TOTAL
NO	408	56.12
YES	319	43.88
	727	100.00

LIGHT	TOTAL SAMPLE	% TOTAL
NO	601	82.90
YES	48	6.62
PROB NO	1	.14
PROB YES	75	10.34
	725	100.00

FORE DEC	TOTAL SAMPLE	% TOTAL
GOOD	4	.68
O.K.	76	12.93
POOR	175	29.76
BAD	121	20.58
NOT MADE	212	36.05
	588	100.00

MGT POLI	TOTAL SAMPLE	% TOTAL
GOOD	30	4.16
O.K.	264	36.62
POOR	298	41.33
BAD	86	11.93
NOT MADE	43	5.96
	721	100.00

MGTTRAIN	TOTAL SAMPLE	% TOTAL
GOOD	1	.14
O.K.	38	5.26
POOR	510	70.64
BAD	173	23.96
NONE	0	0.00
	722	100.00

MGT ATTI	TOTAL SAMPLE	% TOTAL
GOOD	13	1.80
O.K.	258	35.73
POOR	406	56.23
BAD	45	6.23
UNKNOWN	0	0.00
	722	99.99

FEDRULES	TOTAL SAMPLE	% TOTAL
NO	397	71.27
YES	160	28.73
UNKNOWN	0	0.00
	557	100.00

MINE REG	TOTAL SAMPLE	% TOTAL
NO	330	52.88
YES	294	47.12
UNKNOWN	0	0.00
	624	100.00

FORE REG	TOTAL SAMPLE	% TOTAL
NO	58	16.16
YES	300	83.57
UNKNOWN	1	.28
	359	100.01

LST INSP	TOTAL SAMPLE	% TOTAL
0-3 MO.	541	74.72
3+-6 MO.	103	14.23
6+-9	25	3.45
9+-12	5	.69
12+-18	4	.55
18+-24	3	.41
>24	4	.55
NEVER	39	5.39
	724	99.99

EXHIBIT 3

EXPLOSIONS & BUMPS

OVERBURD	TOTAL SAMPLE	% TOTAL
0-199'	1	12.50
200-499'	1	12.50
500-799'	0	0.00
800-1299	1	12.50
1300-190	2	25.00
1900-260	3	37.50
2600-320	0	0.00
>3200'	0	0.00
	8	100.00

EXPLOSIONS

GASSY	TOTAL SAMPLE	% TOTAL
NO	1	10.00
YES-TEST	7	70.00
YES-NT	2	20.00
	10	100.00

COALDUST	TOTAL SAMPLE	% TOTAL
NO	2	25.00
0-.1PPM	1	12.50
.11-.14	0	0.00
.15-.18	0	0.00
.19-.21	0	0.00
.22-.24	0	0.00
.25-.29	1	12.50
.30-.35	0	0.00
.36-.40	0	0.00
>.40PPM	1	12.50
NOT SPEC	3	37.50
	8	100.00

ROCKDUST	TOTAL SAMPLE	% TOTAL
NONE	2	25.00
YES-ADQT	3	37.50
YES-NA	3	37.50
	8	100.00

XPOSDIGN	TOTAL SAMPLE	% TOTAL
NO	1	12.50
YESWIRES	1	12.50
YES MACH	1	12.50
YES CIG	0	0.00
YES SPK	2	25.00
CIG-MATC	0	0.00
COMBINAT	2	25.00
OTHER	1	12.50
	8	100.00

VENTILAT	TOTAL SAMPLE	% TOTAL
GOOD	0	0.00
O.K.	0	0.00
POOR	2	33.33
BAD	3	50.00
NONE BUT	1	16.67
	6	100.00

HUM&BAR	TOTAL SAMPLE	% TOTAL
LOW & LO	0	0.00
LOW & OK	1	16.67
OK & LOW	0	0.00
OK & OK	3	50.00
LOW & -	0	0.00
OK & -	0	0.00
- & LOW	2	33.33
- & OK	0	0.00
	6	100.00

% METH.	TOTAL SAMPLE	% TOTAL
0-.5%	1	14.29
.6-.7%	0	0.00
.8-.9%	0	0.00
1.0-1.2%	0	0.00
1.3-1.6%	1	14.29
1.7-2.2%	0	0.00
2.3-3.0%	0	0.00
3.1-4.0%	0	0.00
>4.0%	3	42.86
EXCESSIV	2	28.57
	7	100.01

HAULAGE ONLY

HAUL CLR.	TOTAL SAMPLE	% TOTAL
0-5"	10	6.80
5+-7"	14	9.52
7+-9	14	9.52
9+-11	7	4.76
11+-13	4	2.72
13+-15	3	2.04
15+-18	2	1.36
18+-21	1	.68
21+-24	2	1.36
24+-30	0	0.00
30+-36	2	1.36
>36"OR A	88	59.86
	147	99.98

TRK COND	TOTAL SAMPLE	% TOTAL
GOOD	42	28.57
OK	81	55.10
POOR	22	14.97
BAD	2	1.36
	147	100.00

COM EQP	TOTAL SAMPLE	% TOTAL
GOOD	2	4.17
OK	36	75.00
POOR	7	14.58
BAD	0	0.00
NONE	3	6.25
	48	100.00

EQP LITE	TOTAL SAMPLE	% TOTAL
GOOD	10	10.87
OK	61	66.30
POOR	7	7.61
BAD	8	8.70
NONE	6	6.52
ONLY RFL	0	0.00
	92	100.00

BRKS-ROL	TOTAL SAMPLE	% TOTAL
GOOD	13	10.74
OK	88	72.73
POOR	4	3.31
BAD	7	5.79
FAILED	3	2.48
NONE	6	4.96
	121	100.01

P-SELF R	TOTAL SAMPLE	% TOTAL
NO	25	62.50
YES	15	37.50
	40	100.00

HAUL GRAD	TOTAL SAMPLE	% TOTAL
0-1%	79	59.40
1+-2%	20	15.04
2+-3	9	6.77
3+-4	8	6.02
4+-5	3	2.26
5+-6	4	3.01
6+-7	4	3.01
7+-8	1	.75
8+-9	0	0.00
9+-10	4	3.01
>10%	1	.75
	133	100.02

EXHIBIT 4

FATAL VICTIM DATA SECTION
(ONE PAGE SAMPLE)

☐☐☐☐☐☐☐☐☐☐☐☐☐ 1. Name

☐☐☐–☐☐–☐☐☐☐ 2. Social Security Number

☐☐ 3. Number of survivors (0, 1, 2 --)

4. Total underground mining experience
☐☐ (Years)
☐☐ (Months, if less than 1 year)

☐ 5. Did victim actions contribute to the accident occurrence?
Yes = 1
No = 2

If answer to #5 is no, skip questions #6 to 12.

6. Total experience at the task victim doing at time of accident
☐☐ (Months)
☐☐ (Weeks, if less than 1 month)

☐ 7. Was task part of victim's normal job responsibilities?
Yes = 1
No = 2

☐ 8. Victim's job level

0 Apprentice
1 Helper
2 Operator/Worker
3 1st Line Supervision
4 2nd Line Supervision
5 Mine Owner, Manager (beyond 2nd Line Supervision)
6 Mine Staff (Engineer, Clerk, etc.)
7 Mine Inspector
8 Mine Visitor
9 Other

CHAPTER 4

ANALYSIS OF THE JOBS AND TASKS OF FATAL ACCIDENT VICTIMS

I. INTRODUCTION

The fatality report data base established under this contract cannot be completely analyzed within the time limits of the contract, nor was the performance of such an exhaustive analysis the intent of the initial contract. The data base, as previously explained, was established to support the basic field I. E. Study and to demonstrate the feasibility and cost effectiveness of a computerized man-machine interactive accident data base.

We have already shown various interested personnel in the Bureau the analysis presented in this report. This analysis, plus the computer demonstration which has been given to Bureau personnel, are designed to "whet the appetite" and to demonstrate the need for and potential benefits of a data base that can be easily queried for complex combinations of interacting variables.

This chapter begins with a capsule overview of fatal accidents as illustrated in the 'JAVAT" (Jobs vs. Activity of Victim vs. Accident Types) Chart. This chart graphically illustrates the relationships between the three variables. Accident frequency rankings of the job classification and job task activity of the primary victim are given next. The last sections of the chapter present an in-depth analysis of the apparent effects of task experience on accident occurrence and give specific recommendations.

A variety of other pertinent topics including federal compliance, seam height relationships to roof falls and roof fall exposure will be discussed in Chapter 5.

II. JAVAT CHART

The 'JAVAT" chart (Job vs. Activity of Victim vs. Accident Types) presented in Exhibit 1 describes who was killed, doing what, and in what kind of accident between 1966 and 1970. The 729 fatal accidents on the chart are distributed in a three-way classification, with each box representing the primary victim of each accident. The type of accident is represented by the columns, the victim's task activities are represented by the rows, and within each box is a letter code for the job classifications.

The job classification most frequently involved in each type of accident is crosshatched. In the case of victims performing repair activities for example, the chart indicates that repairmen are killed most frequently in machinery accidents. Where appropriate, operators and helpers are differentiated.

For each column representing a type of accident, the victim activity with the highest number of fatalities is heavily outlined. For example, tramming is the most dangerous activity for machinery accidents and repair work is most dangerous for electrical accidents.

In general, within each victim activity (for all accident types) the highest number of fatalities occur in the corresponding job classification: timbermen are most frequently killed while setting and removing support; roof bolters are usually killed roof drilling/bolting, etc. For many activities, however, no one job classification stands out: removing support has timbermen as the most frequent job classification, although timbermen are only 4 of the 19 victims involved in removing support; in roof falls within 25 feet of the face, each of the 8 victims who were removing support has a different job classification.

Because many activities are performed by a variety of persons, the typical coal miner is expected to learn and perform a large number of tasks, including those jobs close to the face. This means that new workers, especially those learning on the job, must suffer an unusual amount of frustration trying to learn so many new tasks at once. It is not surprising, therefore, that the new worker is considerably more accident prone than the senior workers. However, the data suggests that a factor called job task experience is even more important than just total mining experience, as will be discussed later in this chapter.

III. FATAL ACCIDENT FREQUENCY RANKINGS OF JOB AND TASK CLASSIFICATIONS

A. Job Classification Rankings

Exhibit 2 ranks the frequency of accidents by the job title or job classification of the principal victim. The frequency rankings are shown for all accidents, and for each of the following accident categories: roof fall, mobile equipment and non-mobile equipment. Roof fall accidents are exclusive of rib or face falls. Mobile equipment accidents are those involving moving equipment (shuttle, tramming, hauling, etc.) in primary and secondary haulageways or active intersections and passageways. Non-mobile equipment accidents include stationary equipment (often being repaired) or equipment active in the face area (continuous miner sumping, roof bolter drilling, etc.).

Operator and helper job classifications were considered separate jobs in the rankings for the following machines: continuous miner, cutting machine, and loading machine. This may not always be a valid assumption because helpers are often killed operating these machines as illustrated in the "JAVAT" chart. Even in this case, however, our field observations indicated that the helper is typically not as well qualified to operate these machines and is also not necessarily the person who operated these machines in the absence of the regular operator. Consequently, we concluded that separate records should be kept for operators and helpers.

As shown in Exhibit 2, the shuttle car operator is the most dangerous job classification in all types of accidents (if the loading and continuous miner operator and helper jobs are classified separately as discussed above). This is not too surprising since the shuttle operator works not only at the face area but also in very active secondary haulage areas and intersections.

Roof bolters rank first in roof falls and second in non-mobile equipment accidents. With such a high percentage of bolters involved in roof fall accidents, it is not surprising that senior and more experienced men bid away from roof bolting positions, leaving them to be filled by new workers, thereby compounding the problem and causing even greater safety hazards. The non-mobile equipment accidents of the bolters involve the machinery they customarily operate. In many instances the bolter is pinned against the rib or roof by the boom as a result of using the wrong control or improperly handling the controls.

Repairmen, who rank second along with the roof bolters in overall fatal accidents, have the highest number of non-mobile equipment accidents. Although they rank third in mobile equipment accidents, this category actually involves a higher number of total accident occurrences than the number one ranking, non-mobile equipment accidents. In other words, more repairmen died when moving face equipment to a safe or convenient place for repair or when traveling in the mine on battery-powered tractors or jitneys than when actually repairing stationary equipment. It is our belief, therefore, that repairmen should be thoroughly trained in the operation of all equipment to avoid handling machinery whose controls are unfamiliar to them.

Loading machine operators ranked third in overall accident frequency, second in roof falls and fourth in mobile equipment accidents. Foremen placed a close fifth in all accidents, ranking fourth in roof falls and third in non-mobile equipment accidents. Since the foreman is usually in the face area and his activities are so varied, it is not surprising that he ranks high in all accident categories. While the continuous miner operator is mainly involved in roof falls (third), the helper places fourth in "other" equipment accidents, although he also ranks high as a victim of roof fall accidents (seventh).

B. Task Activity Rankings

Fatality frequency rankings by task activity are significantly different from job classification rankings. The "JAVAT" Chart in Exhibit 1 indicates that those activities which ranked highest in fatalities, such as tramming, repair, and machine loading, were often performed by crew members not normally assigned that job. For example, only 30 (or 50%) of the accident victims killed while performing repair work were actually repairmen.

On the other hand, although many of the victims were engaged in an activity other than their normal job classification at the time they were killed, in most cases the task activity was related to the victim's job classification (roof bolter setting props, continuous miner tramming, etc.).

Part of the discrepancy between job and task classifications arises from the needs of the mining production cycle. This is especially true in the face area where workers are expected to be able to perform a wide variety of tasks. Setting props, for example, is usually a production bottleneck. Using the continuous miner crew to set timbers between cuts instead of waiting for the timbermen can substantially expedite production.

Another way miners frequently become engaged in unfamiliar tasks is by substituting for absent men. Not many of the fatality reports indicated absenteeism as a contributing cause of the accident. This is inconsistent with our field observations which noticed many cases of high absenteeism and job substitution. The effect of high absenteeism on accident rates should be investigated more thoroughly since it is closely related to the significant task experience effects shown in the next section.

The detailed analysis of fatality frequencies by task classification is given in Exhibit 3. As can be seen from this chart, tramming (72 fatalities), mainline haulage (66 fatalities) and repair work (60 fatalities) are the three most common task activities being performed at the time of the fatal accident. The reader is referred to the "JAVAT" Chart for a complete description of the job classifications of these victims.

C. Implications of Job and Task Variety

In looking at the two types of job activities -- those highly confined to a job classification (e.g., machine loading) and those accomplished by a variety of job classifications (e.g., setting timbers), we cannot determine at this point whether accident frequencies would be reduced if miners were confined to performing only those tasks which are a part of their regular job. That is, setting timbers may result in more roof fall accidents because so many different workers are involved and because many of these workers may lack sufficient roof control training and experience. On the other hand, if the task of setting timbers were confined to the timberman job classification, the result might not be to reduce roof fall accidents during the timbering process, but merely to change who is killed. In other words, the result would be 33 timbermen killed instead of 33 various workers killed while setting timbers. Although one might argue that the higher degree of specialization and experience would decrease the chance of a fatality, the fact still remains that even relatively specialized jobs such as mainline haulage rank high in their respective type of accidents. What can be recommended, however, is that those job classifications requiring a variety of activities also require a corresponding range of proper training in each activity.

IV. UNDERGROUND MINING EXPERIENCE

Two causes of fatalities are frequently cited by members of the industry: lack of mining experience and age. As part of this study we investigated both of these variables. Age was not a particularly significant factor, and mining experience, per se, was a weak factor compared to job task experience.

A histogram dipicting fatalities as a function of total mining experience for all accident classifications is displayed in Exhibit 4. Similar graphs for all roof fall accidents and for all equipment accidents are included in Exhibits 5 and 6. In all three graphs, with the exception of the first year, the number of accidents is almost constant through time. Unfortunately, the number of men in the industry within each category of experience is not known. If the number of men in the industry in each experience category is directly proportional to the accident frequencies shown in Exhibits 4, 5 and 6, then one could conclude that there is no relationship between experience and accident occurrence. Hence, normalizing census data from the industry is needed to draw more precise inferences from the data.

One will also notice in Exhibits 4, 5 and 6 that there is a slight increase in the number of fatalities occurring to men having 20-25 years of mining experience. This phenomenon can be explained by the higher number of miners who fall into this experience bracket, as inferred from Exhibit 7.

A comparison between the age distribution of the fatality sample in the data base and the age distribution of the workers in the coal industry (BCOA survey, December, 1967) is given in Exhibit 7. In this exhibit the similarity between the age distributions is readily apparent. There are two minor deviations, however. The men in the 21-25 year old category have a disproportionately higher number of fatalities while the men in the 51-55 year old category have fewer fatalities than would be expected. These observations may imply that while age does not appear to play a significant role in accounting for the distribution of fatalities among miners, younger and therefore probably inexperienced miners tend to have slightly more fatalities than older men.

V. JOB EXPERIENCE AND ACCIDENT FREQUENCIES

A. Definition

As shown in the previous sections, the task being performed by the victim at the time of the fatal accident is not always the same as the victim's job classification. Similarly the amount of task experience which the victim has is not necessarily the same as his mining experience because of job mobility.

Since there was a suspicion from the field study that task inexperience is related to fatalities, this category was coded in detail up to three years; a single category was used for all victims with greater than three years of experience. (Originally, it was assumed that task experience beyond three years would not be significant.) Only 609 of the 731 fatality reports coded indicate the amount of task experience of the victim or person responsible for the accident.

Task experience refers to the degree of familiarity which the victim had with the activity in which he was engaged at the time of the accident. For instance, the task experience for a foreman who was driving a battery-powered tractor was coded according to his total experience as a foreman since this activity happened to be a normal part of his job. A roof bolter killed as he was setting props or scaling the roof would have a task experience coinciding with his assigned job experience since these are normal job-related activities.

Experienced workers learning new jobs, or engaged in activities not usually associated with their regular jobs, often have low task experience despite their extensive mining experience. A continuous miner operator may have had ten years' experience on a continuous miner; however, if he was killed operating a shuttle car and had only operated the car a few hours or days in the past, he would have been classified as having little task experience. A cutting machine operator who was attempting an electrical repair would have had task experience corresponding to his degree of experience in electrical repair work.

B. Fatal Accident Avoidance Learning Curve

The data presented in Exhibit 4 indicates that almost half of the 609 victims had less than three years of task experience. Approximately 1/3 of the coded victims had task experience of less than one year! Exhibit 5 for roof fall accidents and Exhibit 6 for equipment accidents indicate remarkably similar patterns. Exhibits 4, 5, and 6 suggest a strong relationship between task experience and fatal accident occurrence.

The task experience graphed in Exhibits 4, 5, and 6 is shown in much greater detail in Exhibits 8, 9, and 10, respectively. Each of these exhibits shows task experience by year, by month and by week. The graphs all show a nearly identical exponential-like decline in fatality frequencies over the first several time periods. The significance of the task experience effects measurable in weekly increments may indicate an especially sensitive relationship between task experience and fatal accident occurrence.

The abrupt decline of accident frequencies when related to weeks of task experience shows up particularly clearly in two categories of total underground mining experience as shown in Exhibit 11. The first curve illustrates the task experience time effects in weeks for men who had a total of less than two years' experience in underground mining. The second curve shows the same relationship for men who had over twenty years of total mining experience. The total number of fatal accidents varied significantly between the 50 victims who had less than two years of total experience and the 335 victims having over twenty years of total mining experience. The group of accident victims who had greater than twenty years of total experience have a higher residual curve (after about twenty-six weeks) of fatality frequencies than the new men. This should be expected, however, since over 50% of the men in the industry are 45 years old or older and hence are likely to have 20 or more years of experience.

The significance of Exhibit 11 is the remarkably similar pattern of fatal accident frequency decline per week of task experience for the two most extreme categories of underground mining experience: less than two years and greater than twenty years. (Exhibit 11 is also a good example of the need to obtain normalizing industry data about job and task experience and turnover for more precise conclusions.)

The same exponential-like decline in accident frequency as a function of task experience is again found when roof fall accidents and equipment related accidents are examined individually. (See Exhibit 12.) This similarity was a surprise to our entire staff since the presumed accident causes within the two accident categories are so different.

The same effect is again found in Exhibit 13 for moving and non-moving equipment-related fatal accidents. Although moving equipment fatality frequencies do not decline as rapidly per month or per week of task experience as non-moving equipment-related accident frequencies, the general declining frequency pattern still applies. This effect indicates that it may take longer to learn to avoid fatal accidents when operating moving equipment.

To further verify the learning curve hypothesis developed in the preceding paragraphs, we next investigated all job classifications and task classifications to see if the same characteristic exponential curves fit these classifications. Exhibit 14 compares twelve common job classifications, and Exhibit 15 compares twenty-one common tasks or operations performed in mining. Both exhibits show the percentage of the total number of fatal accidents as a function of task experience measured in months. The results in general tend to support the safety learning curve hypothesis.

Possible exceptions of the learning curve hypothesis are the jobs of face driller and shot firer which peak between 3 and 6 months of task experience. A larger number of fatalities in these categories might have yielded the characteristic curves of the other job categories. Other histograms also show a second peak in the 3-6 month category: cutting machine operator, loading machine operator, timberman, hand loading, supervising, etc. We can offer no explanation at this time for this phenomenon.

The fatality avoidance learning curves for each task activity shown in Exhibit 15 repeat the exponential decline of the previous exhibits. The tasks with the highest percentage of victims killed having less than one month of task experience were: removing support (23%), clean-up (16%), shuttling (13%), inspecting (13%), undercutting (14%), scaling roof (13%), and roof drilling and bolting (14%).

Exhibit 16 illustrates the relationship between roof falls and task experience. We found the strongest task inexperience effects when the victim was under unsupported roof unnecessarily. Since unsupported roof situations are the most common fatal roof fall accidents, it follows that experience is more critical in recognizing potential roof fall situations. Even under permanently supported roofs, there are task experience effects, again indicating that experience is helpful in recognizing when the permanent support is likely to fail.

In trying to verify the fatality avoidance learning curve phenomenon we examined various types of mines. A comparison of fatalities as a function of task experience for mines with less than 15 employees and mines with greater than 15 employees is given in Exhibit 17. Approximately twice as many fatalities occurred during the first month of task experience in small mines as in the larger mines. There are a number of possible explanations for this effect: 1) safety training programs are more likely to exist in the larger organizations, 2) there may be higher worker turnover in the smaller mines, or 3) there may be better equipment or greater adherence to safe procedures in the larger mines.

Throughout the preceding analysis of task experience, fatality data has been aggregated for the period 1966-1970. In Exhibit 19 the fatality frequencies as a function of both task experience and total mining experience are broken down for each of the 5 years. The task experience curves for each individual calendar year are not as regular as when all 5 years are taken together. In each case, however, at least twice as many fatalities occurred during the first year of task experience as during the second; in 1970 <u>five</u> times as many deaths occurred in the first year as the second! Moreover, examination of the data for 1968, 1969, and 1970 indicates that there is an increasing trend in the number of miners killed performing tasks for which they have less than one year's experience. The frequency of fatalities for miners in their first year of task experience increased 50% between 1966 and 1970. This trend may be due to either more new men entering the industry or more experienced men shifting to new jobs.

The total mining experience curves of Exhibit 19 show that more men are usually killed during their first year of underground mining experience than during their second. The exception to this observation is 1966 in which less men were killed during the first year. In 1970, however, the effect was even more pronounced, probably as a result of more men entering the coal mining industry in that year than in the previous years.

C. Mathematical Formula

We believe that these task experience histograms discussed in the foregoing section, all exhibiting the same exponential-like decline, may be statistical evidence of a safety learning curve, at least for fatal accidents. A safety learning curve for equipment accidents was expected, but our industrial engineering staff was surprised to see the nearly identical relationship for roof fall accidents, which are often assumed to be more difficult to avoid. One of the remarkable properties of these curves is that the first year, the first month, or the first week tends to have roughly twice the frequency of fatal accidents as the corresponding second year, second month, or second week of task experience.

Having observed such strong similarities in the curves, we verified that a single characteristic curve ($Y = AX^B$) best fitted each of the fatality frequency curves in Exhibits 1, 2, and 3 using the "per week" scale. The best fit formulae are as follows:

Data	Formula	Coefficient of Determination
All Fatal Accidents	$Y = (15.4)X^{-.55}$	.98
Roof Fall Accidents	$Y = (7.26)X^{-.53}$	.97
Equipment Related	$Y = (6.8)X^{-.58}$	.95

The above curves, fitted by a computer program, were selected as the best fit using the least square criteria. The coefficient of determination indicates the degree of fit between calculated points and actual data points with 1.0 representing a perfect fit. The curves were fitted to the mid-points of the bars of the histograms along the X-axis of experience in Exhibits 1, 2, and 3.

The significance of this curve fitting process is that the same negative exponent ($B = -.5$) best fits all three categories of accident data. This may imply that the distribution of fatal accidents as a function of task experience is characteristic of all these accidents independent of the total number of accidents. Moreover, the formula implies that the declining pattern is independent of the number of accidents in the first time period. Hence, if the number of accidents could be reduced in the first time period, all subsequent time periods should have fewer accidents! Since this mathematic argument seems consistent with the exponential learning curves observed by industrial engineers in production applications, we feel that the curves provide empirical evidence of a statistical fatal accident avoidance learning curve in underground coal mines.

VI. FATAL ACCIDENT AVOIDANCE LEARNING CURVES OR STATISTICAL ILLUSION?

The exponentially declining accident frequencies shown as a function of task experience in Exhibits 4 through 19 are non-normalized accident frequencies and may not be a valid indicator of accident rates as a function of experience. If, for example, one third of the underground mining workers assume new job tasks every year, then the task experience histograms, as a function of the ratio of fatal accident victims to total workers in each task classification, would appear essentially flat. In other words, normalizing the data for task turnover may flatten the task experience histograms shown in Exhibits 4 through 19, thus refuting the hypothesized existence of fatality avoidance learning curves.

The amount of industry task turnover can be seen to be a very important unknown factor that could explain away much of the dramatic impact of the task experience histograms, especially in the case of unpopular and dangerous jobs such as timbermen. In the field, we have observed small mines where the job turnover in the previous year was over 50%. Even in large mines, we have been told of very high turnover rates among new workers recruited for expanded production.

Compounding the effects of the obvious task inexperience of new men is the task inexperience of men who may have considerable underground mining experience but who change job assignments. Job posting and the seniority system combine to create a job turnover effect resembling a game of "musical chairs" among the workforce of a mine. Typically third shift or second shift workers will bid for day shift jobs, creating a perpetual job turnover effect for even normal rates of job attrition. In cases of significant workforce expansion the "musical chair" phenomenon can become severe unless mine management diligently implements a controlled transition expansion program.

On the other hand, we are not convinced that task turnover accounts for all of the task inexperience effects observed in this study. It seems unlikely that one third of all the workers in the industry are in their first year of performing a new task, or that 8% are in their first week of a new task. Part of our confidence that the task inexperience effects will not be completely explained by task turnover is that studies in Britain and Germany using normalized task experience data have observed the same phenomenon. Furthermore, after completing our task experience histograms, we discovered that we are not the first to show the Bureau that a relationship exists between fatalities and task inexperience regardless of total underground mining experience. The report by E. Corp of Spokane, December 1969, mentioned this fact, and Dr. Ken Moore in the Bureau's Operations Research Department indicated that others have noted this phenomenon, although not in as much detail. Only more research will resolve all doubts.

VII. RECOMMENDATIONS

Having observed an apparently significant relationship between task experience and the incidence of fatal accidents, there are several questions which one might logically ask: Is this phenomenon present in non-fatal injury accidents also? What is the total job mobility and experience profile of coal mining workers? How many workers are there in each of the job or experience classifications, performing each of the tasks outlined in our study? Answers to the above questions require the Bureau to extend the research and analysis performed under this contract on fatal injury accidents to non-fatal injury accidents and to normalize all the accident statistics with census data from the coal mining worker population. We strongly recommend that the Bureau fund such a research program.

If the above research verifies the causal relationship between fatalities and task inexperience, then certain measures can be taken to reduce accidents. The first step is to make mine managers throughout the country aware of the criticality of task inexperience. Our interviews indicated that foremen, supervisors and mine superintendents almost universally tend to worry only about the inexperience of new men rather than about all men assigned to new jobs or tasks.

Secondly, we feel more and better training programs would reduce the likelihood of accidents. This statement by itself, however, is almost meaningless and is analogous to recommending more safety in the mines. Everyone in the Bureau and in the industry seems to agree in principle that more training is needed, but very few agree on how to conduct such programs.

In response to their problems of task inexperience, both Great Britain and Germany have adopted a three-pronged program: training, certification or testing of training and close supervision of the worker performing a new task. Conditions in these countries, unlike in the U.S., are conducive to the development of uniform training requirements. In both countries, most of the miners work for a single company: National Coal Board in Britain and the Ruhrkohle A.G. (Ruhr Coal Co.) in Germany. Almost all production in these countries is in deep strata in large mines where mechanized longwall systems are used almost exclusively. The U.S., on the other hand, uses a great variety of mining equipment, has a large number of diverse mining seams and is characterized by widely diverse state manpower certification requirements. Nevertheless, we believe the U.S. Bureau of Mines could profit from the vigorous development of policies similar to those that both Britain and Germany require by law and regulation -- training, certification of training, and close personal supervision of men during the first few weeks on a new job. Each of these is discussed in more detail below.

As a first step, the Bureau should conduct a survey of existing training programs to discover which ones are most effective. Several large, progressive coal mining companies have impressed us with their excellent programs and their records of low accident frequencies and high productivity. An analysis and compilation of the best ideas in each of these programs would serve as a constructive guideline for both the Bureau and for mine management in establishing improved training programs.

At the same time the Bureau should perform a research study to determine if and how certification tests could be administered to verify that workers have been properly trained. This study should include an analysis of the cost of administering a certification program and the expected benefit in terms of fewer accidents and higher productivity.

Experimental training and certification programs could next be designed and tested by getting a few mine operations, both large and small, with mediocre safety records to voluntarily participate in demonstration programs. Control and experimental groups in different sections of the same mine or in different mines having similar conditions would increase the statistical validity of the results.

Training programs that only precede actual work on the job are not likely to address all the problems of task inexperience. The first few weeks or months of performing a job involve the classic on-the-job learning curve for productivity as demonstrated by countless industrial engineering studies of new worker performance. In both Britain and Germany, all new mine workers, after undergoing required training programs above ground, are introduced to actual job experience underground only under a close supervision program. Colliery managers in both countries and safety statisticians of both governments have emphasized that this program is vital to obtaining higher worker productivity quickly, reducing job turnover, and reducing accidents.

In addition to 1) increasing mine operator awareness of the effect of task inexperience on fatalities and 2) improving training, certifying training, and supervising workers performing new tasks, the Bureau should also study and propose ways to reduce worker anxiety during training periods.

One very interesting study of anxiety during on-the-job training was conducted at Texas Instruments Co. In the study, an experimental indoctrination program aimed at reducing anxiety shortened training time by one half, cut costs 15 to 30%, reduced turnover, and reduced waste and scrap costs by 20%. The study, described in an article entitled 'Breakthrough in On-the-Job Training" (Harvard Business Review, July-August, 1966) may be especially relevant to the problem of high turnover among new workers in the mining industry. Our staff is convinced from our field studies that anxiety is one of the key factors relating to poor productivity and high accident occurrence in the first few weeks of a new job in mining.

In summary, our recommendations to the Bureau of Mines concerning task experience are to:

A. Disseminate information on task experience effects to the industry.

B. Continue research on task experience effects.

  1. Add new variables to fatal accident reports.

  2. Obtain and code information on non-fatal accidents and examine relationship to task experience.

  3. Acquire normalizing mine data.

C. Continue research on job training, certification, and on-the-job training programs.

  1. Study selected mining companies with accurate records on training programs and accident frequencies.

  2. Determine cost effectiveness of training certification.

  3. Test training/certification program.

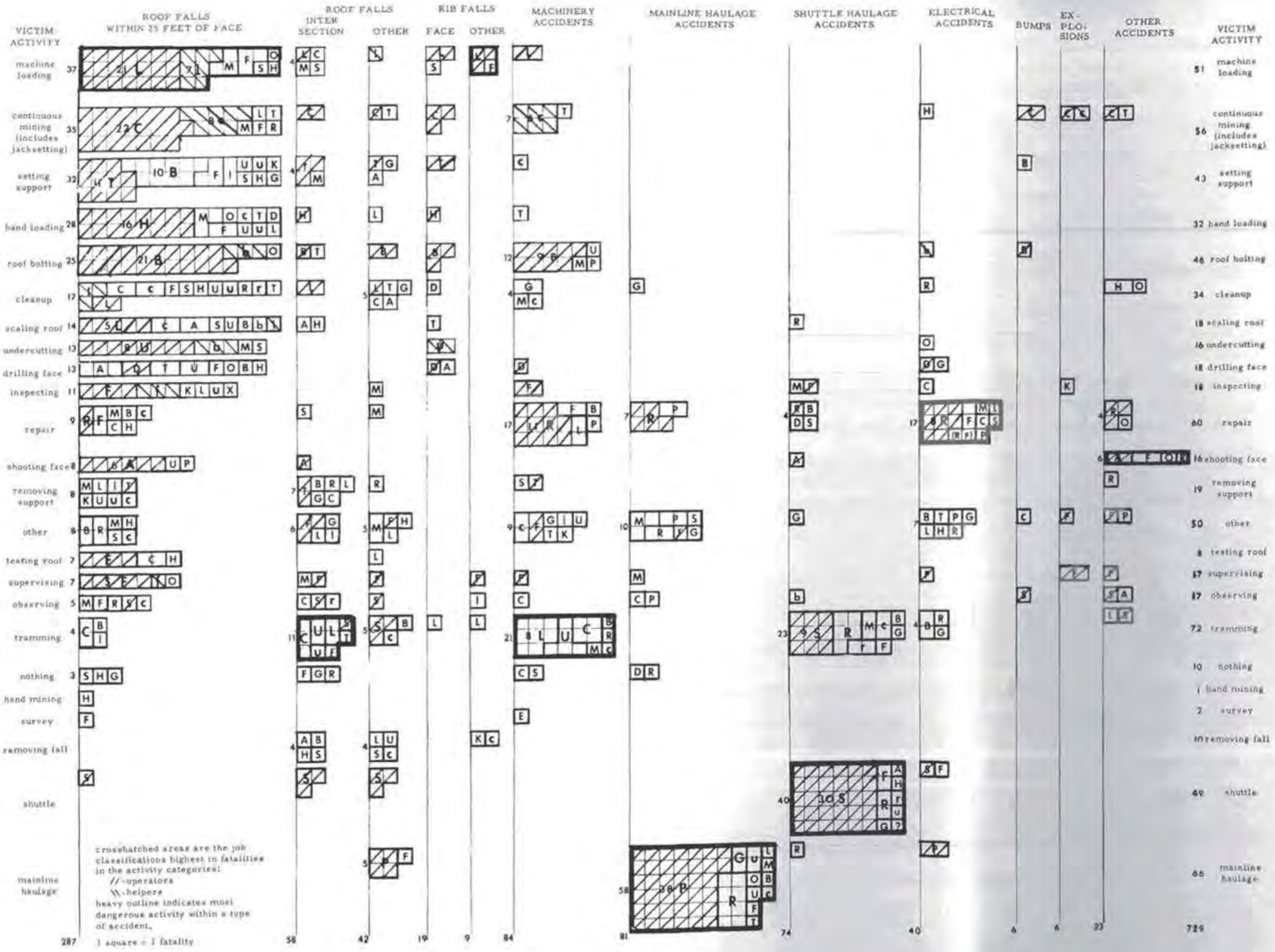
  4. Develop close supervision program.

  5. Study anxiety problems in training programs.

THEODORE BARRY AND ASSOCIATES

JAVAT CHART EXHIBIT I

JOB VS. ACTIVITY OF VICTIM VS. ACCIDENT TYPE



crosshatched areas are the job classifications highest in fatalities in the activity categories:
//-operators
\\-helpers
heavy outline indicates most dangerous activity within a type of accident.

1 square = 1 fatality

KEY

A -- Shot Firer
B -- Roof Bolter Operator
b -- Roof Bolter Helper
C -- Continuous Miner Operator
c -- Continuous Miner Helper
D -- Driller (Face)
E -- Engineer
F -- Foreman
f -- Assistant Foreman
G -- General Laborer
H -- Hand Loader
K -- Mine Superintendant
L -- Loading Machine Operator
l -- Loading Machine Helper
M -- Mine Foreman
O -- Owner
P -- Primary Haulageman
R -- Repairman
r -- Apprentice Repairman
S -- Shuttle Car Operator
T -- Timberman
U -- Undercutter Operator
u -- Undercutter Helper
X -- Mine Examiner

FATAL VICTIM JOB CLASSIFICATION RANKINGS
UNDERGROUND BITUMINOUS COAL
FATAL ACCIDENTS (1966-70)

	ACCIDENT TYPE							
	All Accident Total		Roof Fall		Mobile Equip.		Non-Mobile Equip.	
Job Classification	Rank	(Freq.)	Rank	(Freq.)	Rank	(Freq.)	Rank	(Freq.)
Shuttle Car Operator	1	(75)	6	(26)	2	(41)	9	(4)
Roof Bolter	2	(71)	1	(47)	9	(5)	2	(14)
Repairman	2	(71)	13	(12)	3	(30)	1	(24)
Loading Machine Operator	4	(67)	2	(44)	4	(9)	5	(6)
Foreman	5	(65)	4	(37)	7	(6)	3	(11)
Continuous Miner Operator	6	(59)	3	(40)	11	(4)	9	(4)
Mainline Haulage Worker	7	(55)	15	(5)	1	(43)	5	(6)
Continuous Miner Helper	8	(40)	7	(25)	9	(5)	4	(10)
Mine Foreman/Superintendent	9	(38)	9	(22)	4	(9)	9	(4)
Hand Loader	10	(35)	5	(29)	15	(1)	12	(2)
Timberman	11	(33)	8	(24)	15	(1)	8	(5)
Cutting Machine Operator	12	(27)	10	(19)	7	(6)	12	(2)
Shot Firer	13	(22)	12	(16)	13	(2)	-	-
Loading Machine Helper	14	(19)	11	(17)	-	-	14	(1)
General Laborer	15	(18)	15	(5)	6	(7)	5	(6)
Cutting Machine Helper	16	(14)	14	(9)	12	(3)	-	-
Owner	17	(10)	15	(5)	15	(1)	14	(1)
Face Driller	18	(9)	18	(3)	13	(2)	-	-
Engineer/Other	19	(2)	19	(1)	-	-	14	(1)
Total	730		386		175		101	

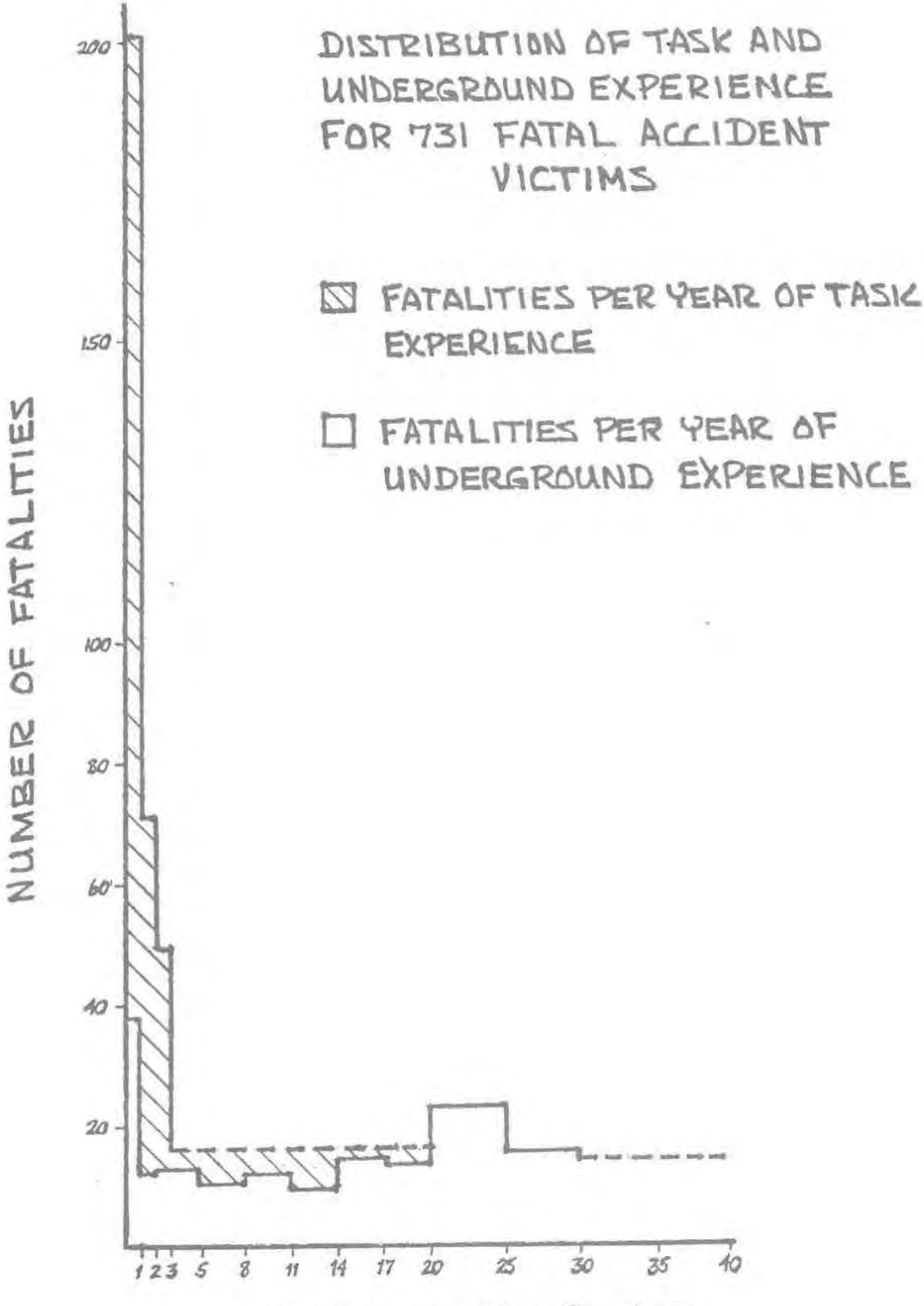
EXHIBIT 2

PRIMARY FATALITY VICTIM ACTIVITY RANKINGS
UNDERGROUND BITUMINOUS COAL
FATAL ACCIDENTS (1966-70)

	ACCIDENT TYPE							
	Total All Accidents		Roof Falls		Mobile Equipment		Non-Mobile Equipment	
Victim Activity	Rank	(Freq.)	Rank	(Freq.)	Rank	(Freq.)	Rank	(Freq.)
Tramming	1	(72)	7	(20)	2	(44)	5	(4)
Mainline Haulage	2	(66)	22	(5)	1	(59)	9	(2)
Repair	3	(60)	13	(11)	4	(11)	1	(34)
Machine Loading	4	(51)	1	(42)	-	-	1	(34)
Shuttle	5	(49)	20	(7)	3	(40)	9	(2)
Roof Bolting	6	(46)	5	(29)	-	-	2	(13)
Continuous Mining	7	(41)	3	(32)	-	-	6	(3)
Setting Timbers	7	(41)	2	(38)	-	-	15	(1)
Cleanup	9	(34)	6	(24)	8	(1)	3	(5)
Hand Loading	10	(32)	4	(30)	-	-	15	(1)
Removing Support	11	(19)	8	(16)	-	-	9	(2)
Drilling Face	12	(18)	10	(13)	-	-	6	(3)
Scaling Roof	12	(18)	8	(16)	8	(1)	-	-
Inspecting	12	(18)	12	(12)	6	(2)	6	(3)
Jack Setting (C/M)	15	(17)	17	(8)	-	-	3	(5)
Supervising	15	(17)	14	(10)	8	(1)	9	(2)
Observing	15	(17)	15	(9)	5	(3)	15	(1)
Undercutting	18	(16)	10	(13)	-	-	15	(1)
Shooting Face	18	(16)	15	(9)	8	(1)	-	-
Removing Fall	20	(10)	17	(8)	-	-	-	-
Nothing	20	(10)	21	(6)	6	(2)	9	(2)
Testing Roof	22	(8)	17	(8)	-	-	-	-
Other	23	(53)	23	(21)	12	(11)	19	(17)
Total	729		387		176		135	

EXHIBIT 3

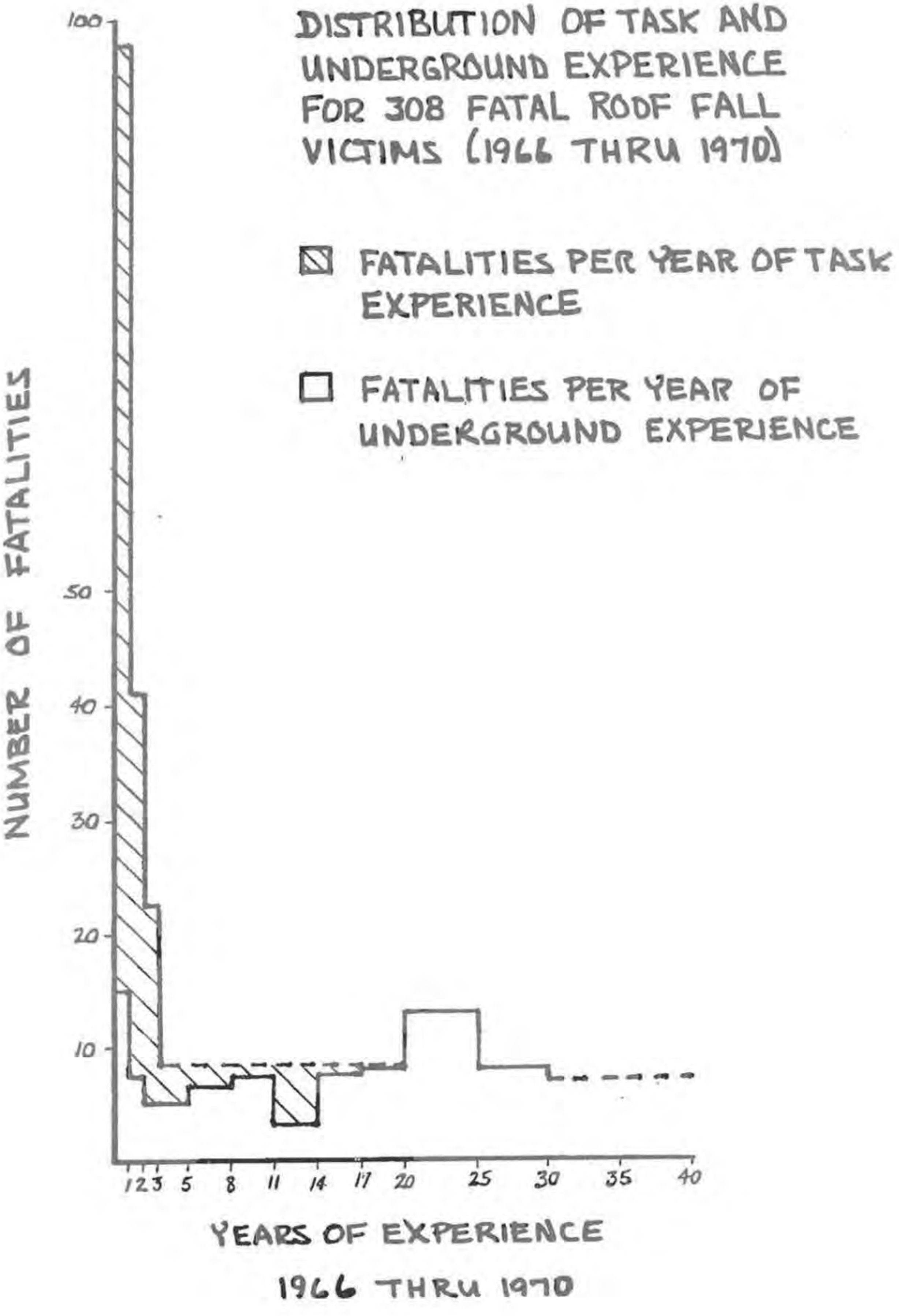
EXHIBIT 4



DISTRIBUTION OF TASK AND UNDERGROUND EXPERIENCE FOR 731 FATAL ACCIDENT VICTIMS

1966 THRU 1970

EXHIBIT 5



DISTRIBUTION OF TASK AND UNDERGROUND EXPERIENCE FOR 308 FATAL ROOF FALL VICTIMS (1966 THRU 1970)

EXHIBIT 6

DISTRIBUTION OF TASK AND UNDERGROUND EXPERIENCE FOR 241 FATAL EQUIPMENT RELATED ACCIDENT VICTIMS

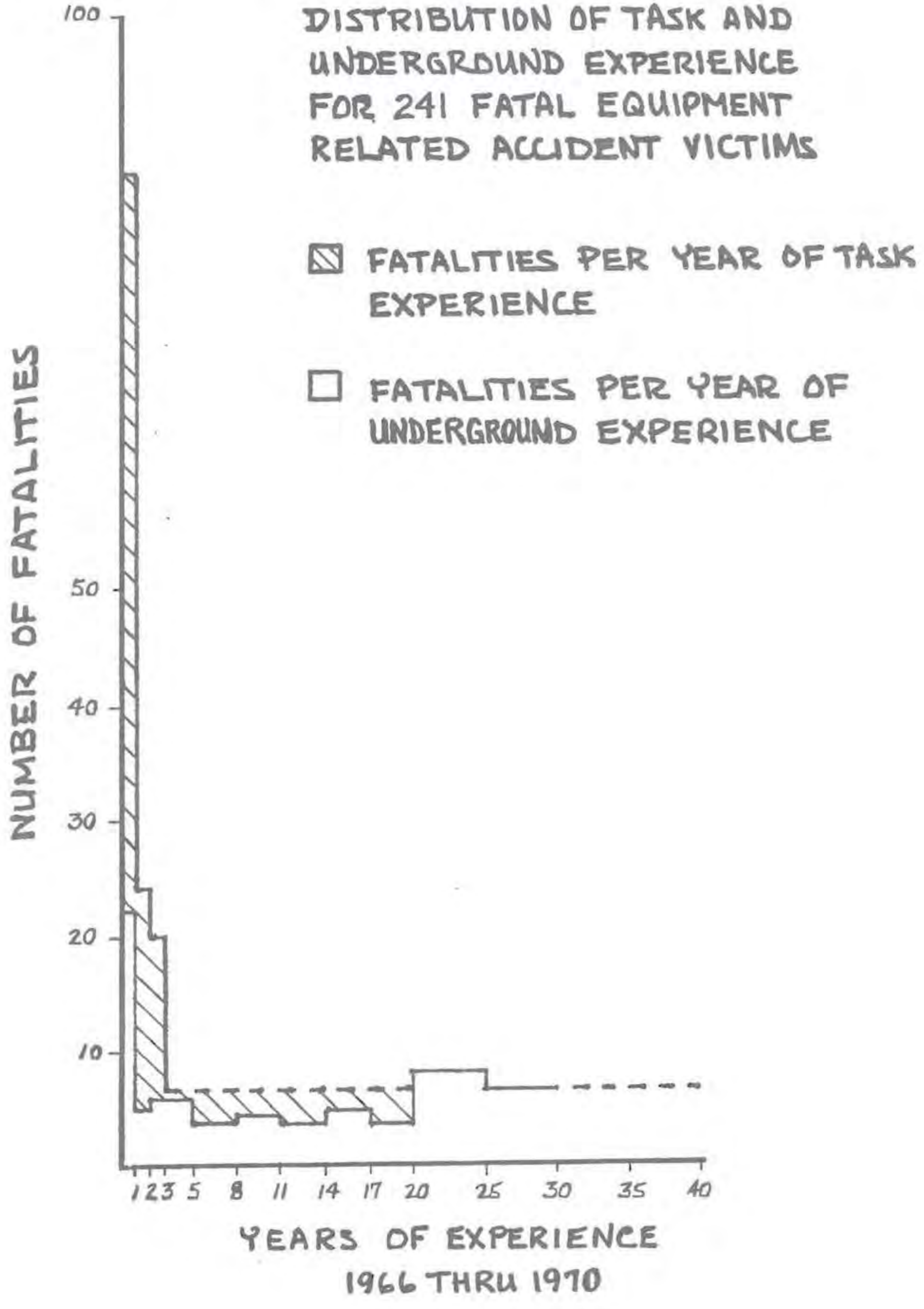
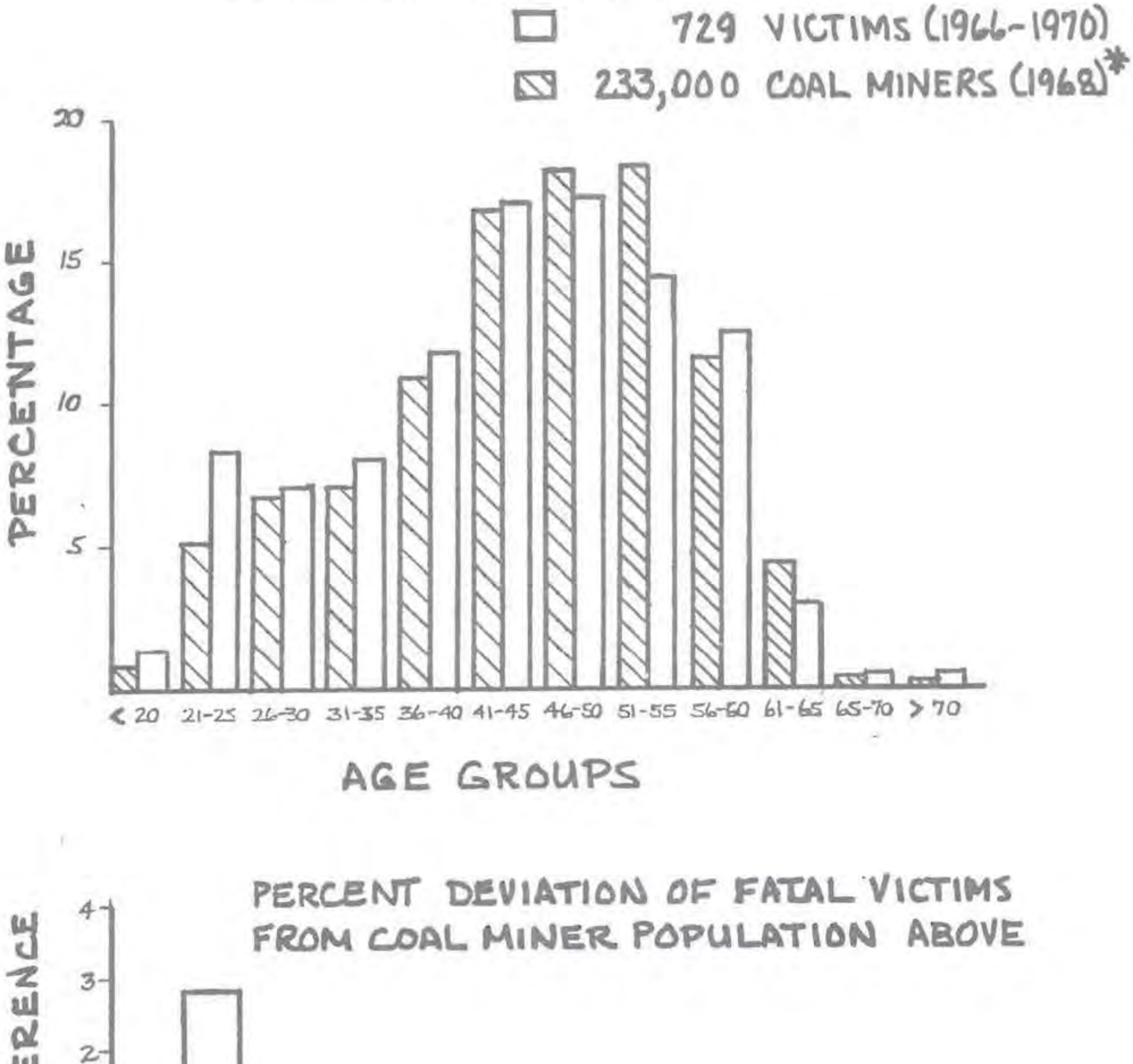
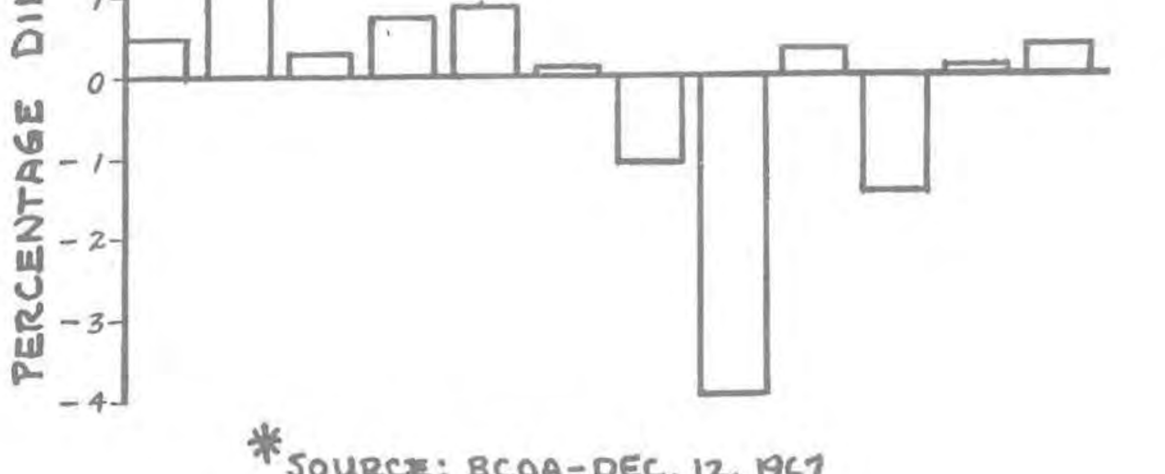


EXHIBIT 7

COMPARISON BETWEEN AGES OF FATAL ACCIDENT VICTIMS AND AGE OF COAL MINERS

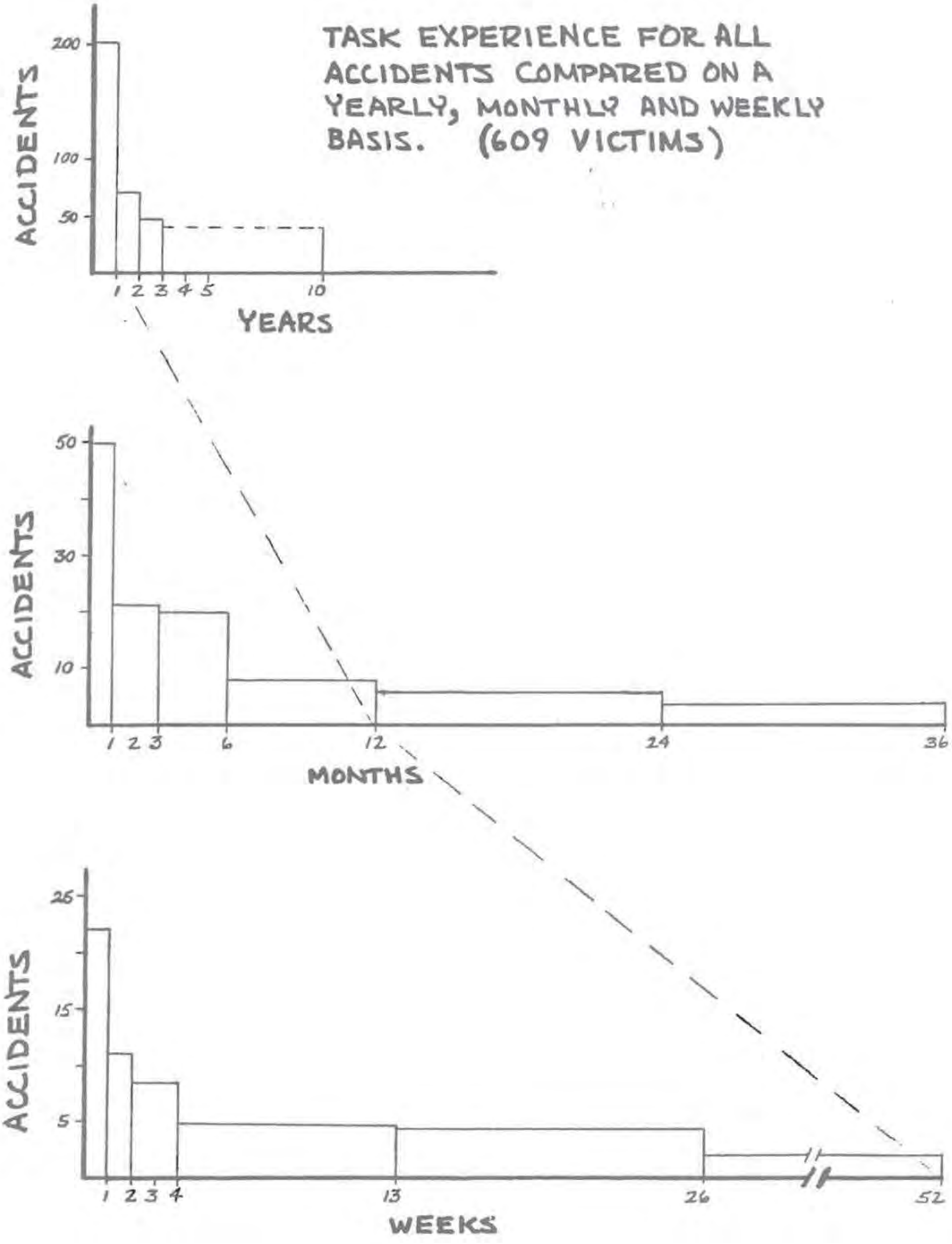


PERCENT DEVIATION OF FATAL VICTIMS FROM COAL MINER POPULATION ABOVE



*SOURCE: BCOA-DEC. 12, 1967

EXHIBIT 8



TASK EXPERIENCE FOR ALL ACCIDENTS COMPARED ON A YEARLY, MONTHLY AND WEEKLY BASIS. (609 VICTIMS)

EXHIBIT 9

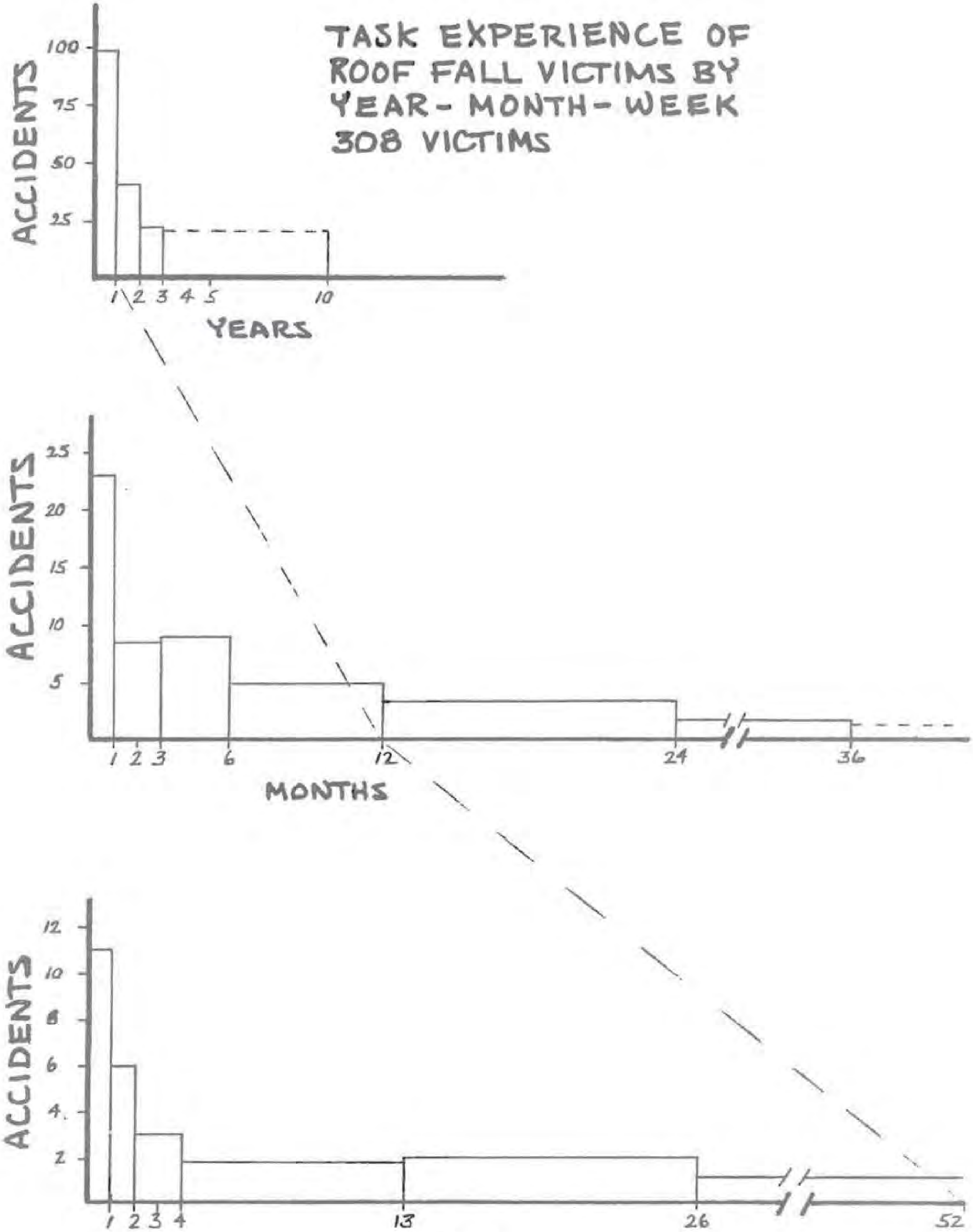
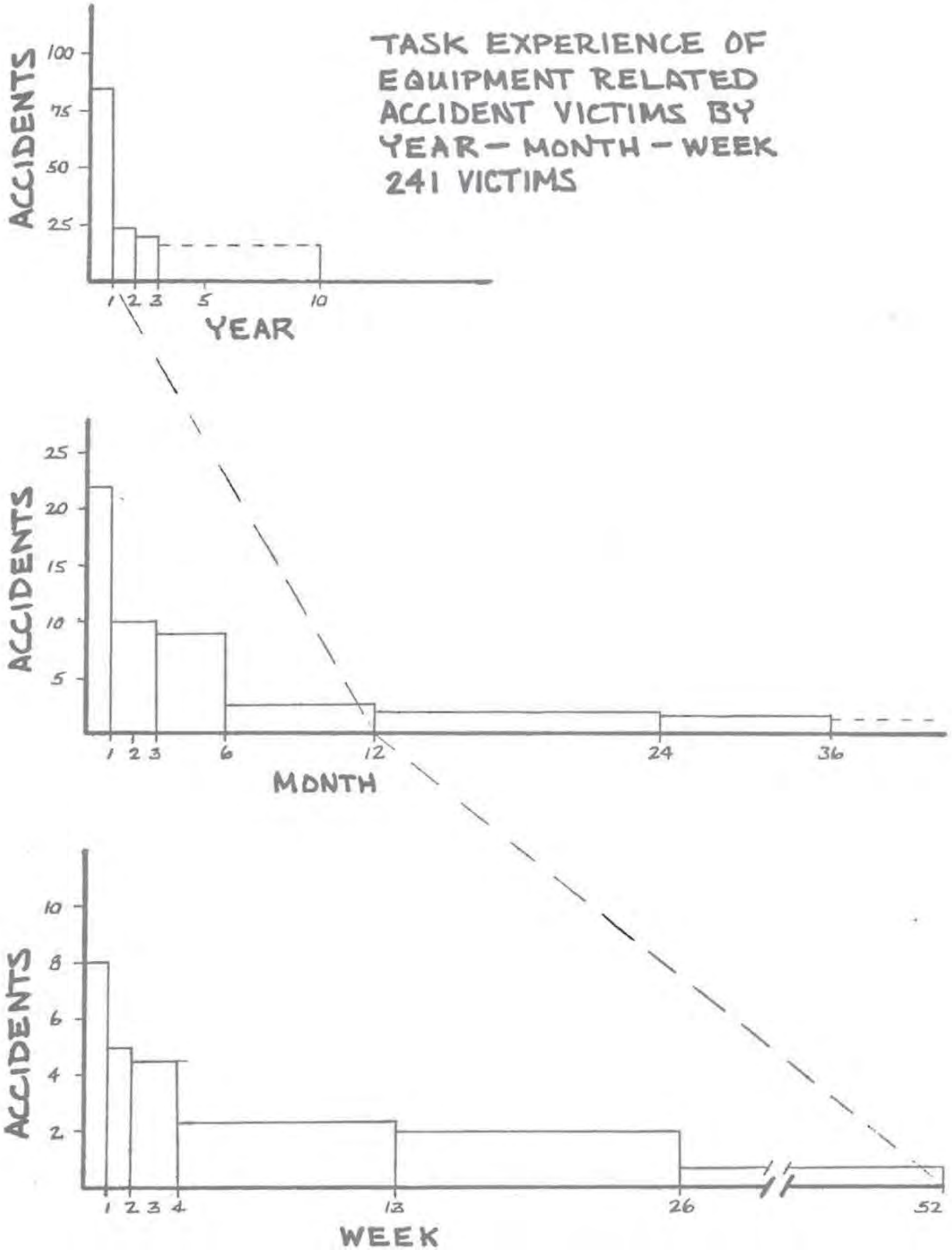

TASK EXPERIENCE OF
ROOF FALL VICTIMS BY
YEAR - MONTH - WEEK
308 VICTIMS
ACCIDENTS
100
75
50
25
1
2
3
4
5
10
YEARS
ACCIDENTS
25
20
15
10
5
1
2
3
6
12
24
36
MONTHS
ACCIDENTS
12
10
8
6
4
2
1
2
3
4
13
26
52
WEEKS

EXHIBIT 10



TASK EXPERIENCE OF EQUIPMENT RELATED ACCIDENT VICTIMS BY YEAR—MONTH—WEEK
241 VICTIMS

EXHIBIT 11

COMPARISON OF THE DISTRIBUTION OF FATAL ACCIDENT VICTIMS PER WEEK OF TASK EXPERIENCE

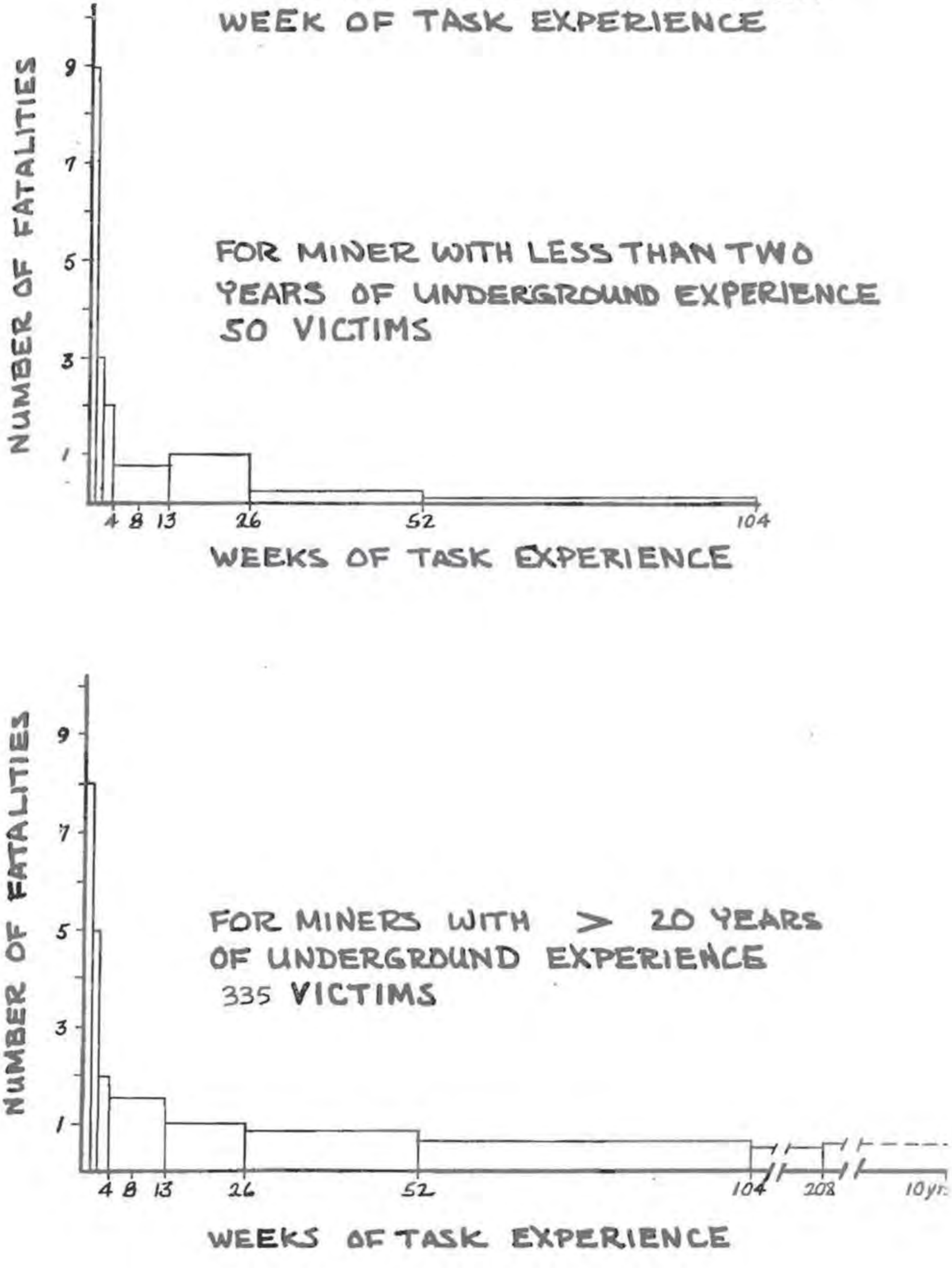


EXHIBIT 12

COMPARISON OF ROOF FALL TO EQUIPMENT ACCIDENT VICTIMS BY (A) TASK AND (B) TOTAL UNDERGROUND EXPERIENCE

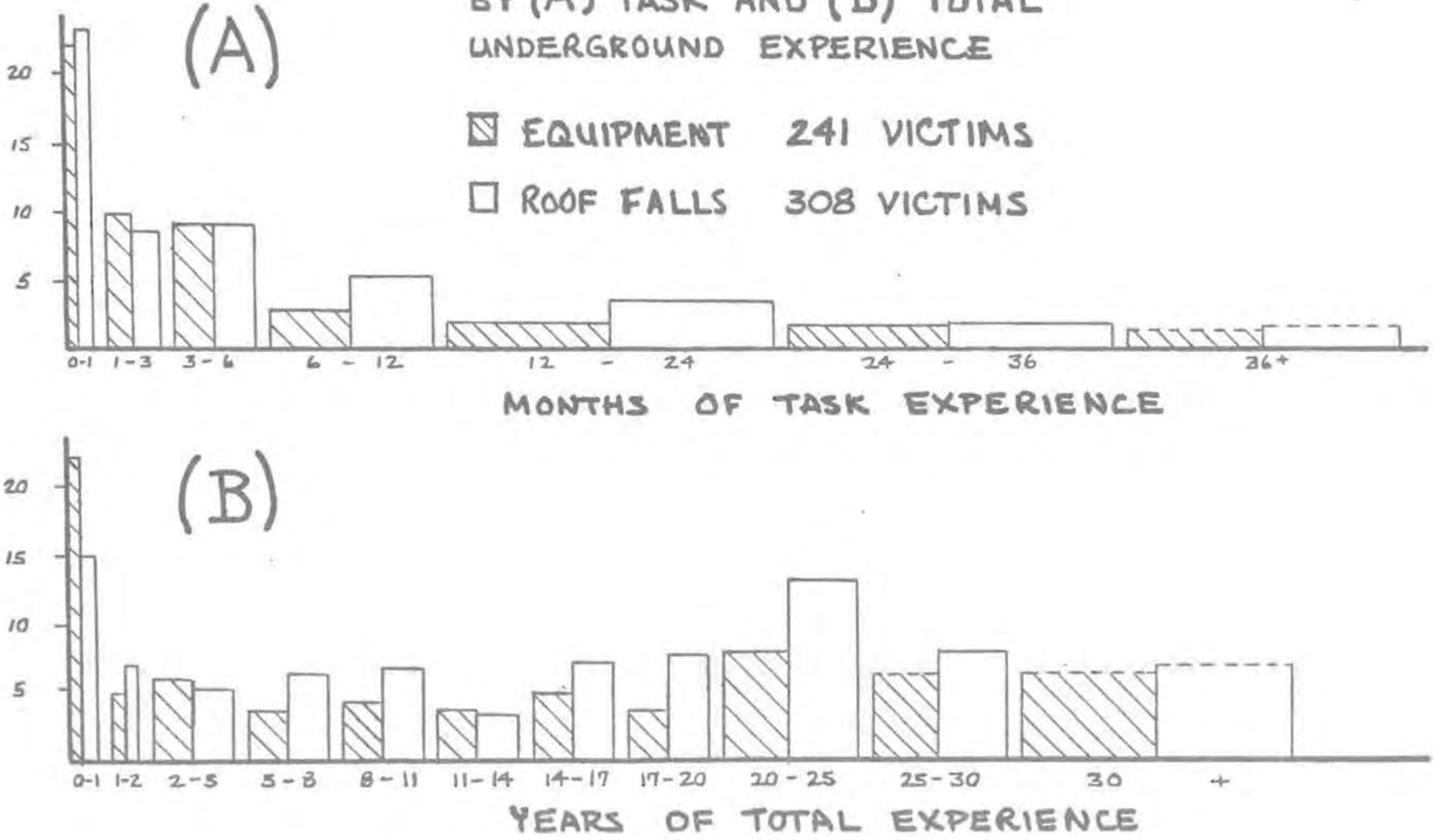


EXHIBIT 13

COMPARISON OF EQUIP. REL. ACCIDENTS INVOLVING TRAINING- SHUTTLING- HAULING VS. NON-TRAVEL EQUIP.

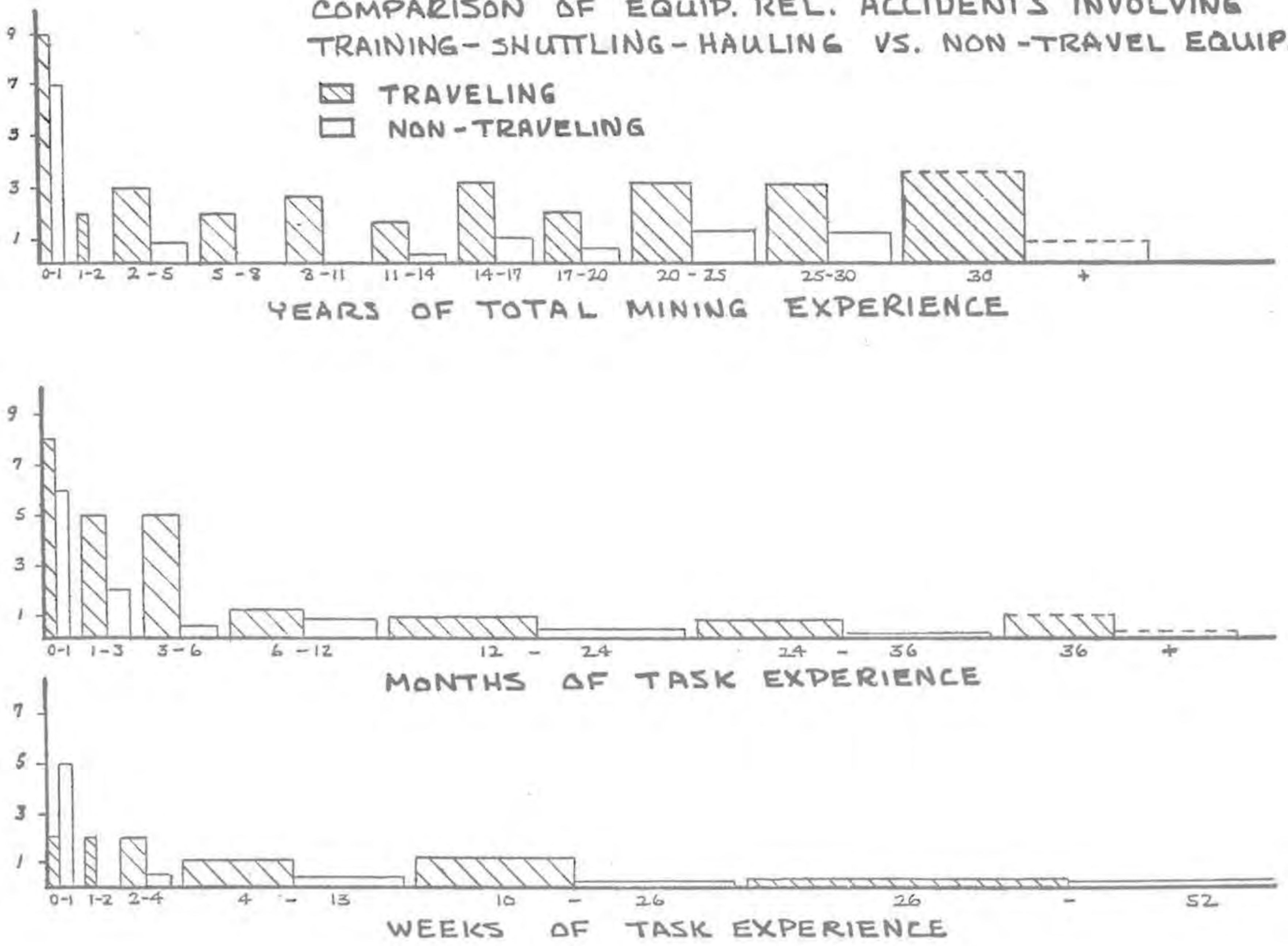


EXHIBIT 14

PERCENTAGE DISTRIBUTION OF FATAL VICTIMS' TASK EXPERIENCE BY MONTH — PER JOB CLASS.

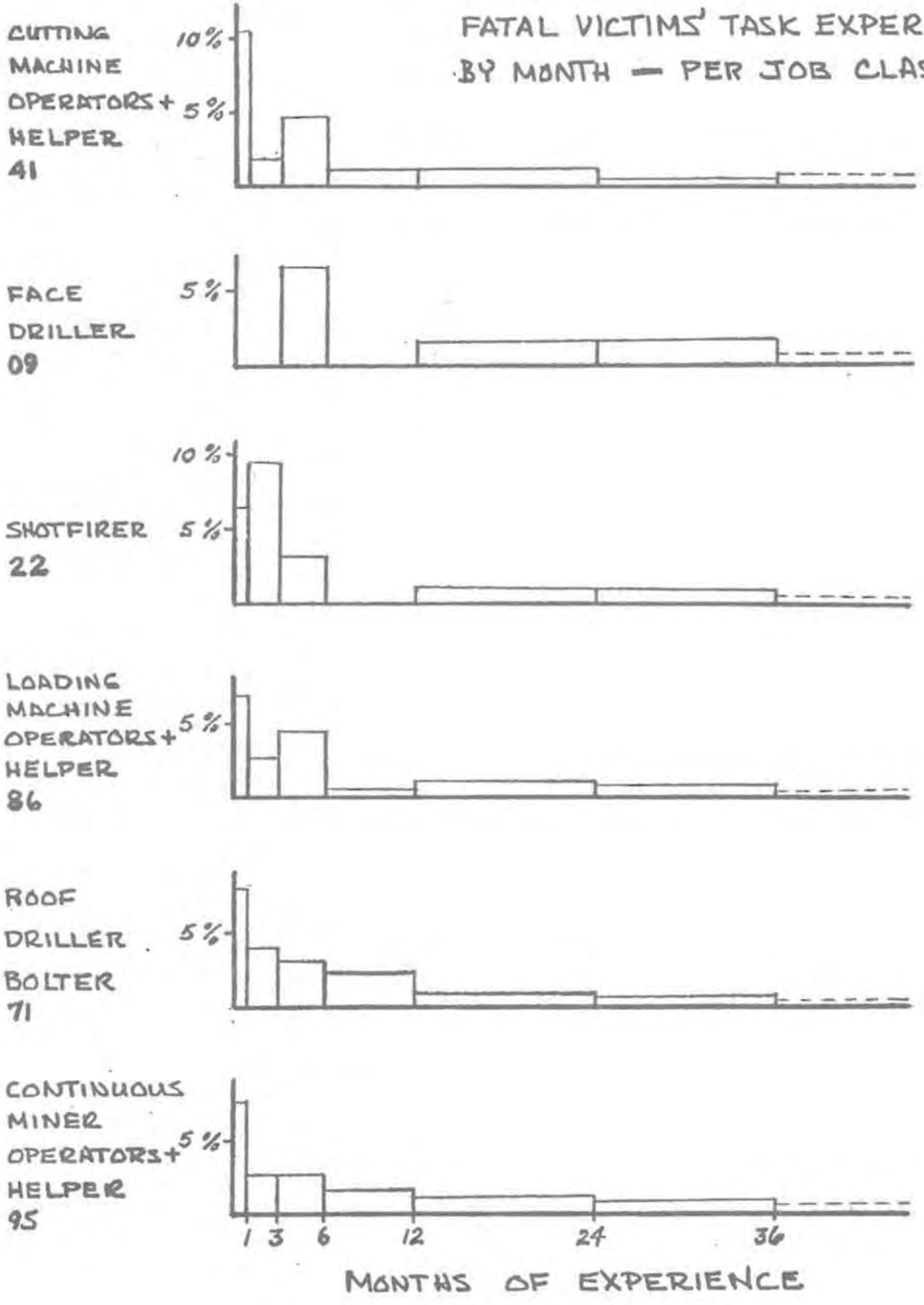


EXHIBIT 14- (CON'T)

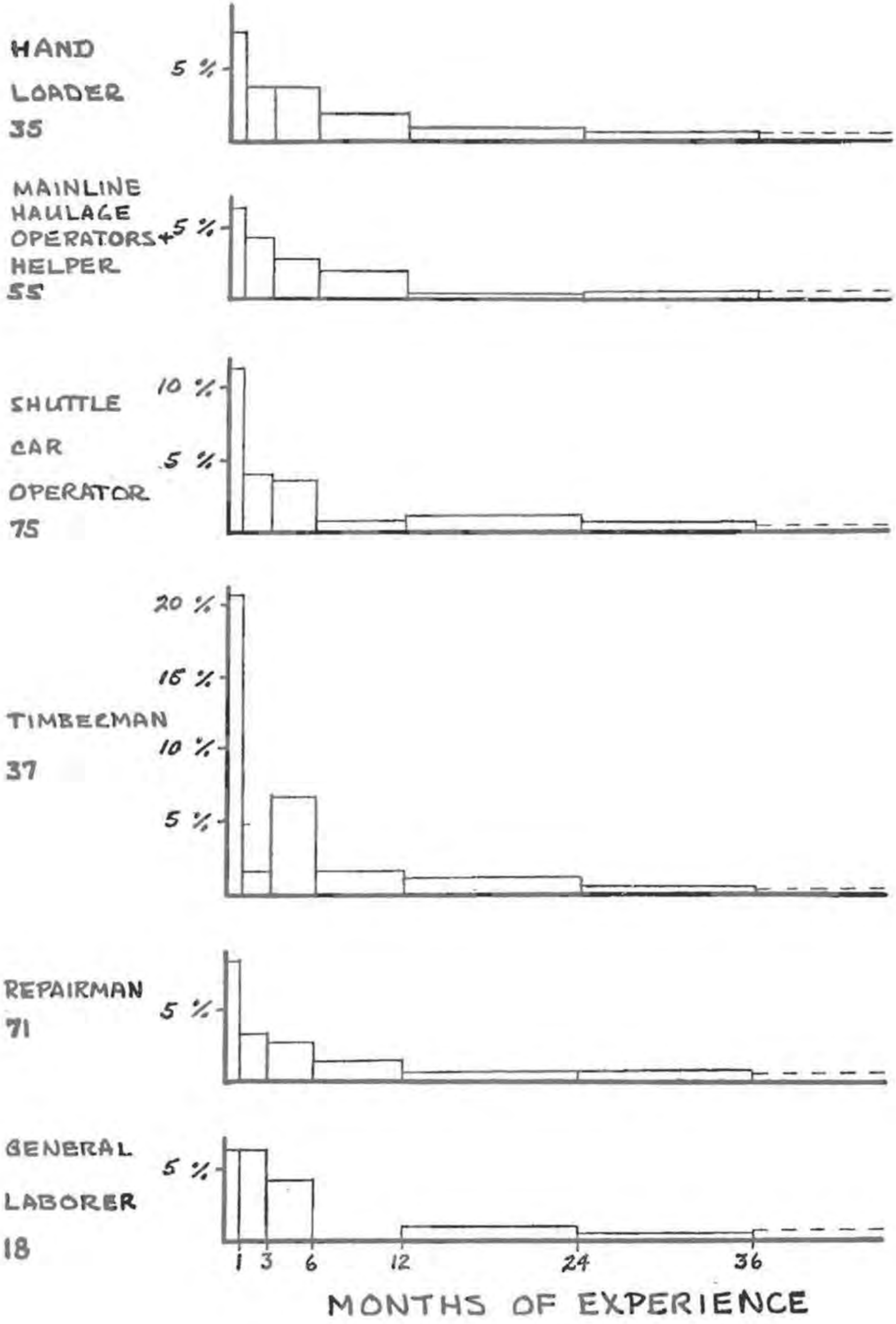


EXHIBIT 15

PERCENTAGE DISTRIBUTION OF FATAL VICTIMS' TASK EXPERIENCE BY MONTH – PER TASK CLASS.

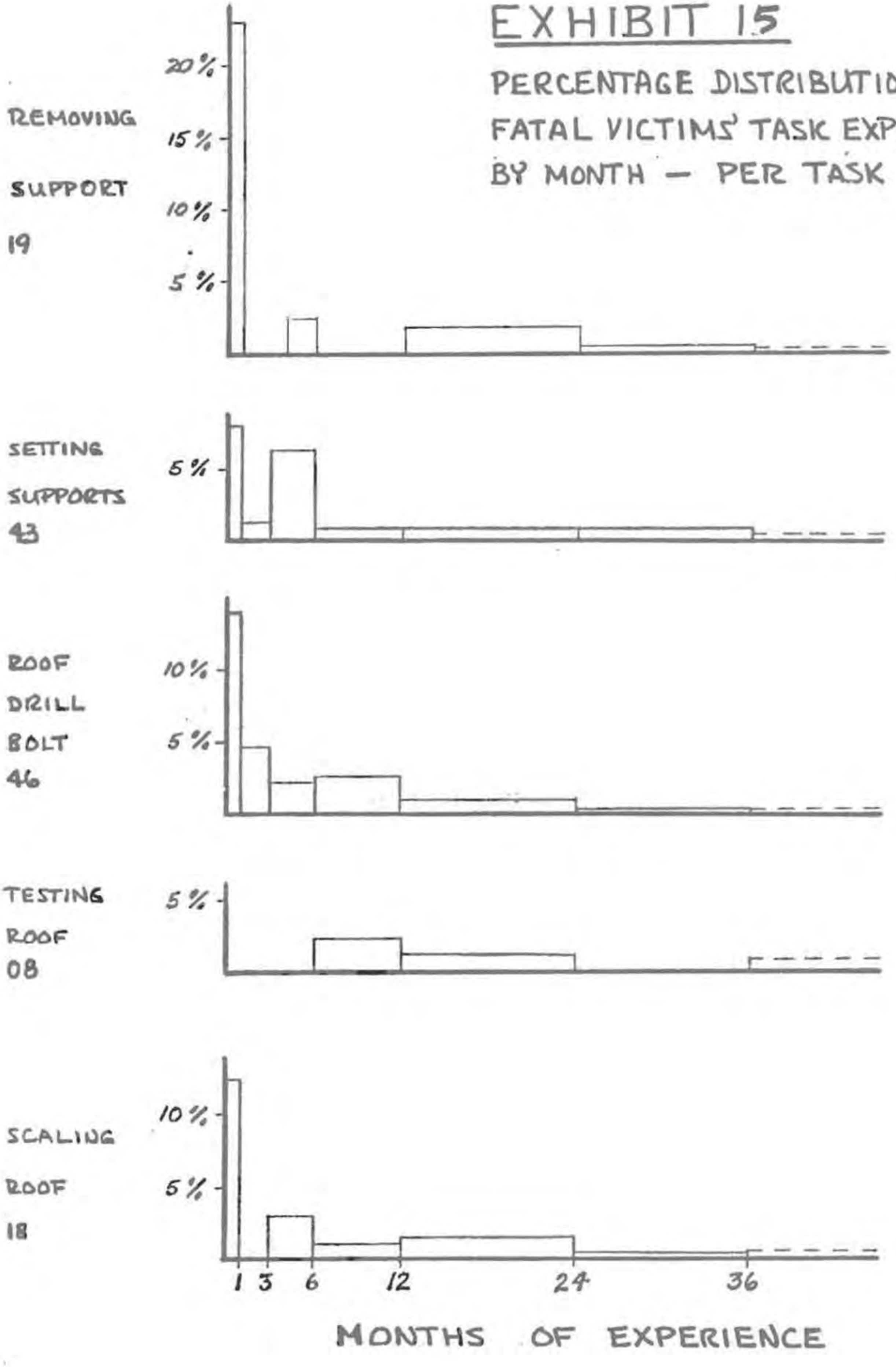


EXHIBIT 15 - (CON'T)

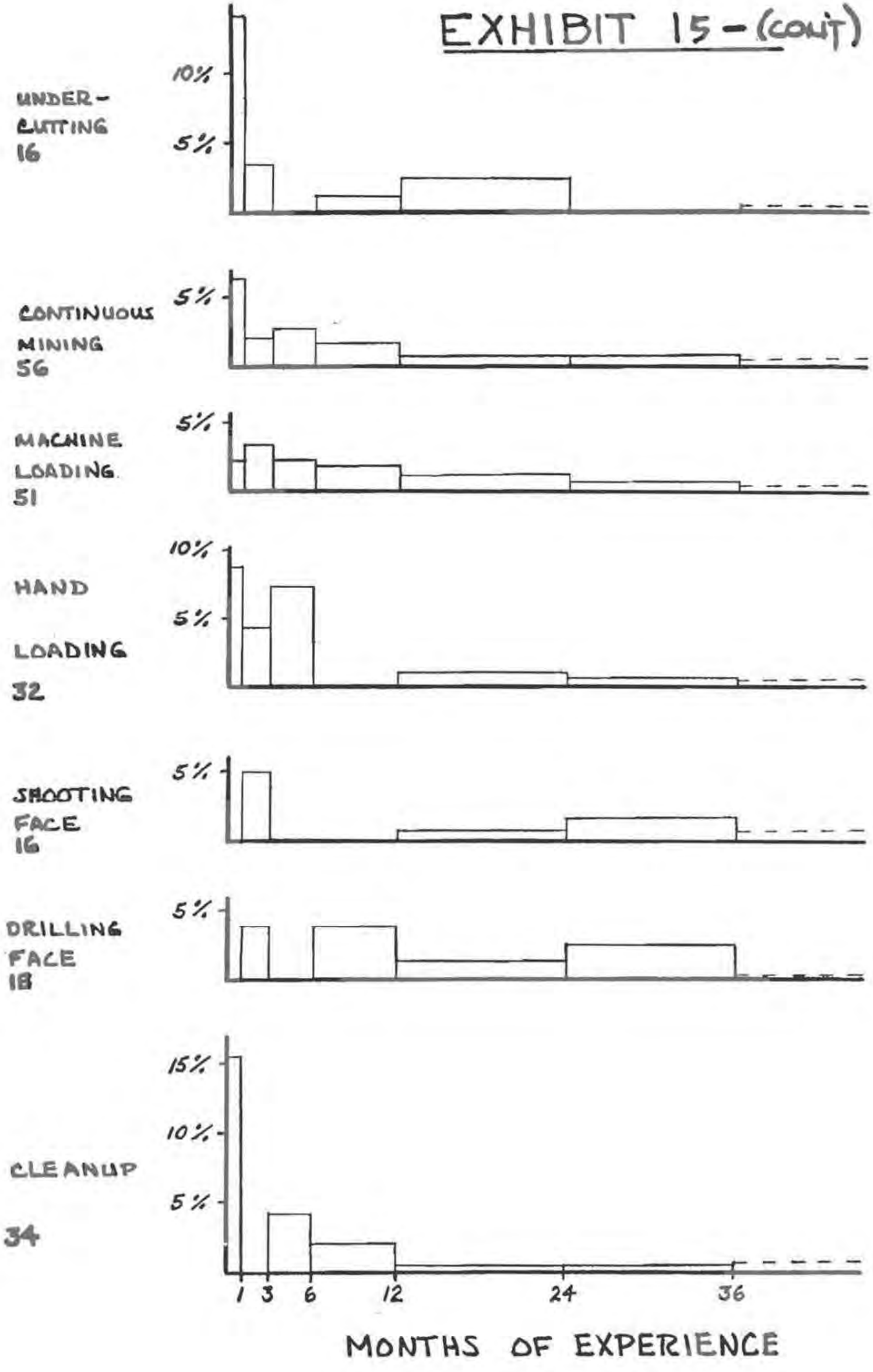


EXHIBIT 15 - (CON'T)

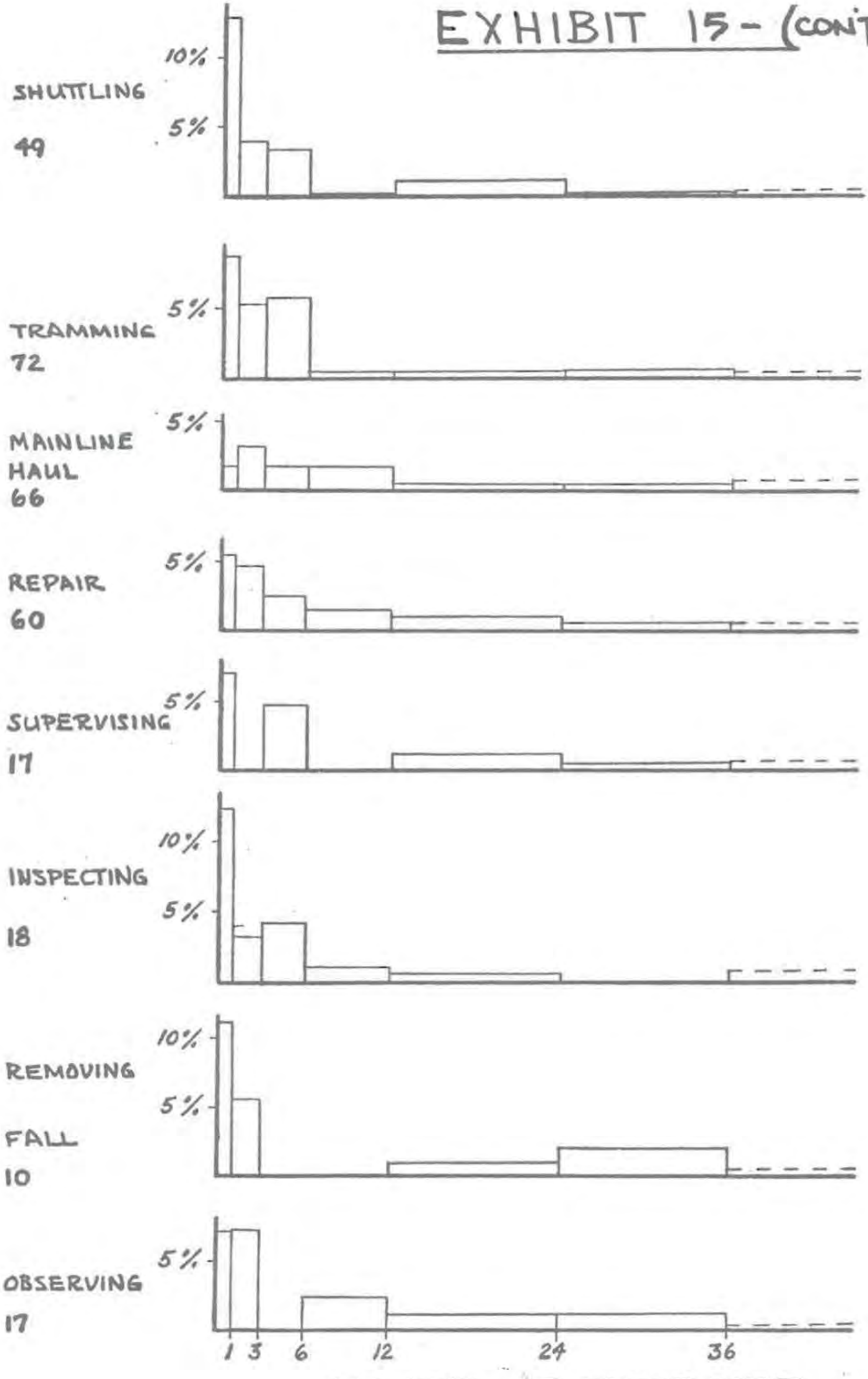


EXHIBIT 16

FATAL ACCIDENT DISTRIBUTION BY TASK EXPERIENCE FOR EACH ROOF EXPOSURE CATEGORY 306 VICTIMS

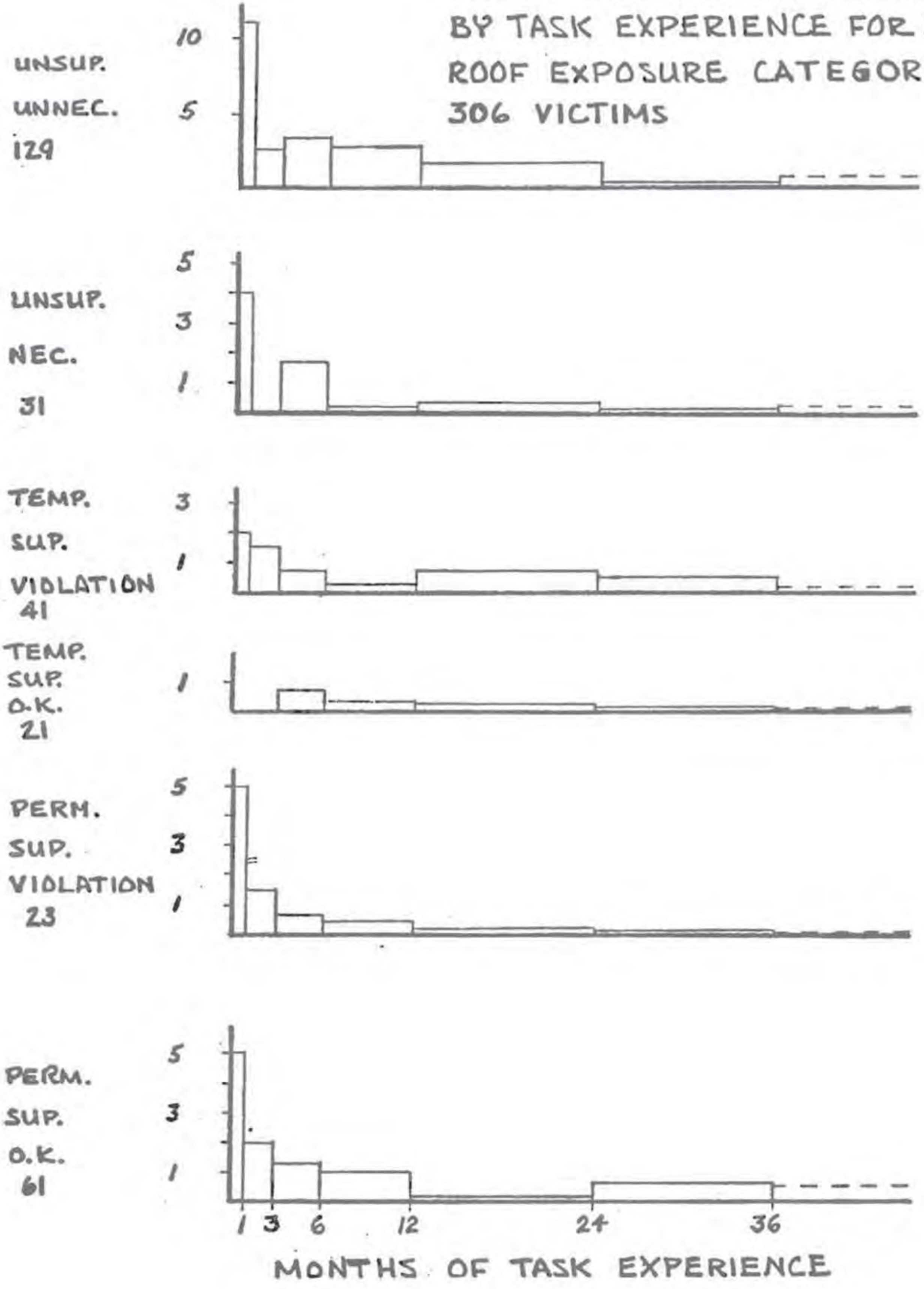
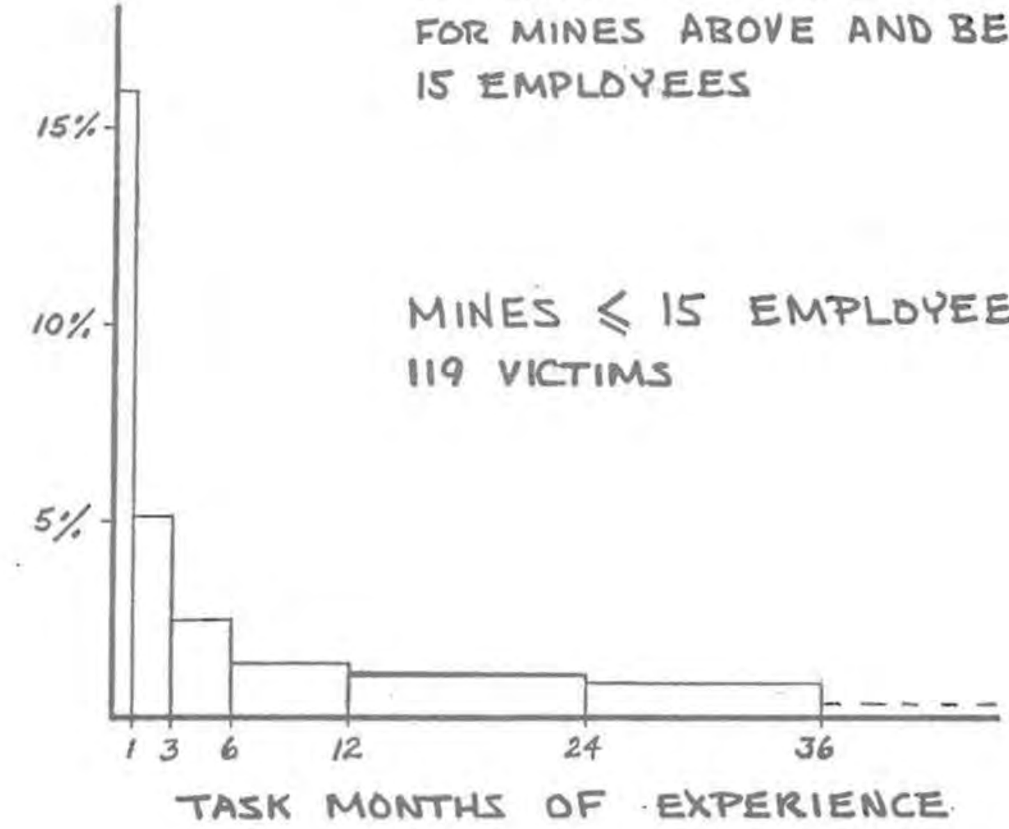


EXHIBIT 17

DISTRIBUTION OF FATALITIES BY MONTHS OF TASK EXPERIENCE FOR MINES ABOVE AND BELOW 15 EMPLOYEES



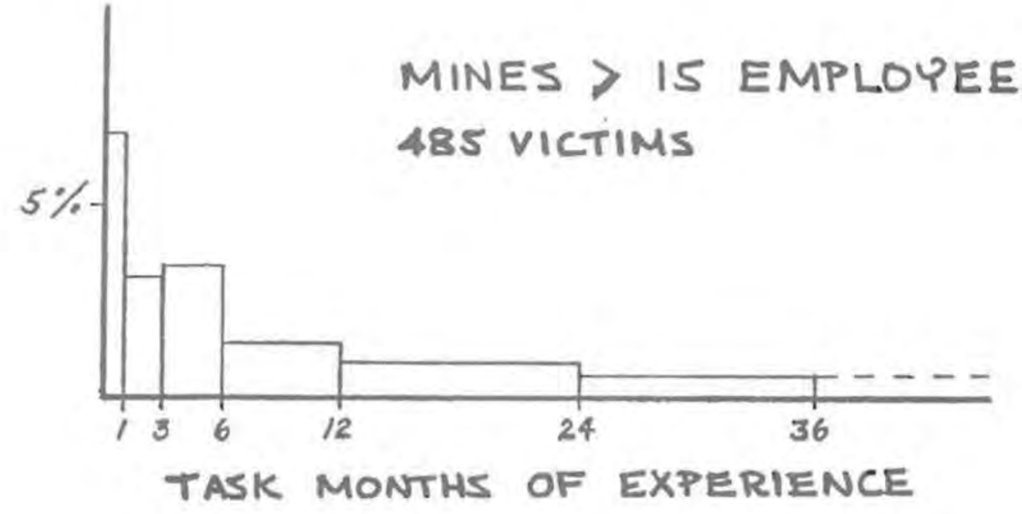
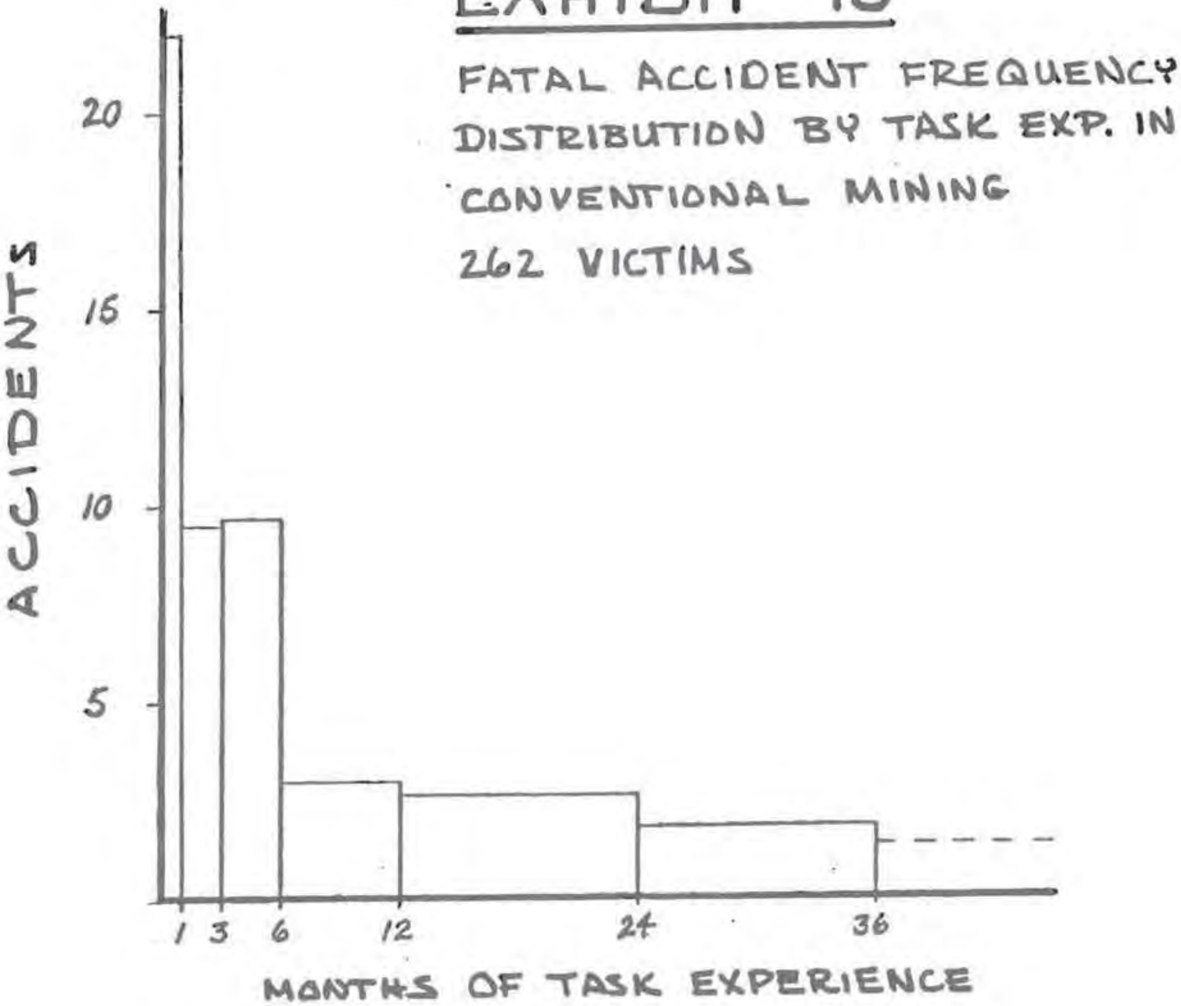
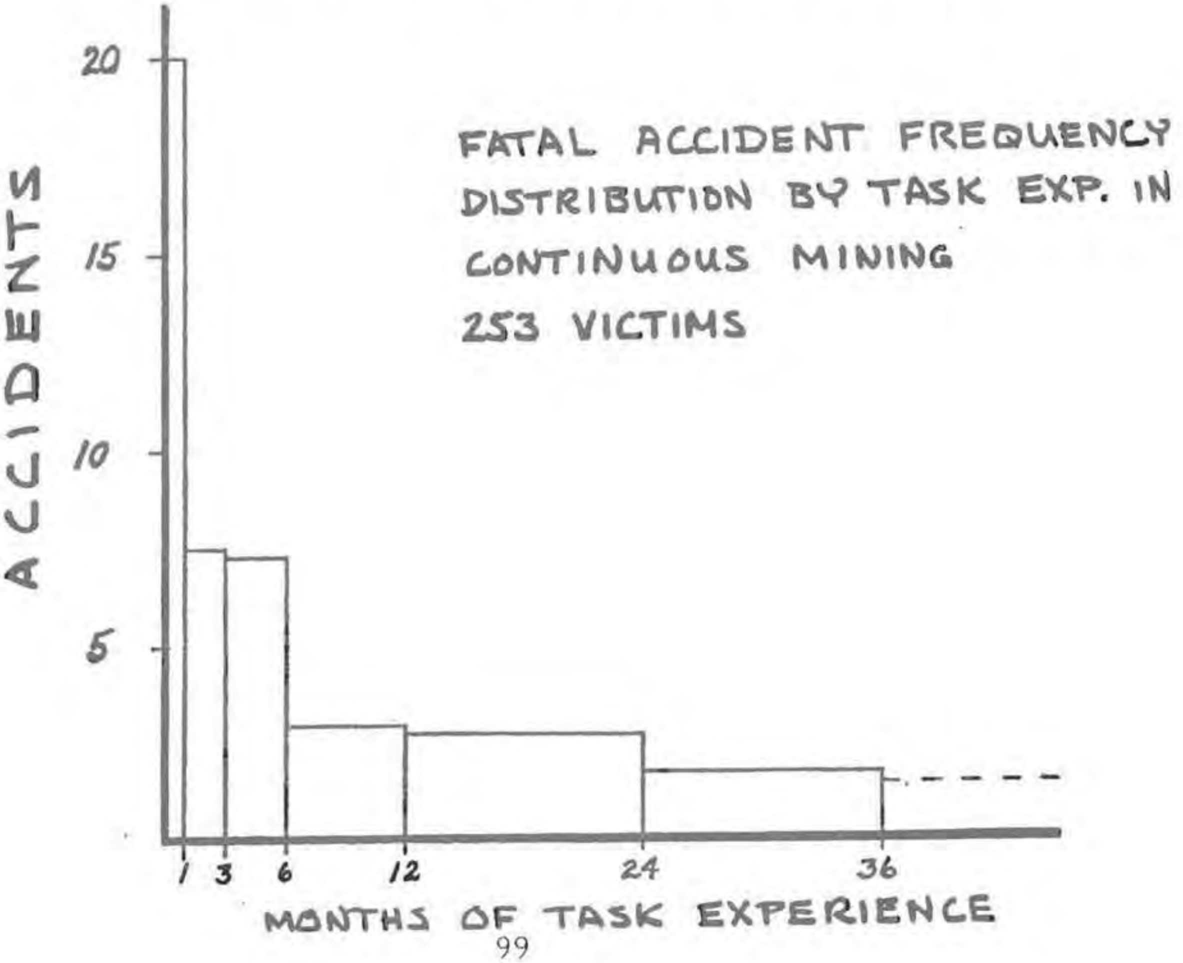


EXHIBIT 18


FATAL ACCIDENT FREQUENCY DISTRIBUTION BY TASK EXP. IN CONVENTIONAL MINING

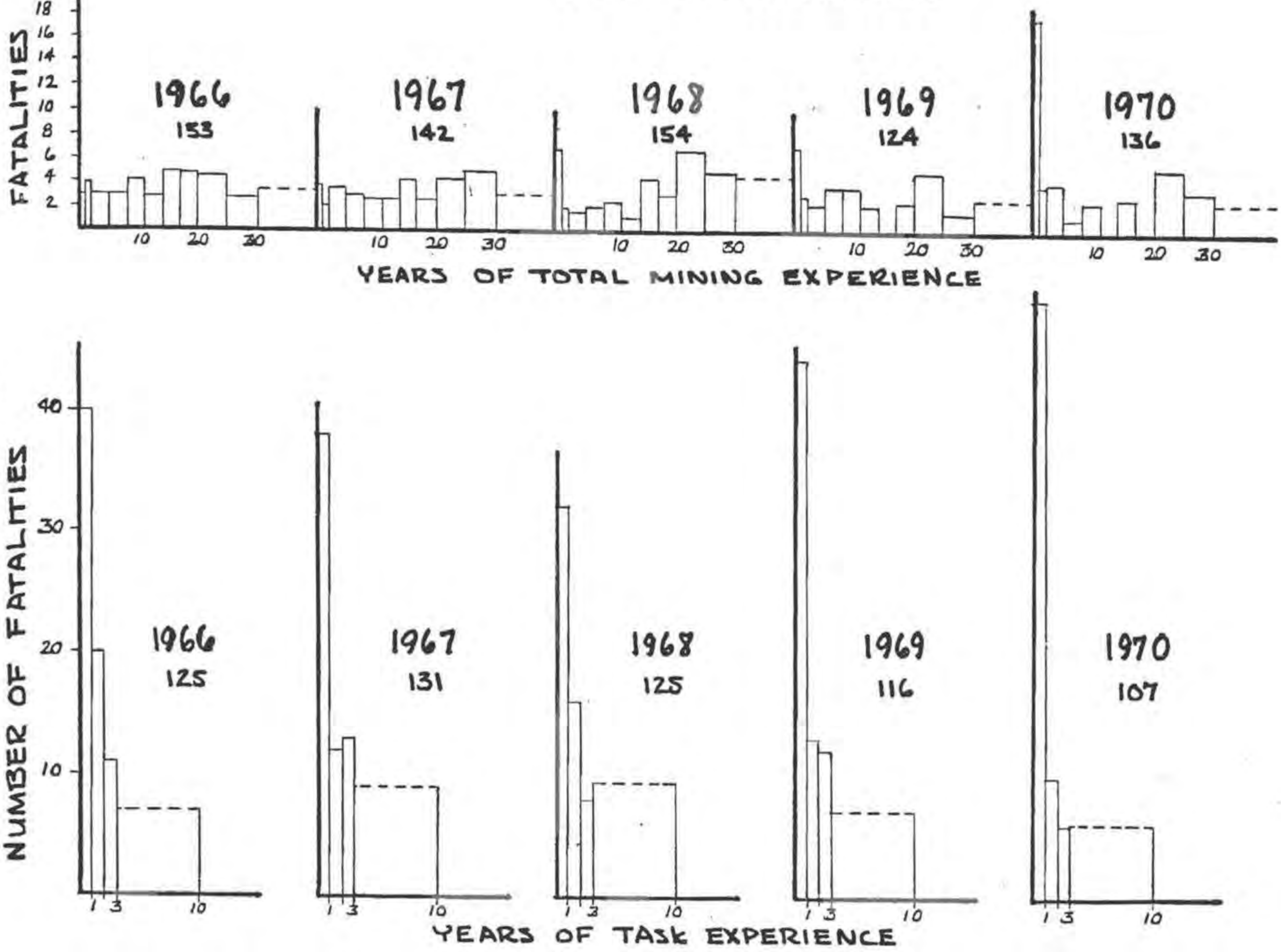
262 VICTIMS


FATAL ACCIDENT FREQUENCY DISTRIBUTION BY TASK EXP. IN CONTINUOUS MINING

253 VICTIMS

EXHIBIT 19

FIVE YEAR TRENDS



CHAPTER 5

SELECTED FATAL ACCIDENT REPORT ANALYSIS TOPICS

I. INTRODUCTION

The fatality data base cannot be completely analyzed within the scope of this project. There are literally millions of combinations of variables that can be tabulated by the computer for frequency of occurrence. Most of the contract cost was devoted to building the data base rather than analyzing it.

This chapter contains a series of briefly discussed topics that should be of interest to the Bureau. The primary intent of the analyses presented here is to illustrate the kind of relationships that can be studied with this data base. Most of this chapter will be devoted to a discussion of the lack of victim compliance with accepted procedures and selected roof fall accident topics.

II. COMPLIANCE WITH FEDERAL, MINE AND FOREMAN REGULATIONS/ INSTRUCTIONS

The USBM inspectors who investigated and reported upon the fatal accidents often indicated whether or not federal regulations, approved roof control plan procedures, written mine management policies, or foreman instructions were being followed at the time of the accident. Exhibit 1 compares the degree of compliance with the three levels of regulations -- federal, mine and foreman -- in fatal accidents occurring during the five-year period 1966-1970.

The coding of these three compliance levels by our staff was difficult because the wording in some reports was not always precise about compliance at each level. Tables 1, 2, and 3 of Exhibit 1 do not necessarily contain data from the same reports, and the response total varies from 358 to 624.

Another problem with this data is that the investigator frequently referred to violations of vague catch-all protective clauses such as "and sufficient additional support shall be provided in areas of known faults or unusual conditions". The term "sufficient support" beyond the minimum is a matter of management or supervisor opinion which may or may not concur with what the inspector felt was sufficient. Moreover, "sufficient support" prior to an accident by definition becomes "insufficient" after a fatal roof fall.

The degrees of non-compliance noted in the fatality reports range from minor infractions to very serious violations; thus it is nearly impossible from the present data base to speculate on how many fatalities could have been prevented by total compliance with federal regulations. As has been noted in other sections of this report, an accident might still have occurred even though all regulations were strictly followed. Since nearly all fatal incidents are the result of a series of contributing circumstances, non-compliance with regulations may not necessarily be the major cause of the accident.

The variable "FEDRULES" in Table 1 includes all Bureau regulations and recommended roof support plan procedures. Note that the definition of federal regulations was changed considerably after the 1969 Health and Safety Act. Despite all the methodological bias and technical weaknesses in the data of Exhibit 1, this exhibit still suggests that compliance with federal regulations seems to have improved over the five-year period, although non-compliance is still a characteristic of one third of the cases.

It is interesting to note in Exhibit 1 that the ratio of compliance with foreman instructions is high (56 "yes" to 8 "no" in 1970) but that compliance with mine management policies is only slightly better than 50% (68 "yes" to 52 "no" in 1970). Compliance with Bureau regulations is even worse (47 "yes" to 74 "no" in 1970). In other words, the foreman instructions seem to be followed in most cases, the mine management policies followed in about half the cases, and Bureau regulations followed in only about one third of the cases. A more precise tabulation is shown in Table 4 which is restricted to compliance comparisons for the same accidents and Table 5 which restricts the compliance comparisons to the same roof fall accidents. Tables 4 and 5 substantiate the implication of Tables 1-3 that foremen are issuing instructions contrary to federal regulations and written company rules in the majority of fatal accidents.

Some examples in the fatality reports of foremen giving contrary instructions to mine policy or federal regulations are: 1) supervising a pillar recovery crew and altering the recovery plan, thus weakening the support provided by pillars and contributing to a roof fall; 2) having the continuous miner recover the pillar stump when the plan called for it to be left; 3) watching a roof bolter bolt off the pattern without correcting the situation; 4) failure to test the roof frequently or properly so that the crew was working under unknown roof conditions; and 5) allowing work to be performed (with the foreman physically present) under unsupported roof without giving instructions to stop. The overwhelming majority of incidents in which the supervisor's instructions were contrary to federal regulations were roof fall fatalities involving non-compliance with the roof support plan. All these examples are in violation of federal regulations and often of written mine company policies. In accidents in which the instructions of the supervisor or the mine management were followed and federal regulations were not, a direct management representative - foreman, supervisor, or owner - was often present, seemingly providing tacit approval to act contrary to his own official policy. The degree to which management's stated regulations differ from actual policy cannot be reliably conjectured from the reports; however, the accident investigators often mentioned this deviation.

Exhibit 2 indicates that compliance on a year by year basis in small mines with less than 15 employees is considerably worse than in mines with 16 or more employees. The trend of increasing compliance seems promising, but this may be merely a result of the closing of many small mines.

Exhibit 3 shows the amount of direct supervision and compliance with foreman instructions for roof fall victims who were exposed to various kinds of roof conditions. (The roof exposure question is explained in detail in the section of this chapter entitled "Roof Exposure".) Both tables in Exhibit 3 are limited to victims who were not supervisors or management.

The results indicate that workers killed in roof falls were often under unsupported roof unnecessarily, under temporarily supported roof in violation of the roof control plan, or under permanently supported roof in violation of the plan with the full knowledge of the immediate supervisor. In a high percentage of cases the workers were in full compliance with the foreman's instructions. These results indicate that many first line supervisors apparently are not completely convinced that unsupported roof is extremely dangerous and that skimping on support greatly increases the risk of a roof fall.

In the field we have met many foremen who say, "I've worked under unsupported roofs for 20 years and it's not dangerous if you know what you're doing". This man's 20 years of experience in escaping injury from falls of unsupported roof presents a barrier to convincing him of the danger evidenced by relatively strong empirical data. It is analogous to convincing a person who habitually drives greatly in excess of the speed limit that by so doing he has increased his probability of having a fatal accident.

A promising area of research for the Bureau is to continue to study the effects of violations on accident occurrences. Dr. Ken Moore in Operations Research has indicated that he made a preliminary attempt for the Bureau but that the data that he was able to assemble was unsatisfactory.

The much improved 1971 fatal accident reports, which list the actual violations, should provide more insight into the effect of non-compliance. We understand that these reports will also include the mine's history of violations and abatements to determine the relationship of violations to actual mine practice. Certainly if a mine with a fatal accident has had a history of related violations and a poor history of abatement, then the management must, in practice, be condoning such action.

The effects of supervision on accidents should also be further examined. Perhaps the high compliance of victims to supervisors' instructions in fatal accidents points out the need for more stringent certification and training of mine supervisory personnel. Since the foreman or supervisor is such a vital link to the worker and is the worker's only source of instruction in many companies, more emphasis on training the foreman might reduce accidents.

Ultimately the Bureau needs to be able to measure the safety benefits that additional costly enforcement programs might yield. The cost effectiveness of such measures could then be compared to the benefits which might be derived from investing funds in changing regulations, in adding training programs, or in technological remedies.

III. FATAL ROOF FALL ACCIDENT ANALYSIS

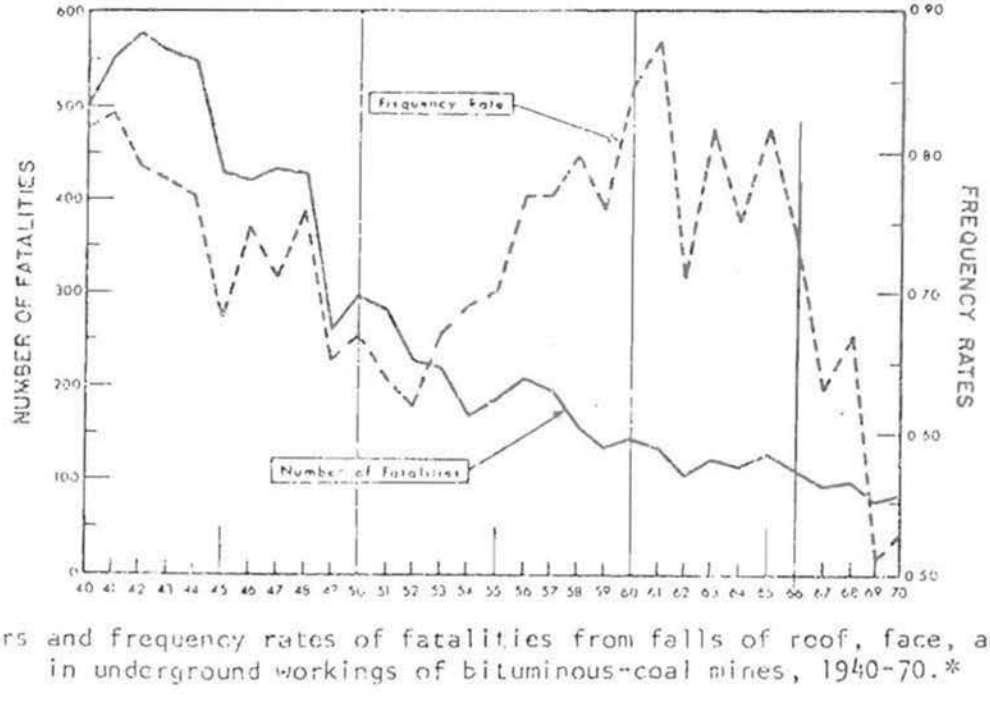
A. Problems

The fatal accident data base was originally designed to support the basic industrial engineering contract to study roof fall fatalities. All of the fatal accident statistics and estimates of lives saved via the recommendations in the 12 major projects in Chapters 7-18 of this report are derived from the fatality report analysis. Most of the projects relate to roof falls; hence they represent fatality roof fall analysis at a detailed level.

On a general level, however, roof fall fatality analysis is very difficult without normalizing data from the roof control plans in the industry. Any meaningful analysis of the general relationship between accident frequencies and proper bolt length, rooms, intersections, entry widths, etc. is almost impossible without quantitative knowledge of the industry practices. If one notices, for example, that virtually all fatal accidents from failures of bolted roof occur at entry widths greater than 22 feet, the observation may not be significant if virtually all entries are also greater than 22 feet wide. The example is no doubt a bit simple-minded, but the point remains that roof control analysis requires normalizing data.

B. Roof Fall Fatalities

The number of official USBM roof and rib fall fatalities have declined as follows:



Numbers and frequency rates of fatalities from falls of roof, face, and rib in underground workings of bituminous-coal mines, 1940-70.*

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* Prepared by the staff of the Office of Accident Analysis, under the supervision of Forrest T. Moyer, Chief, Office of Accident Analysis, Bureau of Mines, August 1971.

While the number of fatalities has declined gradually, the frequency rate per million manhours worked has declined considerably over the five-year period. In light of the slight increase in roof fall fatalities in 1970, the decline does not appear to be attributable to the 1969 law.

Projecting these figures into the future based upon the above data, we can conclude that there is slight chance for dramatic roof fall accident reduction in the 1970's. Even the fatal roof fall accident record of the so-called "permanent support" systems utilizing posts or bolts yields a fatality rate of 0.15 accidents per million manhours worked, which is greater than the 1970 German accident rate of 0.12 per million manhours worked for all underground accidents. (0.15 = 29% x 0.53 roof/rib fall frequency rate per million manhours in the U.S. for 1970. Twenty-nine percent is the percent of 1970 roof fall accidents under "permanent support - plan compliance" from Exhibit 5.)

This picture could be improved somewhat by dramatically reducing unsupported roof exposure via mechanized longwall systems or with devices such as the temporary truss discussed in Chapter 7. The German coal systems are almost exclusively mechanized longwall, which almost eliminates unsupported roof exposure since the entries are supported by yielding arches or trusses.

The challenges of reducing roof fall accidents in the U.S. are nearly as great now with the 1969 law as they were prior to the law. If there is any hope of improving either continuous or conventional mining systems to competitive accident rate levels using mechanized longwall systems, substantial research and development will be required. In order to conduct such research intelligently, substantially better accident data is needed to enable researchers to define the problems more precisely.

C. Roof Exposure

The roof exposure variable in the data base classifies the three basic types of roof conditions -- unsupported, temporarily supported, and permanently supported -- into categories of questionable and accepted mining practice. For each fatal accident involving unsupported roof conditions, our staff interpreted the accident report and coded whether it was necessary or unnecessary for the victim to be under the unsupported roof to perform his job. Examples of victims in situations coded as "under unsupported roof unnecessarily" are as follows:

1. Roof bolter installing bolts without temporary support.
2. Continuous miner operator advancing beyond line of permanent support. (Or any worker doing job without permanent or temporary support.)
3. Foreman testing roof and finding it bad, then standing under it for prolonged time periods discussing it with another worker.
4. Worker repairing equipment or cutting timbers beyond last support line.
5. Workers removing roof fall without installing support.
6. Mining under unsupported roof and removing last stump of pillar which was originally intended to be left as support.
7. Doing scaling or clean-up beyond supported roof without proper temporary support.
8. Failure to install temporary support in accordance with plan such that miner not surrounded by support.
9. Removing support in improper manner (knock out with continuous miner on retreat, strike post to dislodge and move while standing under known bad roof, etc.).
10. Continuing to work in area where supports had been dislodged by equipment or falls.

Unfortunately, an accident involving questionable procedures would not always have been prevented if accepted methods had been followed. For example, a massive fall might not be related to whether the roof bolter who was under unsupported roof had set temporary jacks or not. On the other hand, following accepted practices would no doubt have prevented a large number of these roof fall fatalities.

In roof fall accidents involving temporary or permanently supported roof, questionable practice refers to violations of the roof support plan as noted by the USBM inspector who wrote the report.

The results of this coding are shown in Exhibits 4 and 5. Exhibit 4 shows the exposure tabulation for the five-year period and Exhibit 5 shows only the 1970 exposure tabulation. Although the total number of roof fall accidents declined over the five years, over half of the roof fall accidents occurred under unsupported roof. The overall percentage of questionable practice instances declined from a five-year average of 65% to about 50% in 1970, with most of the percentage drop in accidents in the unsupported-roof-unnecessarily category. This apparent improvement could be real or it could be a coincidence or even a coding bias. The improvement might also be related to the closure of mines, especially small mines notorious for roof fall accidents. The number of mines has declined from about 5,000 in 1965 to under 3,000 in 1971.

D. Roof Fall Size

As shown in Exhibit 6, 50% of all fatal roof falls over the 1966-1970 period were in the 101-130 square foot or smaller categories. The median size of fatal accident roof falls lies between 101 and 130 square feet. The trend over the five-year period has been toward larger roof falls; 1966 had a median category of 71-100 square feet and 1970 had a median category of 181-230 square feet. When weighted by the number of victims, the roof fall size for the five years is in the 131-180 square feet category. This is not surprising since multiple roof fall fatalities occur in the massive roof falls.

In attempting to determine the reason for the apparent trend toward larger roof falls, we examined other dimensions of roof size. We could find no corresponding increase in the size of intersection or pillar falls, which are the more massive ones, no trend toward poorer support conditions or increased area between pillar, room, or intersection ribs, and no strong trends in seam height profiles. Our only conclusion, then, is that falls are getting significantly longer since a stable face entry width precludes their getting wider. Our present data base cannot positively support this theory since we worked in terms of square foot size rather than actual dimensions. The other possibility is that this is not a significant or lasting trend.

The median thickness of the roof fall in fatal accidents as shown in Exhibit 6 has historically been fairly consistent at 11", while the average for the five-year period was 22" -- accounting for 77% of all roof falls. (See Exhibit 2 in Chapter 3 for coding definitions of roof fall thickness.)

Analysis of roof fall size as illustrated here can quickly include a large number of other variables. Not all relevant relationships have been investigated and much work remains to be done. The roof fall size variable needs to be partially recoded. Obtaining industry-wide roof control plan data would also make it possible to normalize the frequency data shown in Exhibits 6 and 7.

E. Seam Height Effects

Roof fall size as a function of seam height is shown in the lower table of Exhibit 7. Roof fall size seems to decrease as a function of increased seam height. Larger roof falls in lower seams may be related to the wider entry widths and greater areas of unsupported roof typically found in smaller mines with lower seams. The wider, unsupported entries probably both increase the probability of a fall and provide a larger area over which a "running fall" can develop.

Exhibits 8 through 14 depict normalized frequencies of roof falls in each seam height. All the exhibits compare the distribution of roof fall accidents with the 1966 distribution of coal tonnage in the seam height categories. Production for 1966 was used because these figures were the latest published by the Bureau at the time this report was written. Consequently, 1966 is the only year for which a valid comparison can be made. (The Bureau maintains current production data but it was not available in a published form according to the Chief, Office of Accident Analysis, USBM, as of June 1971.)

Taken together, these exhibits help explain roof fall problems in low coal. Exhibit 8 indicates that the 0-3 foot coal seams experience a disproportionate percentage of roof fall accidents. Exhibit 10 may suggest that low coal is more dangerous even if the worker is necessarily out under unsupported roof; however the sample size is small. Exhibit 9 suggests that one of the contributing factors is lack of support. Exhibits 11 and 12 indicate that another reason for more roof falls in low coal is a greater degree of roof control plan violations. The sample sizes in Exhibit 13 are too small for valid inference. Exhibit 14 indicates that low coal may even have inadequate temporary roof control plans in relation to other seams.

The problems in low coal are especially frustrating. The mines are small, manpower turnover is high, roof support is often ignored, and mine management is often hostile to the Bureau. The inspection problems are very great because of the needs and the number of small mines.

F. Other Promising Roof Fall Accident Analysis Topics

We have identified a number of factors which may be associated with a large number of roof fall accidents. Each of these requires more research, recoding of data or obtainment of normalizing data. These research leads are partially listed below.

1. Roof falls are most prevalent in retreat mining when 11-20% of the pillar has been mined. See "%PIL RMV" in Exhibit 3 of Chapter 3.
2. When driving entries (room and pillar) the most dangerous roof fall point along the typical entry is at about 20% of the total entry penetration distance (typically 12-15 feet of a 60-foot center-to-center distance between crosscuts).
3. Massive failure of bolted roof above the bolt anchor line occurs almost exclusively in entries wider than 22 feet.
4. There is some evidence that bolts hold up roof a few feet inby the last line of support, but their effectiveness in fatal accidents seems only slightly better than posts.
5. Bolted roof failures are prevalent in wide entries in lower seams with short bolts (30" or so).
6. Less than 35% of all fatal roof fall victims were killed in areas where the distance between the closest rib points is under 20 feet.
7. More fatal roof fall accidents occur in development areas (room or crosscuts - 39%) than in the typically larger intersection areas (28%) or pillar areas (10%).

Obviously, the list is incomplete and much work remains to be done on roof fall accident analysis.

IV. RECOMMENDATIONS ON SELECTED FATAL ACCIDENT REPORT ANALYSIS TOPICS

A. Considerable research is needed on the effect of the USBM enforcement of regulations on accident occurrence. This research will lead to a more cost effective selective enforcement program, similar to that used by all large urban police departments.

B. Roof fall accident analysis needs much more work. (Most of the effort of this contract was spent building the data base.) Additional analysis work should be done in cooperation with Bureau roof control experts.

C. Normalizing data is desperately needed for roof fall accident analysis. The first step would be to create a data base of roof control plans. The next step would be to associate roof control plans with a data base on violations of roof control plans.

D. The existing data base should be revised and recoded; 1971 roof-fall accidents should also be coded.

EXHIBIT 1

THEODORE BARRY AND ASSOCIATES

DEGREE OF COMPLIANCE WITH THREE LEVELS OF REGULATIONS AND/OR INSTRUCTIONS IN FATAL ACCIDENTS

1966-1970

Table 1

Federal Regulations Followed	1966	1967	1968	1969	1970	Total
NO	102	66	86	69	74	397
YES	25	39	32	17	47	160
TOTAL	127	105	118	86	121	557

Table 2

Mine Regulations Followed	1966	1967	1968	1969	1970	Total
NO	87	58	75	58	52	330
YES	48	68	54	56	68	294
TOTAL	135	126	129	114	120	624

Table 3

Foreman Instructions Followed	1966	1967	1968	1969	1970	Total
NO	15	5	15	15	8	58
YES	68	67	55	54	56	300
TOTAL	83	72	70	69	64	358

EXHIBIT 1
(Continued)

THEODORE BARRY AND ASSOCIATES

DEGREE OF COMPLIANCE WITH THREE LEVELS OF REGULATIONS AND/OR INSTRUCTIONS IN FATAL ACCIDENTS
1966-1970

Table 4

Foreman Instructions Followed	Fed. Regs. Not Followed Mine Regs. Not Followed	Fed. Regs. Followed Mine Regs. Not Followed	Fed. Regs. Not Followed Mine Regs. Followed	Fed. Regs. Followed Mine Regs. Followed	Total
NO	47	0	1	0	48
YES	129	3	35	95	262
TOTAL	176	3	36	95	310

Table 5*

Foreman Instructions Followed	Fed. Regs. Not Followed Mine Regs. Not Followed	Fed. Regs. Not Followed Mine Regs. Followed	Fed. Regs. Followed Mine Regs. Followed	Total
NO	39	1	0	40
YES	115	20	63	198
TOTAL	154	21	63	238

* Roof fall accidents only.

EXHIBIT 2

THEODORE BARRY AND ASSOCIATES
FATAL ACCIDENT FREQUENCY

COMPLIANCE WITH FEDERAL REGULATIONS
SMALL MINES VS LARGE MINES
1966-1970

Number of Employees	1966		1967		1968		1969		1970		Total	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
15 and Less	4	36	3	27	3	29	1	16	4	21	15	129
16 and Greater	21	65	36	39	29	57	16	53	43	53	145	267
Total	25	101	39	66	32	86	17	69	47	74	160	396

EXHIBIT 3

THEODORE BARRY AND ASSOCIATES

ROOF FALL ACCIDENTS

Type of Roof Exposure

Victims Supervised	Unsup. Unnec.	Unsup. Neces.	Temp. Violation	Temp. Concur.	Perm. Violation	Perm. Concur.	Total
NO	67	13	24	4	9	23	140
YES	54	20	25	14	20	37	170
TOTAL	121	33	49	18	29	60	310

Victim Level — Trainee, Helper or Operator/Worker

Type of Roof Exposure

Foreman Instructions Followed	Unsup. Unnec.	Unsup Neces.	Temp. Violation	Temp. Concur.	Perm. Violation	Perm. Concur.	Total
NO	24	3	7	3	3	1	41
YES	35	20	25	10	18	45	153
TOTAL	59	23	32	13	21	46	194

Victim Level — Trainee, Helper or Operator/Worker

EXHIBIT 4

ROOF EXPOSURE
ROOF FALL ACCIDENTS
(1966 - 1970)

CLASSIFIED BY THEODORE BARRY & ASSOCIATES

ROOF OVER VICTIM	Questionable Practice	Accepted Practice	
Unsupported Roof			
Unnecessarily	163 43%		
Necessarily		39 10%	
SUBTOTAL			202 53%
Temporary Support			
Plan Violation	54 14%		
Plan Compliance		21 6%	
SUBTOTAL			75 20%
Permanent Support			
Plan Violation	31 8%		
Plan Compliance		73 19%	
SUBTOTAL			104 27%
TOTAL ROOF FALL INCIDENTS	248 65%	133 35%	381 100%

EXHIBIT 5

ROOF EXPOSURE
ROOF FALL ACCIDENTS
1970

CLASSIFIED BY THEODORE BARRY & ASSOCIATES

ROOF OVER VICTIM	Questionable Practice	Accepted Practice	
Unsupported Roof			
Unnecessarily	25 *43-37%		
Necessarily		10 10-15%	
SUBTOTAL			35 53-52%
Temporary Support			
Plan Violation	7 10%		
Plan Compliance		2 3%	
SUBTOTAL			9 20-13%
Permanent Support			
Plan Violation	4 6%		
Plan Compliance		20 29%	
SUBTOTAL			24 24-35%
TOTAL ROOF FALL INCIDENTS	36 65-53%	32 35-47%	68 100%

* 1966-1969 vs. 1970

EXHIBIT 6

THEODORE BARRY AND ASSOCIATES
FATALITY ACCIDENTS (1966-1970)

Roof Fall Size-Square Feet/Frequency of Occurrence

Fall Square Feet	1966	1967	1968	1969	1970	Total
0- 10'	2	2	3	3	7	17
11- 20'	5	3	4	2	3	17
21- 30'	5	6	7	6	5	29
31- 50'	15	7	15	7	6	50
51- 70'	9	3	2	6	4	24
71-100'	* — 10 —	8	8	3	4	33
101-130'	10	3	— 4 —	3	1	— 21 —
131-180'	3	— 7 —	4	3	1	18
181-230'	1	7	2	6	— 4 —	20
231-330'	4	9	6	6	6	31
331-630'	11	10	20	10	11	62
> 630'	18	12	8	11	16	65
Total frequency	93	77	83	66	68	387
Median freq. point	100 SqFt	180 SqFt	120 SqFt	180 SqFt	230 SqFt	130
Average Size	254 SqFt	264 SqFt	245 SqFt	268 SqFt	306 SqFt	266 SqFt

Roof Fall Thickness/Frequency of Occurrence

Fall Thickness - Inches	1966	1967	1968	1969	1970	Total
1- 4"	15	9	15	8	10	57
5- 7"	23	20	15	9	8	75
8- 11"	— 12 —	12	— 15 —	18	— 16 —	— 73 —
12- 17"	9	12	18	7	13	49
18- 24"	12	5	10	6	5	38
25- 32"	7	4	3	2	3	19
33- 42"	7	0	4	6	3	20
43- 52"	2	2	1	2	2	9
53- 64"	2	3	2	1	1	9
65- 74"	1	2	2	1	1	7
75-114"	1	4	3	2	6	16
> 114"	1	3	2	4	1	11
Total frequency	92	76	90	66	69	383
Median freq. point	11"	11"	11"	11"	11"	11"
Average thickness	18"	23"	21"	26"	23"	22"

* -----: Median

EXHIBIT 7

THEODORE BARRY AND ASSOCIATES
FATALITY ACCIDENTS (1966-1970)

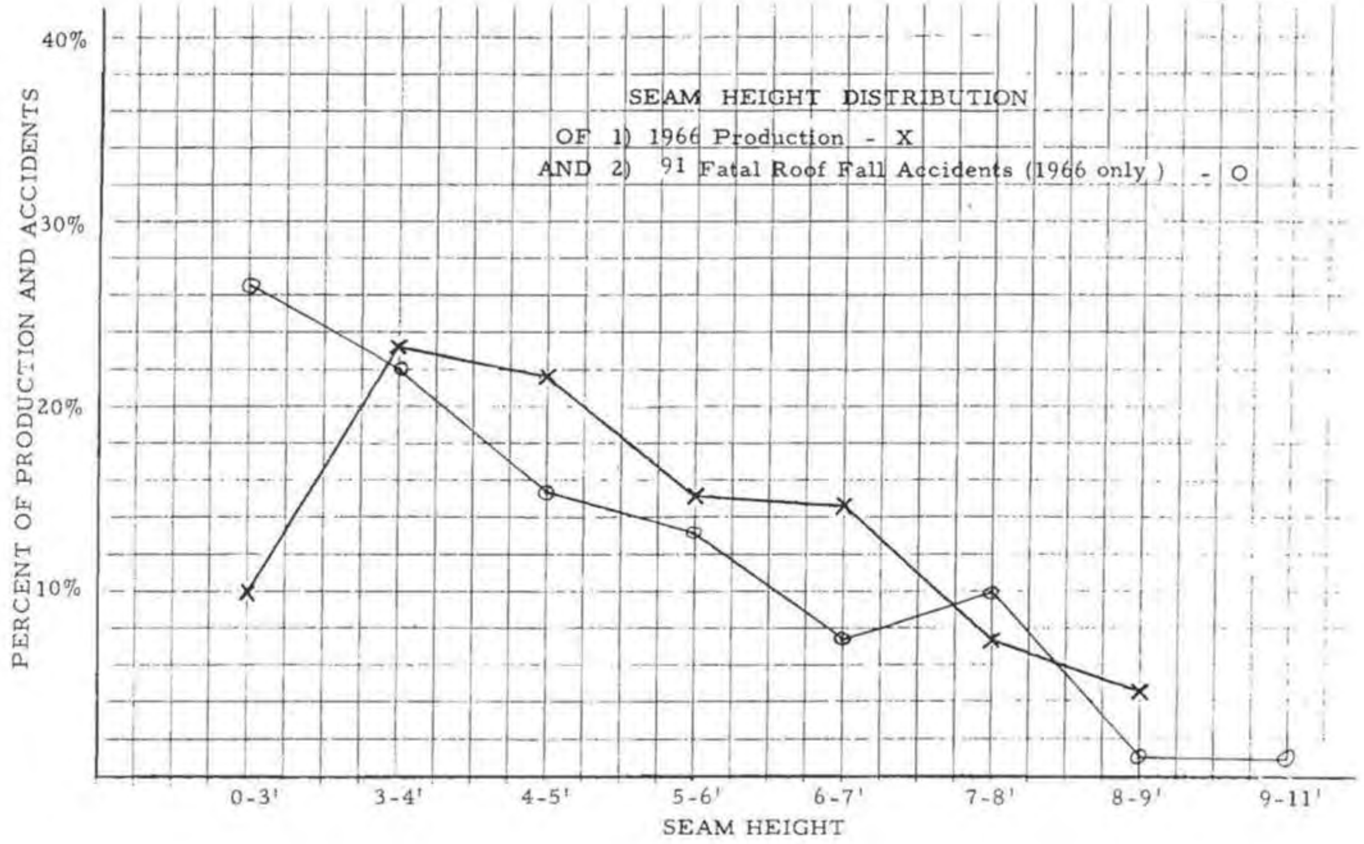
Seam Height Versus Support

Support Type	0-3'		3+-4'		4+-5'		5+-6'		6+-7'		7+-8'		Total
None	5	8%	13	12%	10	12%	5	10%	5	16%	3	14%	41
Posts, Rib Posts	46	75%	60	52%	33	38%	17	33%	4	13%	3	14%	161
Bolts & Bolt Comb.	11	18%	39	36%	43	50%	29	57%	23	72%	16	73%	163
TOTAL	62	101%	112	100%	86	100%	51	100%	32	101%	22	101%	365

Seam Height Versus Fall Size (Square Footage)
Frequency of Occurrence

Fall Sq. Ft. /Seam Height	0-3'	3+-4'	4+-5'	5+-6'	6+-7'	7+-8'	Combined
0- 10'	1	1	5	0	4	5	16
11- 20'	3	5	3	2	2	1	16
21- 30'	2	8	5	7	2	3	27
31- 50'	4	16	14	8	5	2	49
51- 70'	5	7	7	2	1	0	22
71-100'	7	9	10	2	4	1	33
101-130'	6	7	4	3	0	0	20
131-180'	6	7	4	0	1	0	18
181-230'	3	7	4	4	1	1	20
231-330'	2	12	5	2	6	2	29
331-630'	12	18	11	10	4	1	56
> 630'	11	16	14	11	2	6	60
Total Frequency	62	113	86	51	32	22	366
Median Freq. Point	180 SqFt	130 SqFt	100 SqFt	230 SqFt	100 SqFt	50 SqFt	

EXHIBIT 8


SEAM HEIGHT DISTRIBUTION
OF 1) 1966 Production - X
AND 2) 91 Fatal Roof Fall Accidents (1966 only) - O
PERCENT OF PRODUCTION AND ACCIDENTS
40%
30%
20%
10%
0-3'
3-4'
4-5'
5-6'
6-7'
7-8'
8-9'
9-11'
SEAM HEIGHT

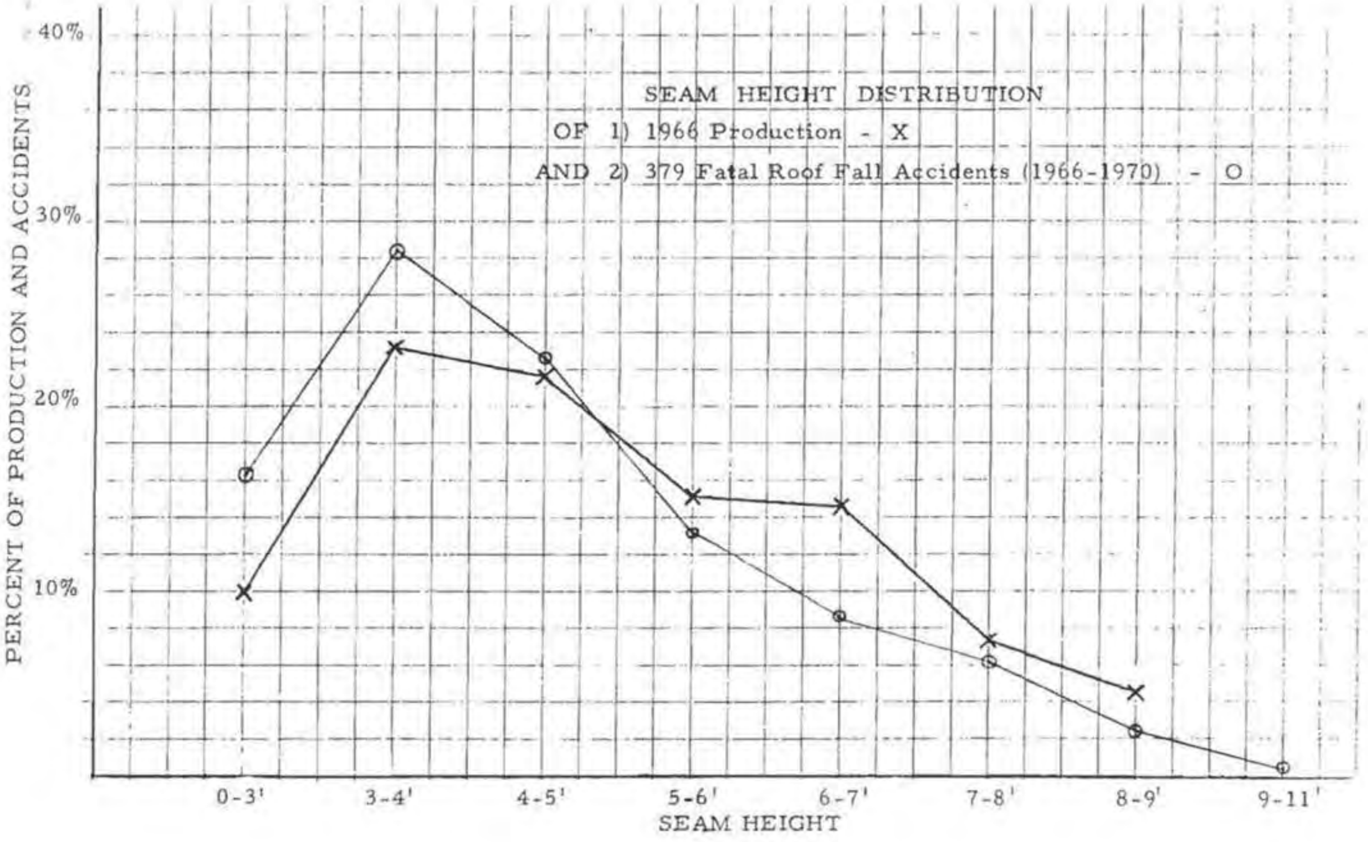
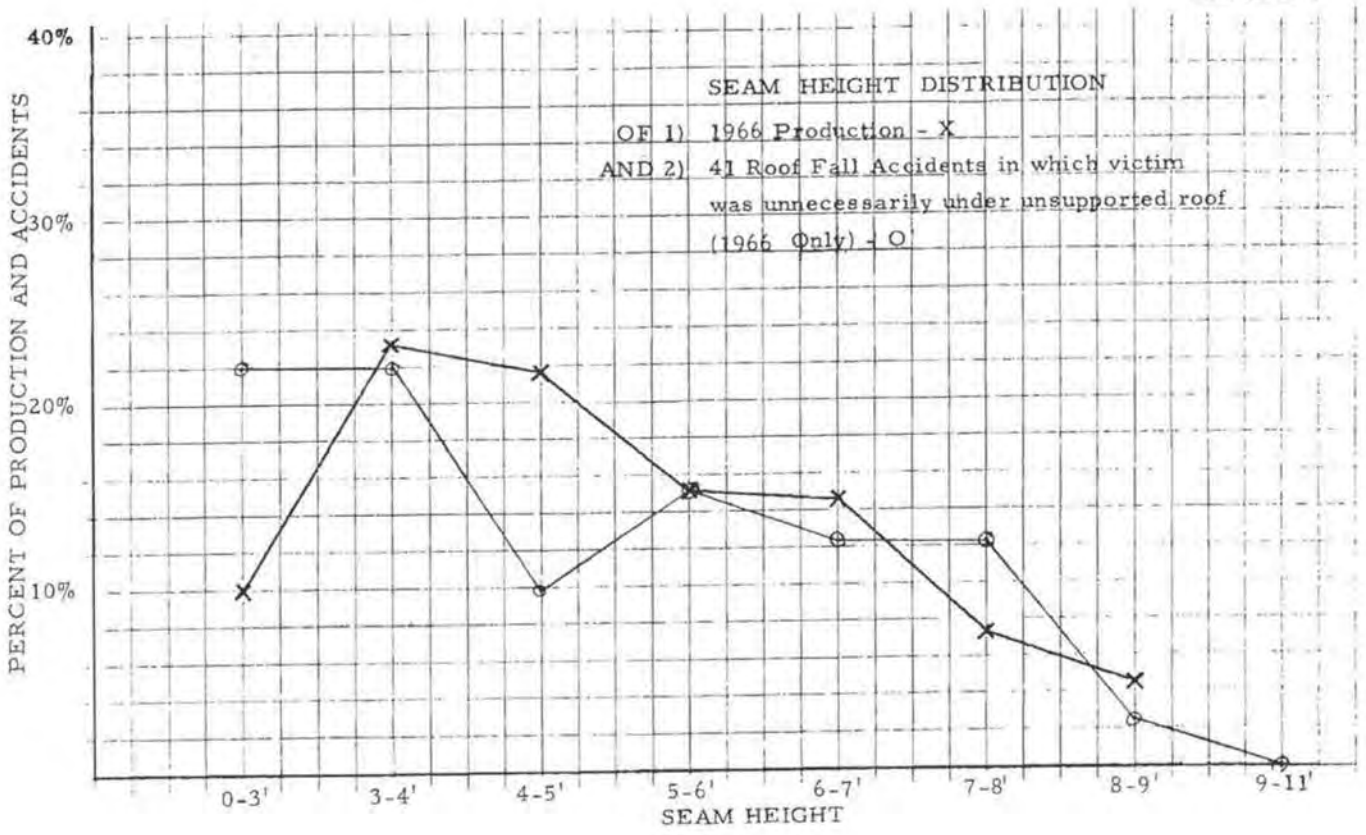

SEAM HEIGHT DISTRIBUTION
OF 1) 1966 Production - X
AND 2) 379 Fatal Roof Fall Accidents (1966-1970) - O
PERCENT OF PRODUCTION AND ACCIDENTS
40%
30%
20%
10%
0-3'
3-4'
4-5'
5-6'
6-7'
7-8'
8-9'
9-11'
SEAM HEIGHT

EXHIBIT 9


SEAM HEIGHT DISTRIBUTION
OF 1) 1966 Production - X
AND 2) 41 Roof Fall Accidents in which victim was unnecessarily under unsupported roof (1966 Only) - O
PERCENT OF PRODUCTION AND ACCIDENTS
40%
30%
20%
10%
0-3'
3-4'
4-5'
5-6'
6-7'
7-8'
8-9'
9-11'
SEAM HEIGHT

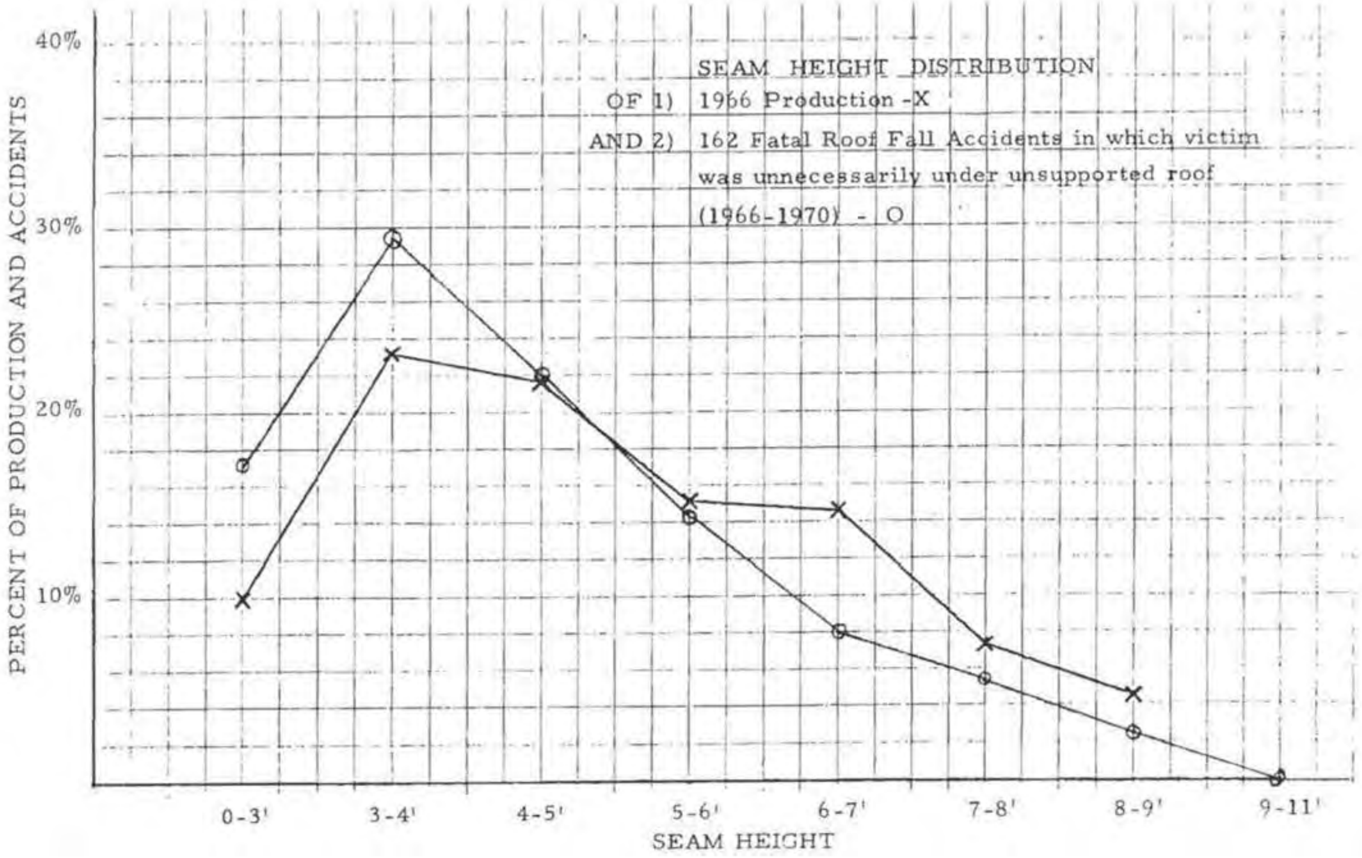
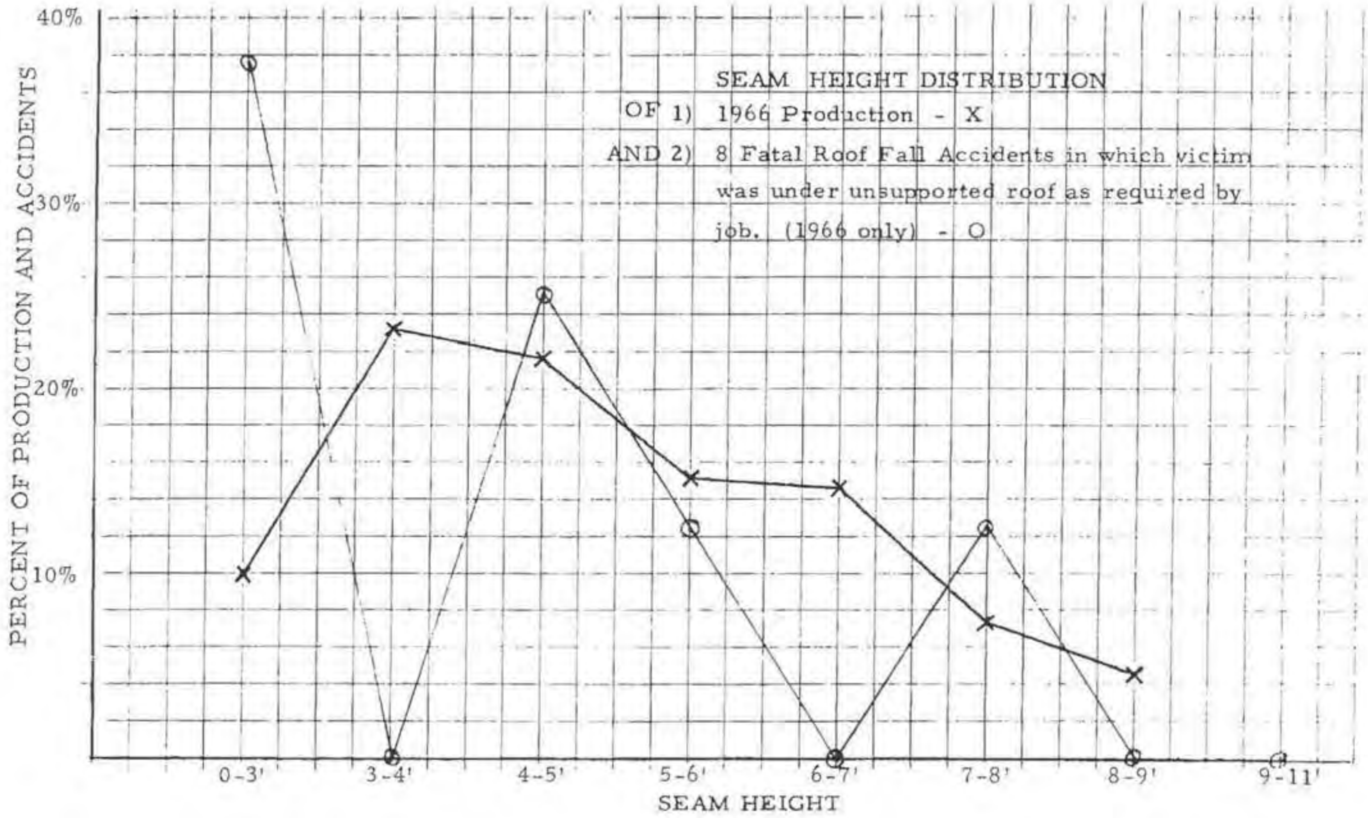

SEAM HEIGHT DISTRIBUTION
OF 1) 1966 Production -X
AND 2) 162 Fatal Roof Fall Accidents in which victim was unnecessarily under unsupported roof (1966-1970) - O
PERCENT OF PRODUCTION AND ACCIDENTS
40%
30%
20%
10%
0-3'
3-4'
4-5'
5-6'
6-7'
7-8'
8-9'
9-11'
SEAM HEIGHT

EXHIBIT 10


40%
30%
20%
10%
PERCENT OF PRODUCTION AND ACCIDENTS
SEAM HEIGHT DISTRIBUTION
OF 1) 1966 Production - X
AND 2) 8 Fatal Roof Fall Accidents in which victim was under unsupported roof as required by job. (1966 only) - O
0-3'
3-4'
4-5'
5-6'
6-7'
7-8'
8-9'
9-11'
SEAM HEIGHT

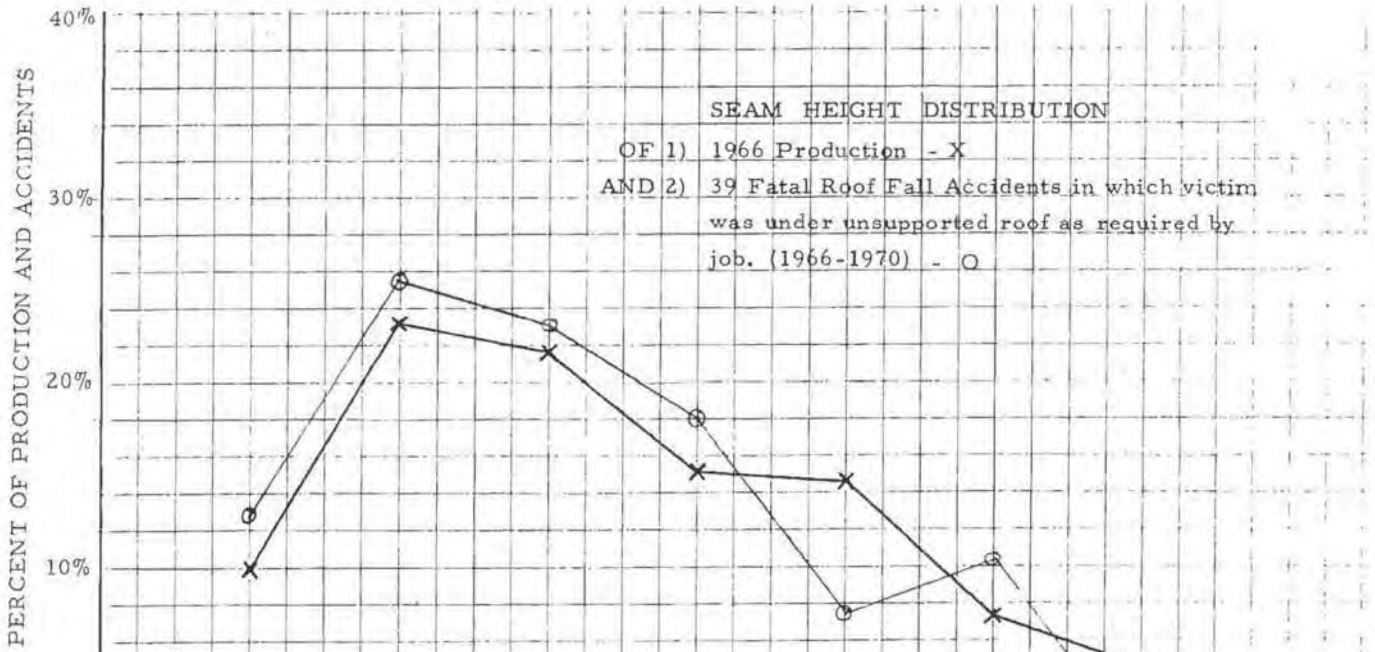
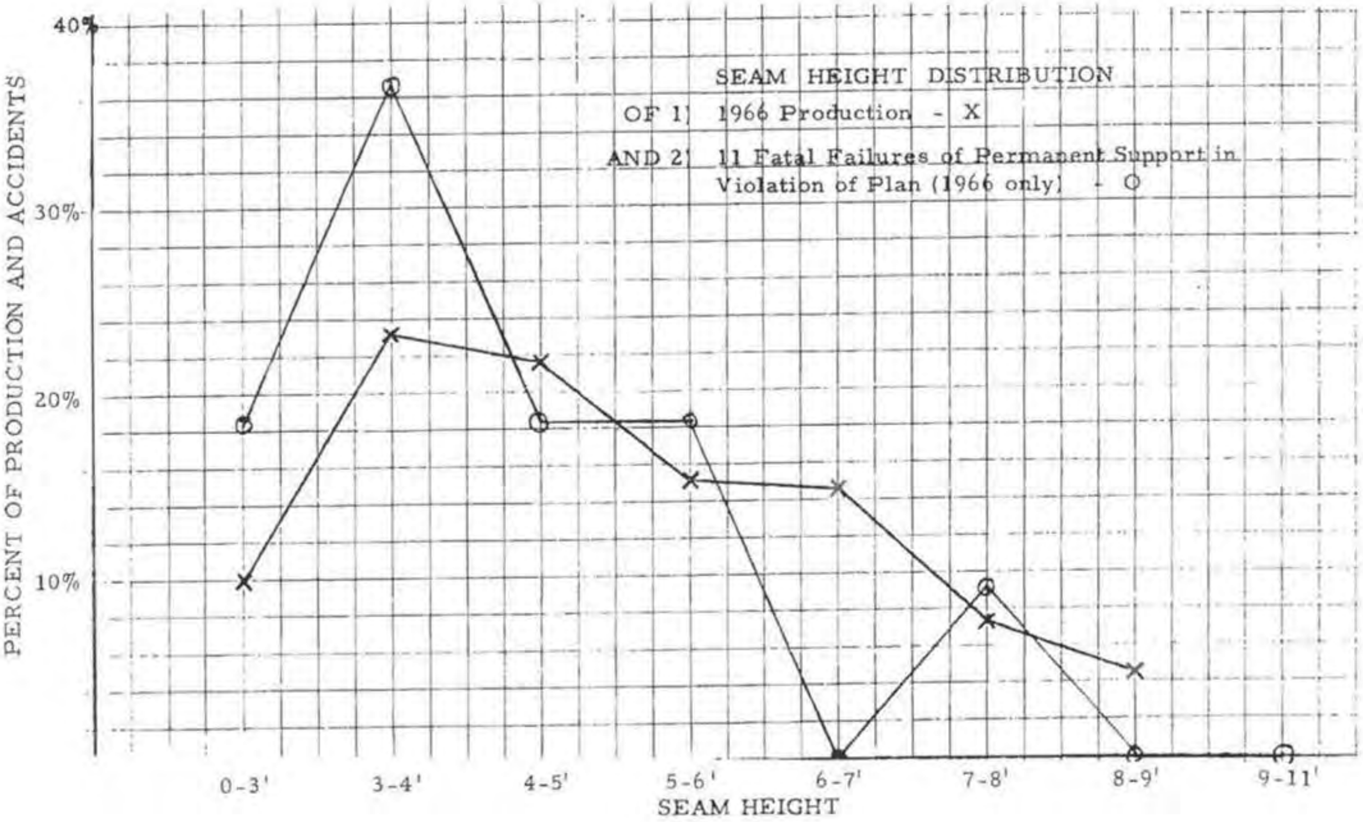

40%
30%
20%
10%
PERCENT OF PRODUCTION AND ACCIDENTS
SEAM HEIGHT DISTRIBUTION
OF 1) 1966 Production - X
AND 2) 39 Fatal Roof Fall Accidents in which victim was under unsupported roof as required by job. (1966-1970) - O
0-3'
3-4'
4-5'
5-6'
6-7'
7-8'
8-9'
9-11'
SEAM HEIGHT

EXHIBIT 11


SEAM HEIGHT DISTRIBUTION
OF 1) 1966 Production - X
AND 2) 11 Fatal Failures of Permanent Support in Violation of Plan (1966 only) - O
40%
30%
20%
10%
PERCENT OF PRODUCTION AND ACCIDENTS
0-3'
3-4'
4-5'
5-6'
6-7'
7-8'
8-9'
9-11'
SEAM HEIGHT

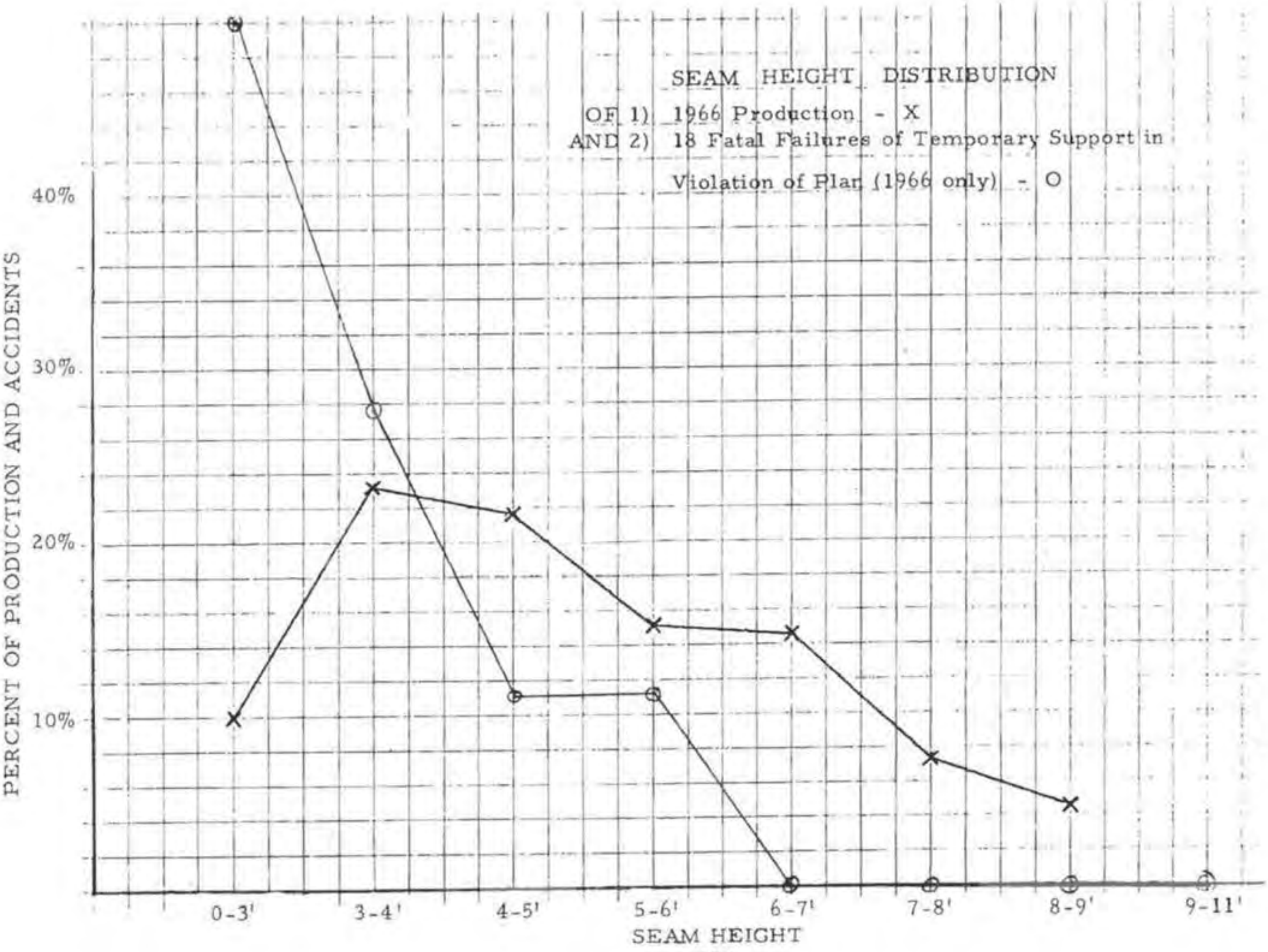
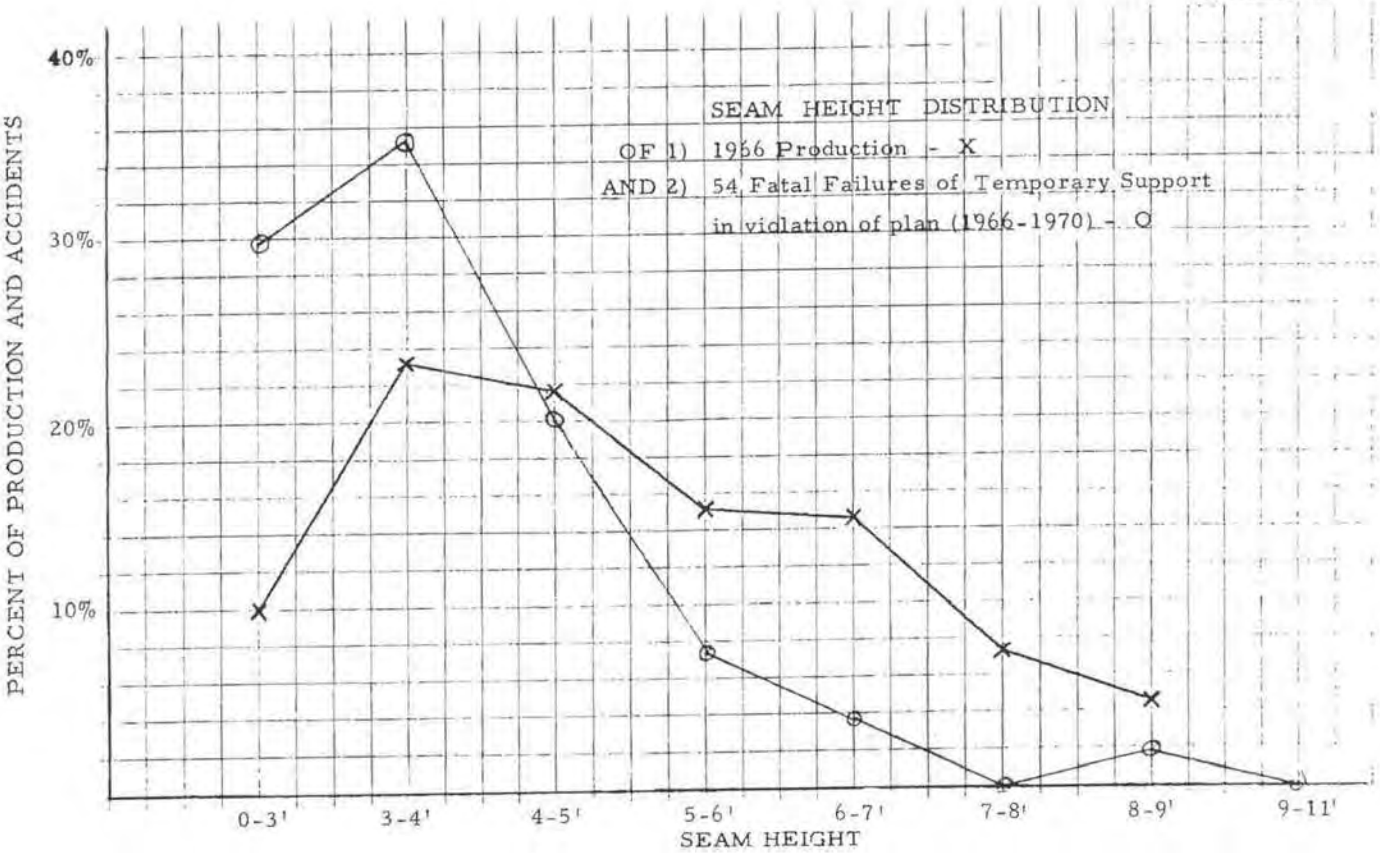
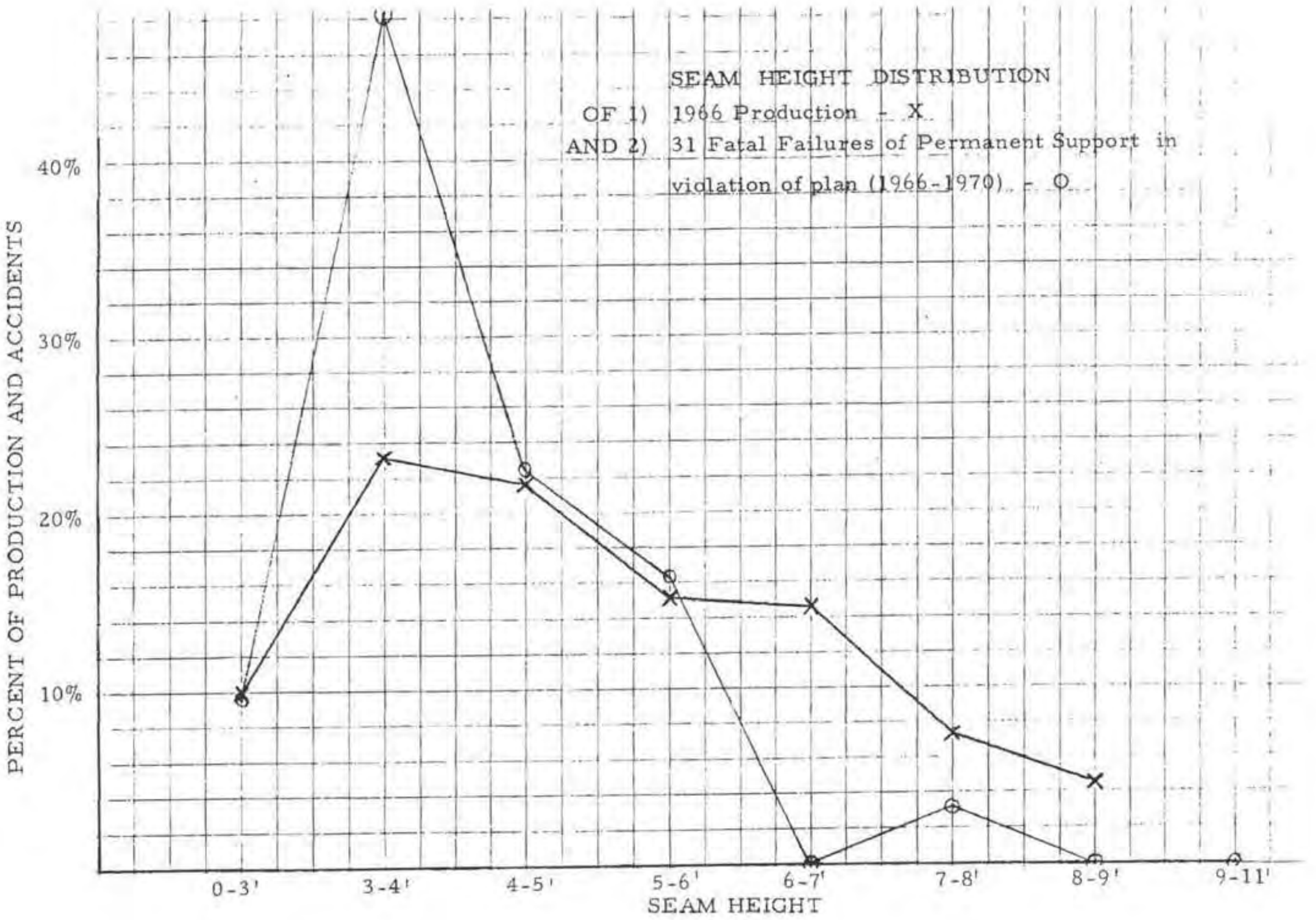

SEAM HEIGHT DISTRIBUTION
OF 1) 1966 Production - X
AND 2) 18 Fatal Failures of Temporary Support in Violation of Plan (1966 only) - O
40%
30%
20%
10%
PERCENT OF PRODUCTION AND ACCIDENTS
0-3'
3-4'
4-5'
5-6'
6-7'
7-8'
8-9'
9-11'
SEAM HEIGHT

EXHIBIT 12

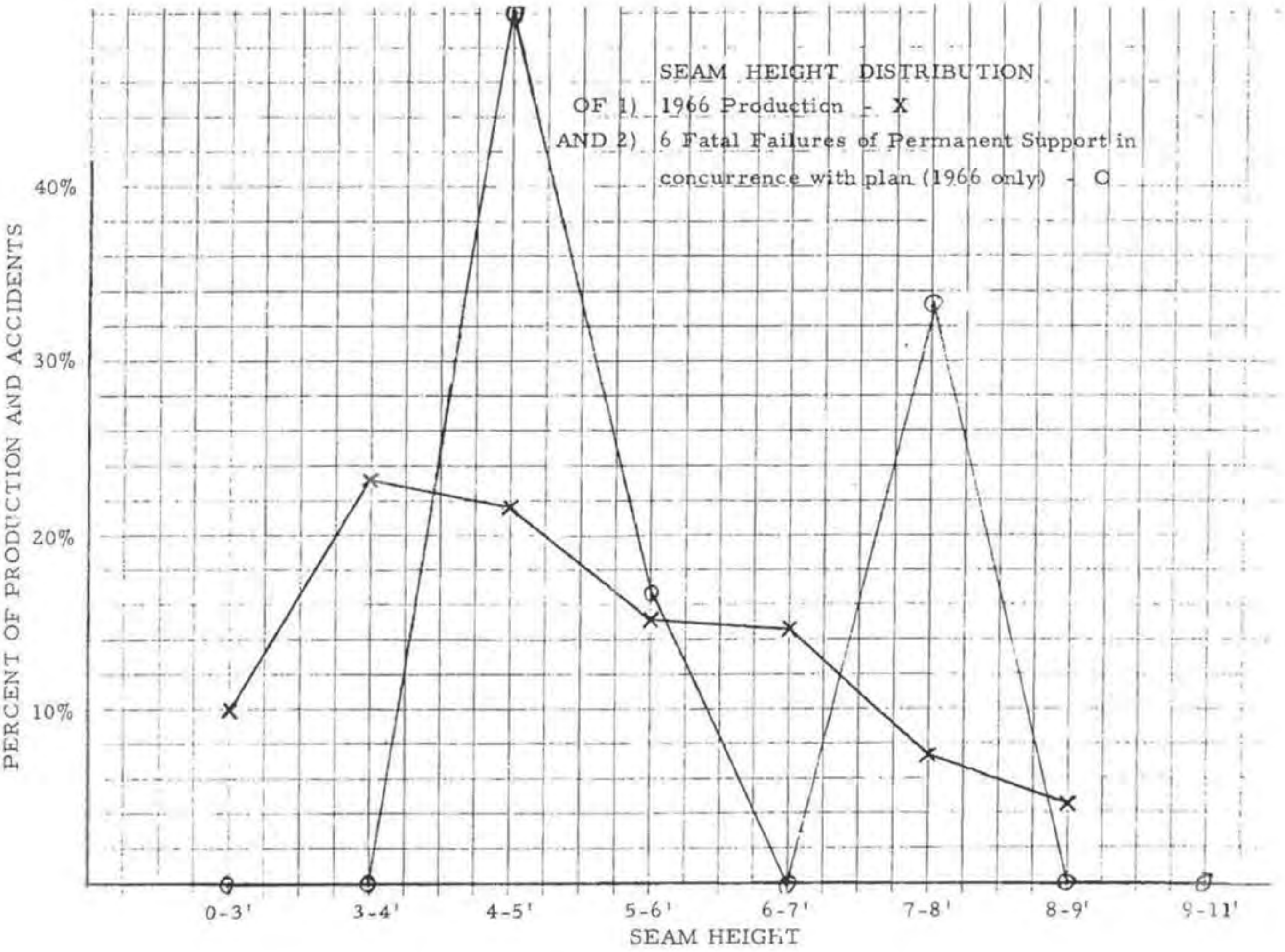


SEAM HEIGHT DISTRIBUTION
OF 1) 1966 Production - X
AND 2) 54 Fatal Failures of Temporary Support in violation of plan (1966-1970) - O
PERCENT OF PRODUCTION AND ACCIDENTS
40%
30%
20%
10%
0-3'
3-4'
4-5'
5-6'
6-7'
7-8'
8-9'
9-11'
SEAM HEIGHT



SEAM HEIGHT DISTRIBUTION
OF 1) 1966 Production - X
AND 2) 31 Fatal Failures of Permanent Support in violation of plan (1966-1970) - O
PERCENT OF PRODUCTION AND ACCIDENTS
40%
30%
20%
10%
0-3'
3-4'
4-5'
5-6'
6-7'
7-8'
8-9'
9-11'
SEAM HEIGHT

EXHIBIT 13


SEAM HEIGHT DISTRIBUTION
OF 1) 1966 Production - X
AND 2) 6 Fatal Failures of Permanent Support in concurrence with plan (1966 only) - O
PERCENT OF PRODUCTION AND ACCIDENTS
40%
30%
20%
10%
0-3'
3-4'
4-5'
5-6'
6-7'
7-8'
8-9'
9-11'
SEAM HEIGHT

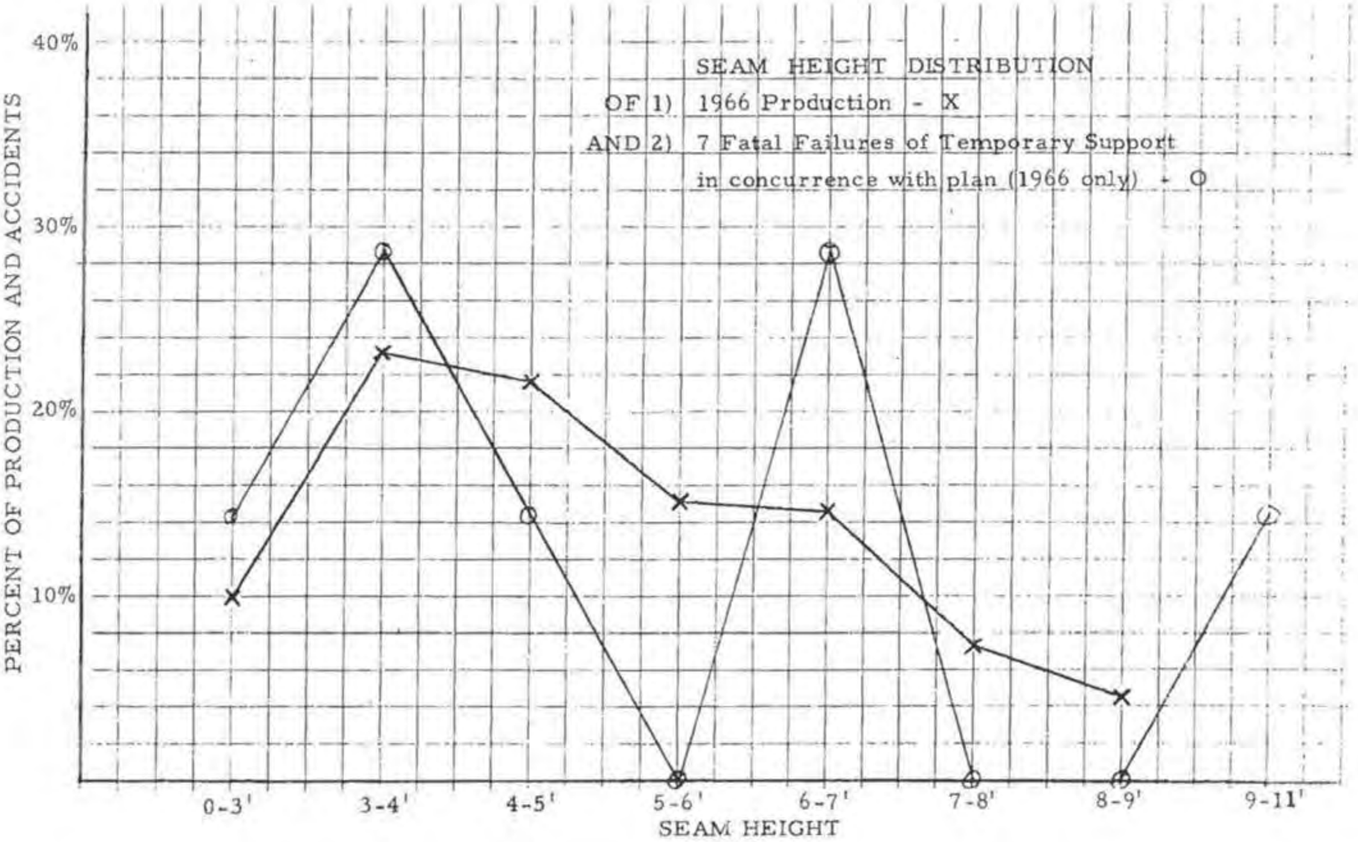
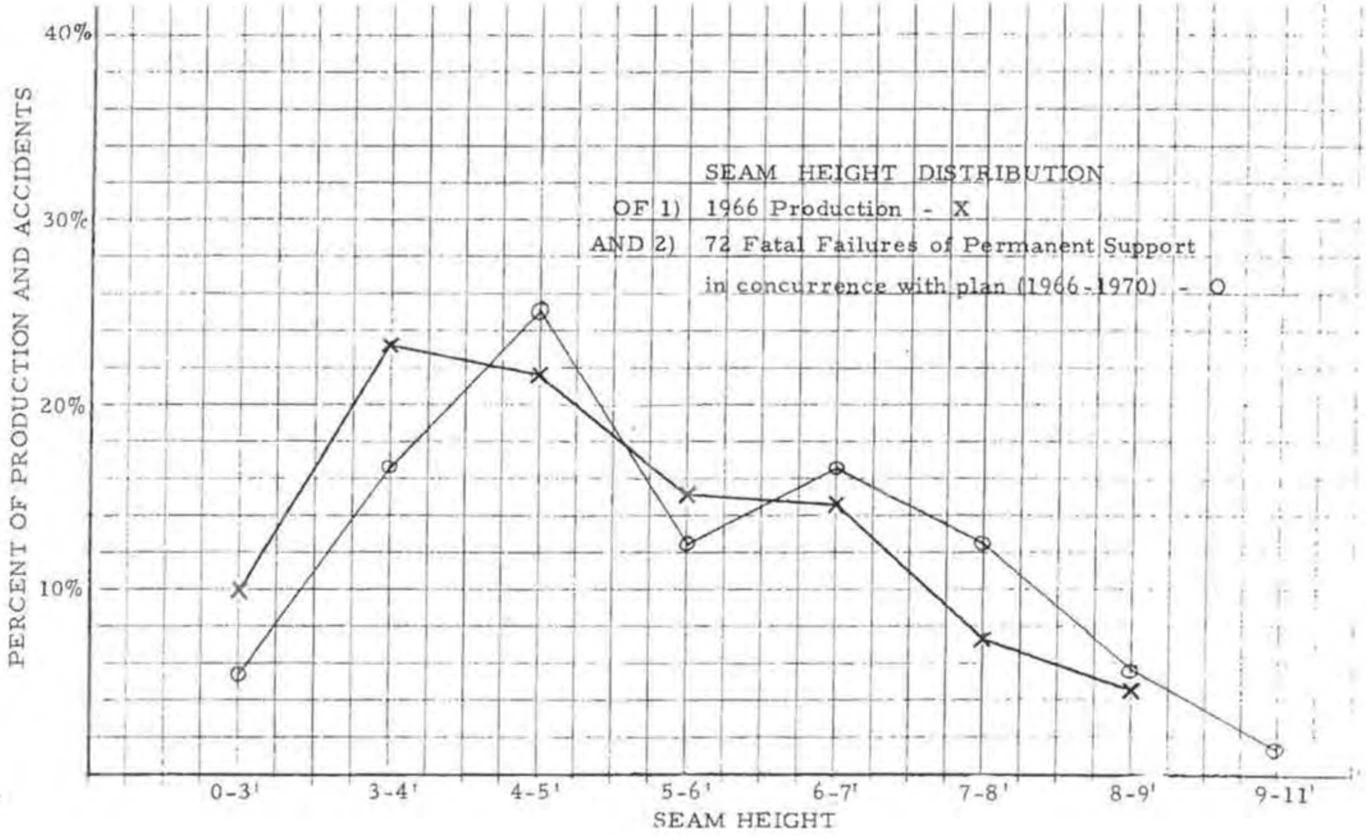
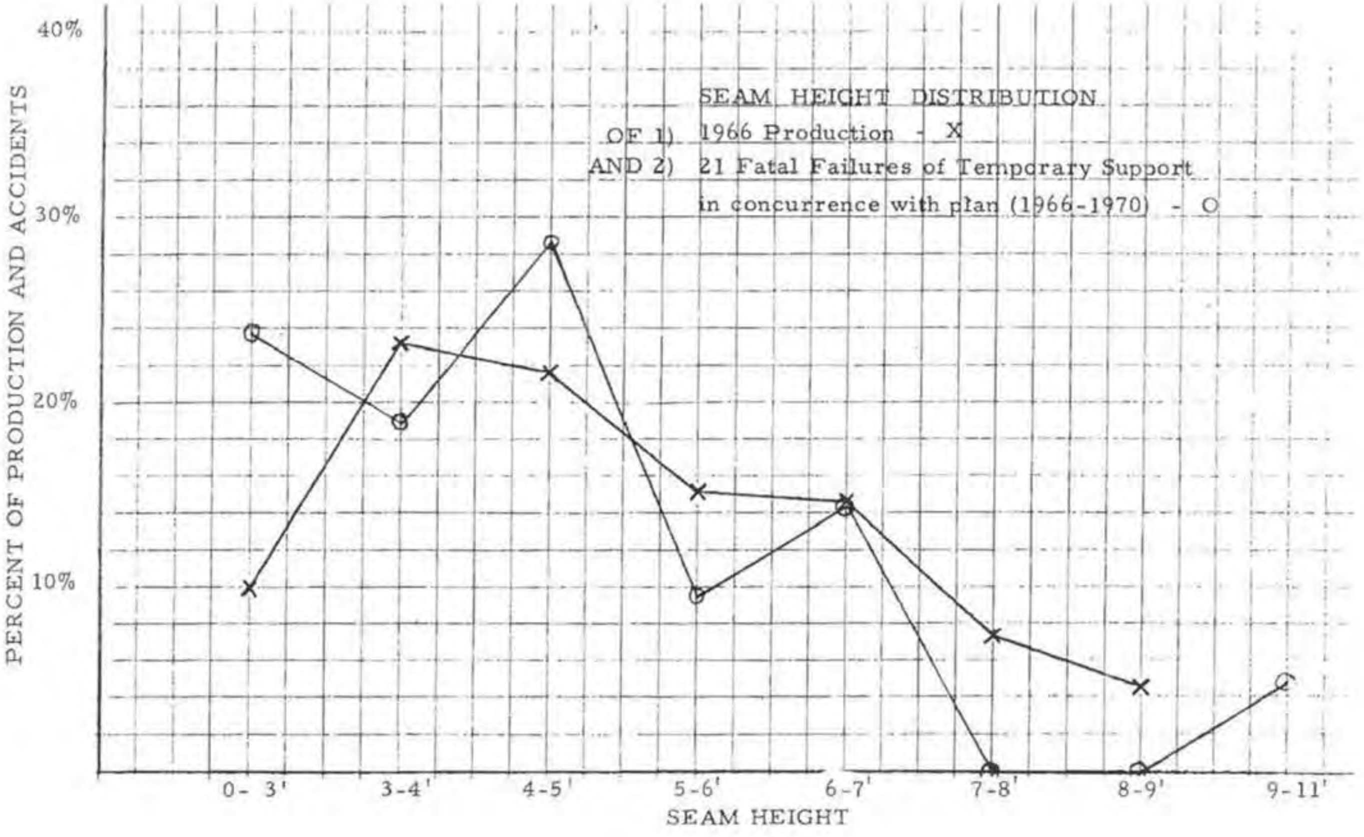

SEAM HEIGHT DISTRIBUTION
OF 1) 1966 Production - X
AND 2) 7 Fatal Failures of Temporary Support in concurrence with plan (1966 only) - O
PERCENT OF PRODUCTION AND ACCIDENTS
40%
30%
20%
10%
0-3'
3-4'
4-5'
5-6'
6-7'
7-8'
8-9'
9-11'
SEAM HEIGHT

EXHIBIT 14


SEAM HEIGHT DISTRIBUTION
OF 1) 1966 Production - X
AND 2) 72 Fatal Failures of Permanent Support
in concurrence with plan (1966-1970) - O
40%
30%
20%
10%
PERCENT OF PRODUCTION AND ACCIDENTS
0-3'
3-4'
4-5'
5-6'
6-7'
7-8'
8-9'
9-11'
SEAM HEIGHT


SEAM HEIGHT DISTRIBUTION
OF 1) 1966 Production - X
AND 2) 21 Fatal Failures of Temporary Support
in concurrence with plan (1966-1970) - O
40%
30%
20%
10%
PERCENT OF PRODUCTION AND ACCIDENTS
0- 3'
3-4'
4-5'
5-6'
6-7'
7-8'
8-9'
9-11'
SEAM HEIGHT

SECTION III

FATALITY REDUCTION PROJECTS

CHAPTER 6

INTRODUCTION TO FATALITY REDUCTION PROJECTS

This section presents the analysis and underlying rationale for the major recommendations of the Industrial Engineering Study. Twelve Fatality Reduction Projects are presented in Chapters 7 through 18. Each of these projects focuses upon equipment, procedures, or situations which commonly cause accidents and which, if improved, offer potentially high "payoffs" in terms of lives saved per dollar expended.

Each project is organized according to the following outline:

I. STATEMENT OF THE PROBLEM

II. ANALYSIS OF THE PROBLEM

III. SUMMARY OF RECOMMENDATIONS

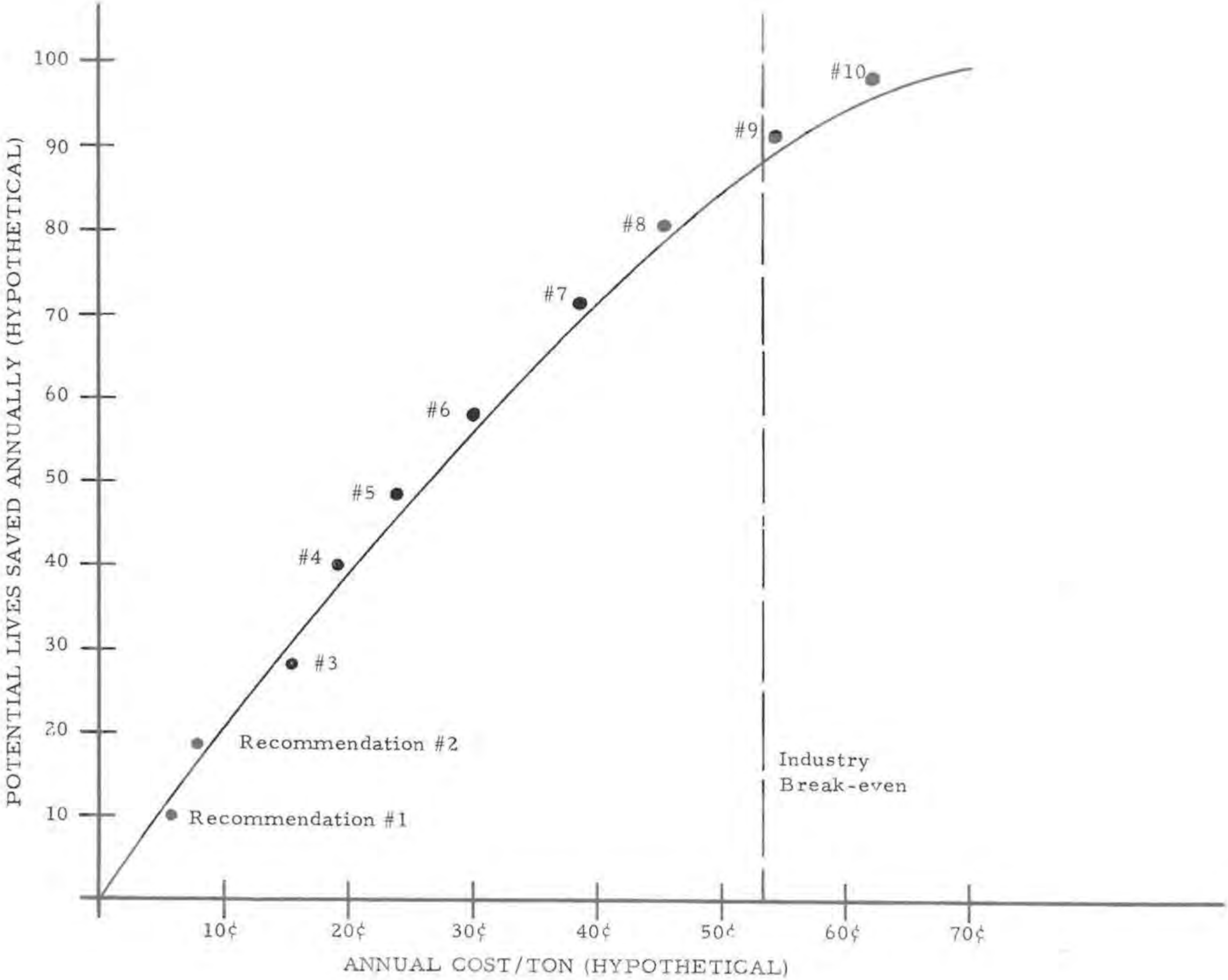
IV. POTENTIAL LIVES SAVED ANNUALLY

V. COST TO IMPLEMENT RECOMMENDATIONS

A Cost-Benefit Approach

Our approach to the problem of reducing underground fatalities has been to evaluate potential solutions from a "real-world" perspective. The bituminous coal industry in the United States is a private, self-supporting, profit-making industry, and we believe that recommendations for improving safety must be made within that context. More specifically, we believe that every recommendation for improved safety must be carefully weighed in terms of both reduced fatalities and cost to the industry as a whole. In our analysis, we have attempted to deal with the relationship between reduced fatalities and increased costs by using classic evaluation tools. Our approach is outlined in the following paragraphs.

Conceptually, if precise "payoffs" in terms of lives saved could be attached to specific safety recommendations, and if precise estimates could be made of the industry-wide cost of implementing these same recommendations, a classic cost-benefit curve could be constructed as follows:


POTENTIAL LIVES SAVED ANNUALLY (HYPOTHETICAL)
100
90
80
70
60
50
40
30
20
10
#10
#9
#8
#7
#6
#5
#4
#3
Recommendation #2
Recommendation #1
Industry
Break-even
10¢
20¢
30¢
40¢
50¢
60¢
70¢
ANNUAL COST/TON (HYPOTHETICAL)

What the curve suggests is that some potential safety improvements are more efficient than others. Recommendation #1, for example, has a greater potential impact upon fatality reduction per dollar invested than Recommendation #10. The dashed line indicates that only limited resources exist with which to deal with the safety problem and that recommendations which push the cost of safety beyond a certain level of total capital investment (shown on the chart as a hypothetical break-even point) are infeasible.

A cost-benefit curve such as the one described above would be a useful tool for evaluating safety recommendations. In our case, lives saved (potential benefits) would be measured in terms of dollars invested (potential costs). In reality, however, such a curve is difficult, if not impossible, to construct since it assumes perfect knowledge of future events -- "How many lives will it save?", and "How much will it cost?" The cost-benefit curve also assumes an ability to measure costs and benefits precisely.

Because future events are uncertain and because our estimates of costs and benefits cannot be measured exactly, we shall perform only a crude cost-benefit analysis in this report as a means to provide a sensible way of evaluating the practicality of our recommendations. In each Fatality Reduction Project, an estimate is made of the number of potential lives to be saved annually as a result of implementing a particular recommendation. An estimate of the industry-wide cost is also presented. Some recommendations require investment in new or re-designed equipment; other recommendations involve only procedural changes in work cycle design and therefore are "free" in the sense that lives can be saved for no additional investment by the industry; still other recommendations, we believe, not only will save lives but will actually reduce costs or improve productivity.

Overall Payoff

We estimate that the annual, industry-wide gross cost of the recommendations outlined in Chapters 7 through 18 lies in the $50 - 100 million range, depending upon the system of implementation. This amounts to approximately 14 - 28¢ per ton of coal, assuming annual industry production of 360 million tons. This expenditure will result in 60 to 100 lives saved annually. The recommendations are not mutually exclusive; the results are therefore not additive. For example, some lives can be saved either by a mobile skid-truss (Chapter 7) or by better operator protection on the continuous miner (Chapter 10). The collective overlap makes the total number of lives saved difficult to estimate.

We would like to emphasize that throughout this report we have employed conservative estimates. It is quite probable that productivity increases associated with various recommendations could substantially reduce the industry costs presented here. We think it also important to point out that the increased industry costs resulting from implementation of the 1969 Health and Safety Act may well have exceeded the cost estimates presented here. Consequently, many of our recommendations, if combined with selective revisions of those portions of the law which are not now cost effective, might be implemented at a net savings, or at least at no additional cost to the industry.

One further point must be made regarding the cost analysis conducted throughout this study. Because the approach taken in this study is a broad, industry-wide evaluation of underground safety, costs are evaluated on an industry-wide basis as well. Even though broad, macro-analysis is the tool utilized in this report, we would caution the reader to remember that the cost impact of various recommendations will vary with productivity from mine to mine throughout the country. It is quite likely, for instance, that the economic impact of any recommendation in this report would be greater in a small, low production mine than in a large, captive mine. This variation in the ability of individual mines to absorb the increased cost of safety has already proven to be a reality in the implementation of the 1969 Health and Safety Act.

CHAPTER 7

TEMPORARY SUPPORT

I. STATEMENT OF THE PROBLEM

This fatality reduction project should be considered in conjunction with the project concerning "Permanent Support" discussed in the following chapter. They are both part of the total support problem and overlap in many areas

The single most dangerous underground activity for the period 1966-1970 is the group of tasks performed under temporary or no support. Approximately 73% of the roof fall fatalities for this period fall in this category (277 fatal accidents) and most frequently involve the following job duties:

A. Set Temporary Support

B. Remove Temporary Support

C. Test Roof

D. Scale Roof

E. Bolt Roof

Almost all other face activities involve some direct or indirect dependency upon temporary support also.

The greatest single problem with temporary support is the use of improper and unsafe methods of installing these supports. Only 6% (21) of the fatal roof fall accidents during the 1966-1970 period occurred under properly installed temporary support; 10% (39) of the fatal accidents occurred while the victim was under unsupported roof necessarily. In contrast, 43% (163) of fatal roof fall accidents occurred while the victim was under unsupported roof unnecessarily; and 14% (54) occurred with improperly installed temporary supports.

While permanent support and other physical conditions can be observed by an inspector during regular visits, temporary support is essentially a procedural activity which cannot be adequately evaluated on a "spot-check" basis. It may require an impractical number of inspectors to guarantee adherence to safe unsupported and temporarily supported roof procedures in underground bituminous mines. In other words, if safe procedures could be installed, monitored, and enforced with any constancy, then temporary support fatalities could be significantly reduced. However, since constant enforcement appears impractical, the most effective approach seems to be to design a temporary support system which eliminates or reduces the opportunity for procedural violations.

II. ANALYSIS OF THE PROBLEM

Industrial Engineering provides an insight into the reasons for violation of safe operating procedures and outlines some of the physical/economic constraints that affect safety decisions. Roof fall and other fatalities have been found to occur most frequently under unsupported roofs in small mines, low seams, less productive operations, less affluent states which are farther from markets. These factors add up to a description of marginal operations whose economic opportunities are significantly less than the industry average. These mines commonly operate with high labor turnover, minimal management expertise, low capital and tight profit margins. There are outstanding exceptions to this generalization, but even the exceptions operate with one or more of these handicaps.

In spite of the relative problems of these small mines, it is important to keep in mind the high productivity of these handicapped operators when compared to non-U.S. coal production. Capital intensive mines in Europe would break records if they could achieve even half the productivity per man of some of our smaller mines. These small operators are a national asset but need help in the form of safety devices that do not decrease productivity.

The small mines suffer over four times as many fatalities per million man-hours and over six times the number of fatalities per million tons as mines employing over 250 workers. In our 1966-1970 roof fall fatality analysis, small mines accounted for over 32% of the total fatalities while contributing only 12% of the total production. Much of this difference is due to physical and other conditions not related to the size of the mine. For example, their equipment may be hand-me-downs from larger mines investing in new and more efficient machines.

The number of roof fall fatalities is particularly high in seam heights under five feet. These seams yield about half of the bituminous coal produced underground but account for over 70% of the fatal roof fall accidents under unsupported or temporarily supported roofs. Since approximately 59% of these unsupported fatal accidents were coded as under unsupported roof unnecessarily, the largest single problem appears to be keeping workers under support when it is not necessary to be under unsupported roof. This category includes a variety of workers and exposures. A frequent observation during the Industrial Engineering study was the worker who chatted with a machine operator or perhaps held a roof bolt or other needed object while under unsupported roof. In one instance the roof bolter helper stood outside the temporary supports during the entire roof bolt cycle in order to hand the operator the roof bolt at the end of the drilling subcycle. The roof bolter operator was protected, but the helper was not. A great deal of casual "visiting" also takes place under these circumstances and solutions must consider this senseless pastime.

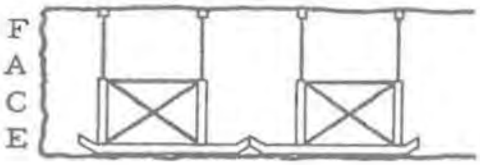
The danger is not restricted to any one mining style or situation. In a typical mine, the area of unsupported or temporarily supported roof might average only one to two percent of the total underground workings, but the occupancy rate is substantially higher. A method of providing temporary support that is equivalent to or better than permanent support must be developed. In addition, ease of use, cost, and the ability to remotely install temporary support should also be considered.

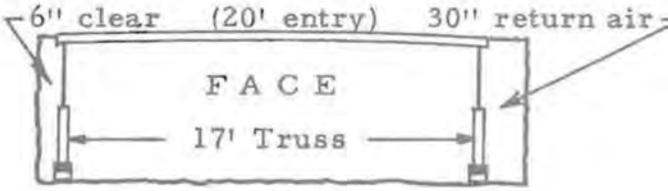
Any temporary support system must: 1) protect workers who inspect or test roof in newly cut areas, 2) protect the roof bolter while he installs permanent support, 3) prevent roof flexing and sagging, 4) serve as a warning device for roof movements, and 5) provide support from which the brattice curtains can be hung (optional). In addition, the practicality of an improved system rests on three factors: cost, productivity, and improved safety. These criteria all suggest a lightweight, low cost, manageable piece of equipment such as the portable hydraulic skid truss described below.

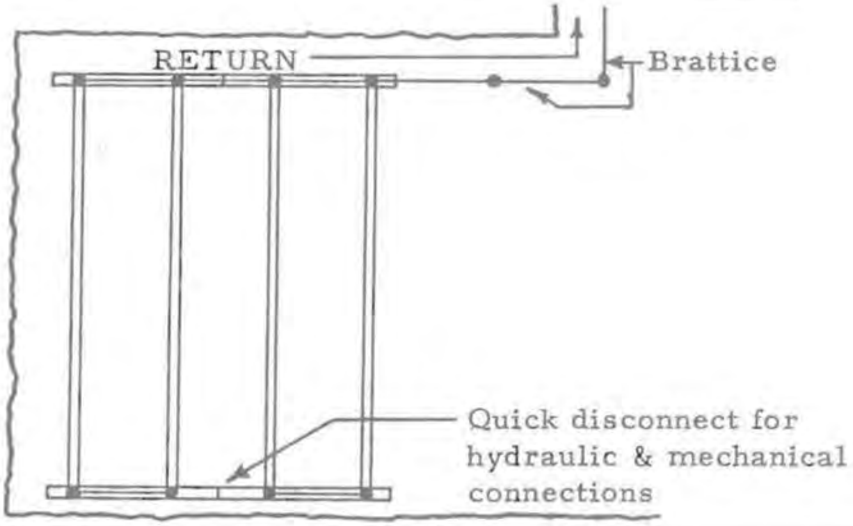
The following illustrations outline a possible configuration and mining procedure for using a skid truss with a continuous miner. A loader would handle the truss in a similar manner but might have to pull the truss back a few feet to load coal shot from the face.

CONTINUOUS MINING EXAMPLE

Place bolted and ready for advance of 18 to 20 feet

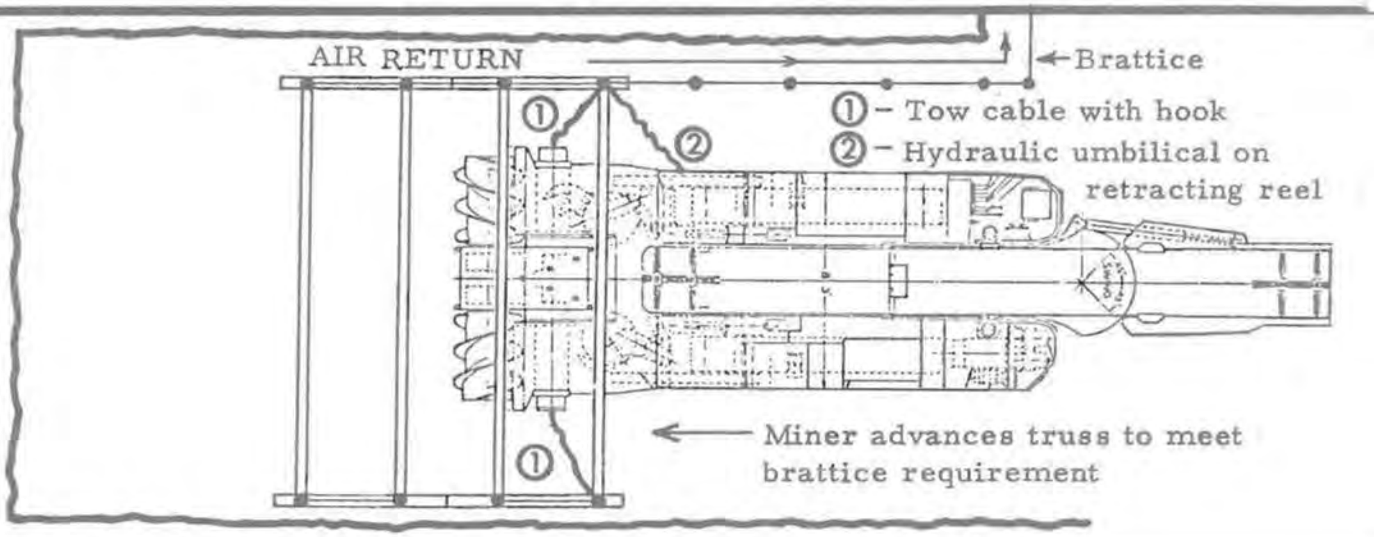




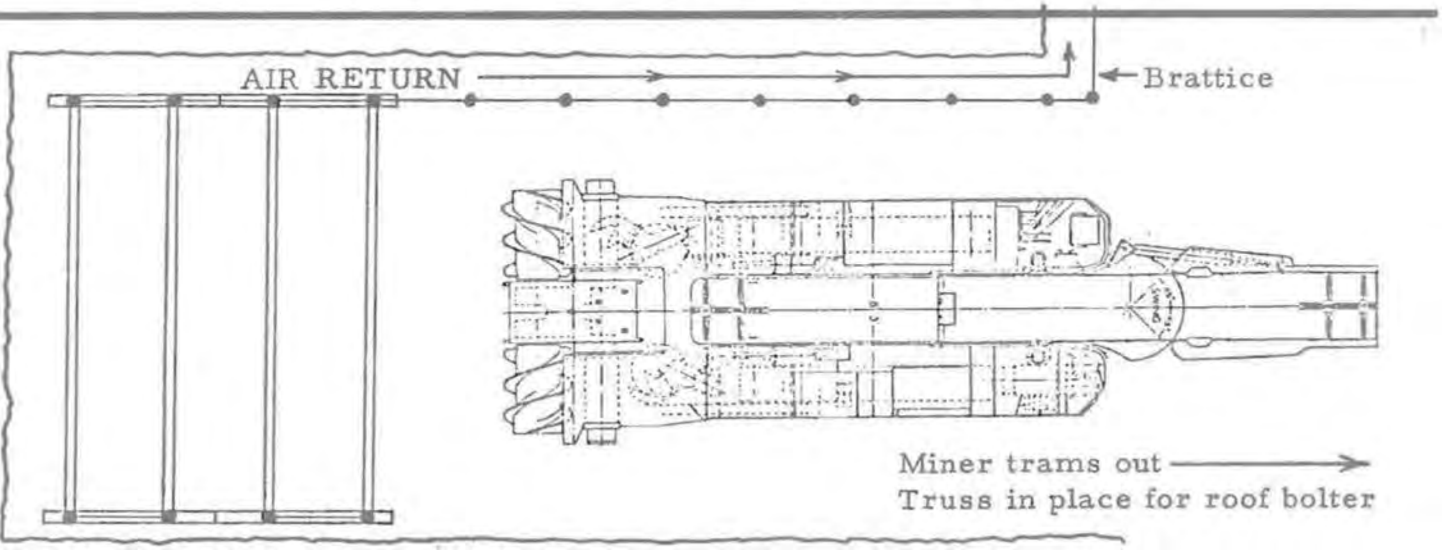


Jacks fully erect awaiting miner. Right panel of support is "CLOSED" and serving as brattice. Connect to regular brattice by 20' of loose material on "CURTAIN" cable.

FIRST CUT



Miner advances truss to meet brattice requirement



Miner trams out →
Truss in place for roof bolter

SECOND CUT – 18' to 20' Total

Although the truss module would be light enough to be pushed by two men, it should be maneuvered by machine without the presence of helpers to minimize the potential for injury. The double module would have a quick disconnect so that intersections could be negotiated one unit at a time or with only one side attached. This would minimize the problem of moving a bulky piece of equipment (17' x 12') through intersections and eliminate rounding of corners, thereby increasing the span.

The truss width is subject to analysis but probably could not be wider than the room width minus 3'. This clearance is needed for maneuvering the module and allowing an adequate cross-section for return air in most mines. The brattice curtains would be permanently mounted on the return side of the module and connected to more permanent ventilation control with a spring tension material looper. This feature would enable the machine operators to advance the system without delays for ventilation control.

Attachment to the continuous miner/loader could be as simple as two lengths of light cable with appropriate hooks and eyelets, or as complex as remote control cable reels actuated by the operator. The hydraulic umbilical could also be rather simple with a weighted pulley looper or tensioned reel, both of which would keep the slack out of the hookup. The machine hydraulic reservoir and pressure system would be modified to provide jack control from the operator's seat. Bracing for the jacks and truss would be minimal since lateral forces would not be significant.

It is likely that a skid arrangement might require some mechanical leverage for manual movement so a simple lever arrangement on each skid should be considered. The lever could be a reversible foot that would be operated by the weight of a man, lifting and advancing the skid in small increments. Another possibility would be caster-mounted lightweight but large diameter tires which would be very lightly sprung to lift the weight of the module with jacks retracted. The remaining alternatives become heavier, more expensive and less flexible as self-advancing designs are considered (piston or crawler types); however, they may also be much more appropriate in actual use. Particularly interesting because of cost and weight advantages is the piston concept. The cost estimates do not differ greatly from the "skid" estimates outlines in the next section.

This proposed truss system is not particularly innovative in character. A western mine is currently using lightweight trusses supported by hydraulic jacks to advance the full length of an entry. Alloy trusses for this purpose are now manufactured in a configuration that is strong, lightweight and inexpensive. The safety and productivity benefits of such a system are unquestionable, but is it a workable alternative?

Information previously available suggests that roof falls average about one foot in thickness. While not complete, TB & A roof fall analysis indicates significant differences in fall size by location in the mining system. Almost 60% of the falls occurring during the development phase of continuous mining operations within 25' of the face are less than 11" thick. In conventional development in seam heights of 4' - 8', 68% of the roof falls near the face fall into this category.

1966-1970 roof fall percentages in array:

	All Roof Falls (% under 11" thick) (≤ 25' to Face)	4-8' Seams (% under 11" thick) (≤ 25' to Face)
Continuous Development	61.5 %	59.4 %
Continuous Pillaring	15.1 %	12.0 %
Conventional Development	63.8 %	68.0 %
Conventional Pillaring	50.0 %	50.0 %

Static loadings can now be calculated by type of mining, seam height, location and other variables that have not yet been fully analyzed. USBM roof control scientists may be able to provide predictive modifiers for static loading that would consider the natural support characteristics of various roofs. If dynamic loading considerations are eliminated, a given strength will support much more than the static weight. Numerous roof falls have occurred as a result of removal of one or two posts that in themselves were capable of supporting only a tiny fraction of the total weight that fell.

Calculations that use static weights to stress supports will drastically understate the percentage of falls that would have been avoided if a given support system were present. An 80% static support level could conceivably be a 99% effective support level under certain conditions. For example, a lightweight support system that is capable of supporting approximately 40 static tons would have supported 83% of the conventional development falls. If we assume that all falls under 24" in thickness would shear at the support and not subject the support to the weight of the entire mass, over 93% of the falls were supportable. However, the same support system in continuous pillaring would have supported only 36.5% and 42-44% of falls in these two categories. Obviously, there are differences in stress; a lightweight system may not have the support capacity required for pillaring in continuous systems.

III. SUMMARY OF RECOMMENDATIONS

A. We propose the development of a portable hydraulic skid truss to be used in conjunction with the continuous miner and mechanical loader. The device would be a simple lightweight support module incorporating four conventional jacks and two lightweight trusses. For continuous development two of these modules would be needed, while for conventional development one would be sufficient. One or more modules could be used for retreat mining.

Each module would be equipped with a quick disconnect for hydraulic and mechanical connection to other units and equipment. An umbilical cord would allow remote operation by the loader/miner operator. Lightweight cable attachments could be attached to other equipment for convenient movement on the skids. The target weight of each module would be under 500 pounds so that the unit could be manually moved by two men. Eight single (conventional mining) or double (continuous mining) modules would be appropriate for the development of 5 entries with regular crosscuts.

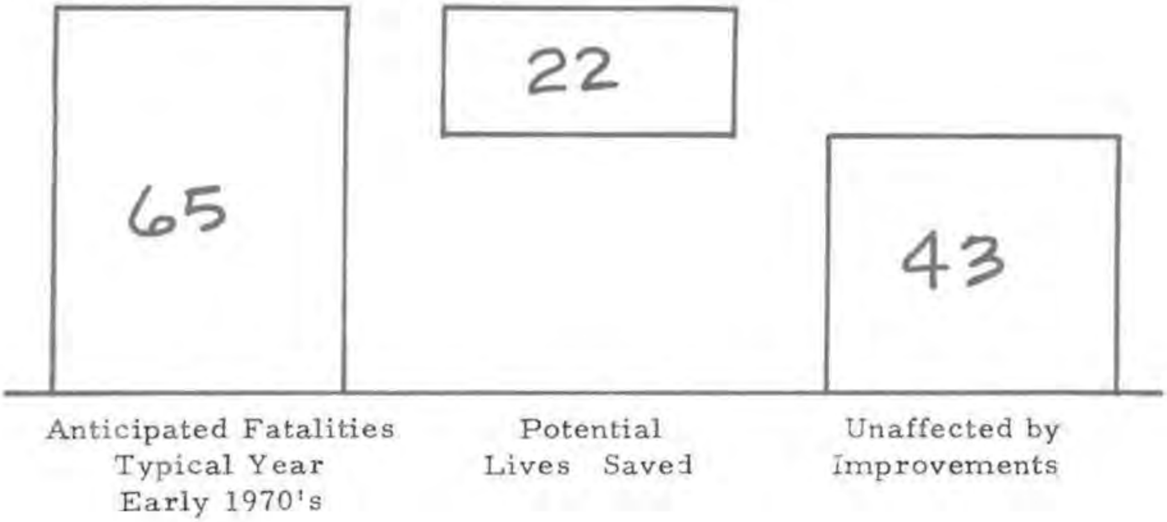
The brattice could be attached on one side of the modules to eliminate the need for the manual performance of this duty during the mining/loading cycle. Extra brattice material, hung on a spring-loaded storage looper or curtain cable by the roof bolter or other worker under the safety of supported roof, would be advanced automatically to the back of the skid truss unit.

B. Many other partial solutions are possible with more widespread communication of safe and effective work cycle procedures throughout the industry. For example, due to the frequency of falls near a rib or face, the timberman is probably better off placing the first temporary support post near a rib. At present, the location of the first prop is often in the center of the working place. Both management and unions should be responsible for insuring the adoption of safe work procedures involved in the hazardous tasks associated with temporary support.

C. Improvements in hydraulic props which provide an indication of pressure leakdown and roof-floor convergence would lead to more widespread use of hydraulic jacks. Since these provide an inherently safer temporary support system than timbers, many roof fall fatalities could be avoided by their use. (See Section IV, Chapter 20, Areas of New Research, for a discussion of hydraulic jack improvements.)

IV. POTENTIAL LIVES SAVED ANNUALLY

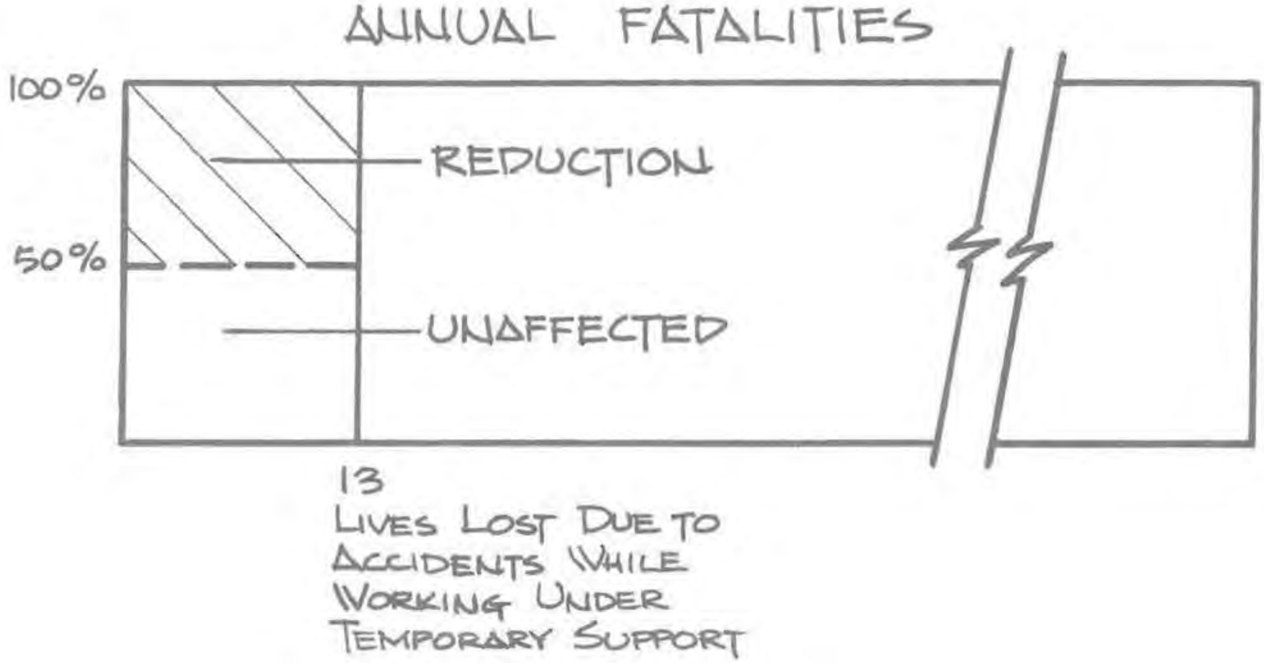
Potential Lives Saved: 22

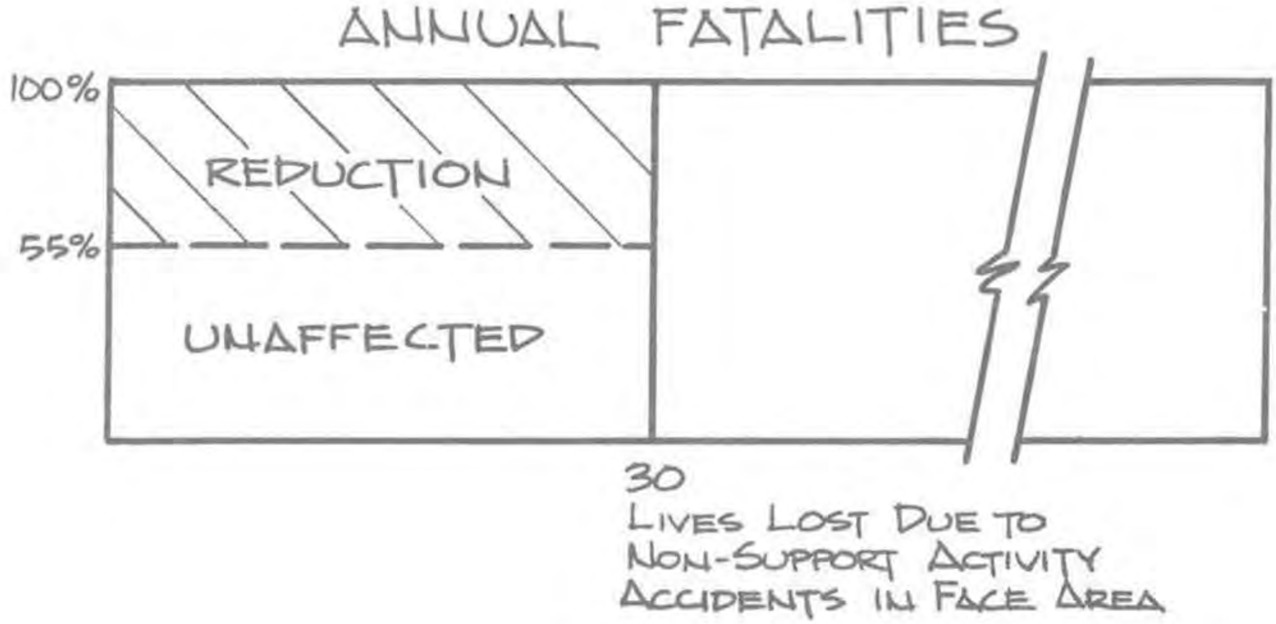


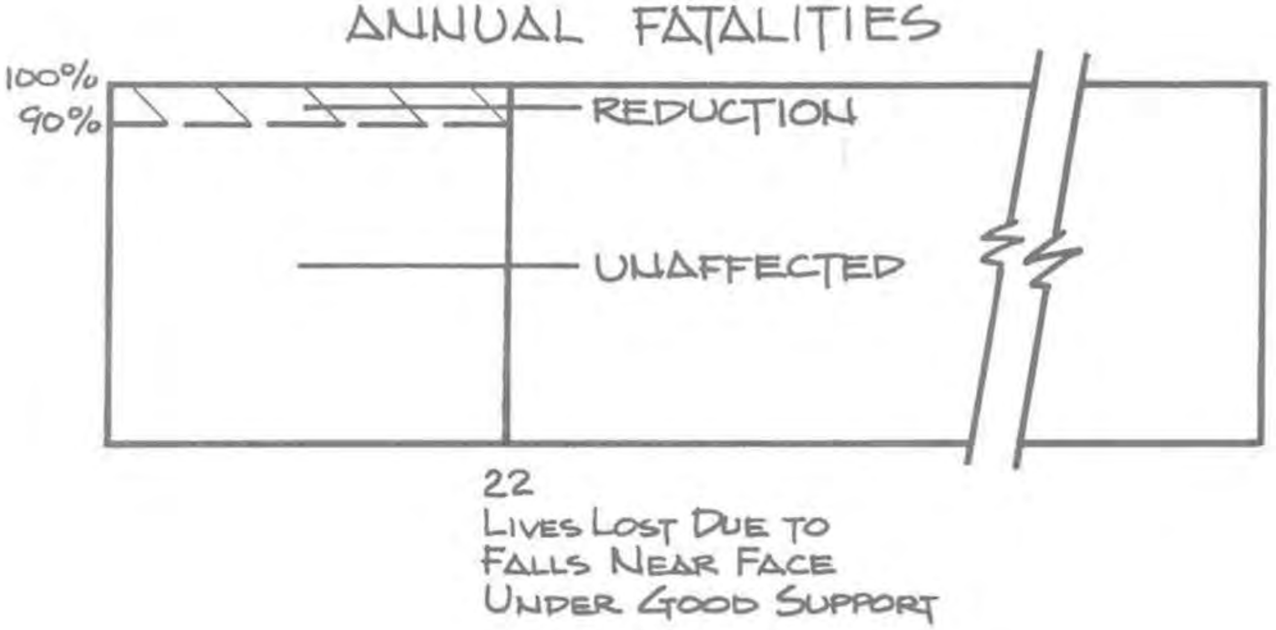
The potential payoff of an improved temporary support system is the highest of all functional areas surveyed, since fatalities under temporary or unsupported roof represent one third of the total fatalities for the period 1966-1970. The aggregate figures above are broken down in the illustrations which follow.

POTENTIAL LIVES SAVED ANNUALLY

(ROOF FALLS EARLY 1970's)




ANNUAL FATALITIES
100%
REDUCTION
55%
UNAFFECTED
30
LIVES LOST DUE TO
NON-SUPPORT ACTIVITY
ACCIDENTS IN FACE AREA


ANNUAL FATALITIES
100%
90%
REDUCTION
UNAFFECTED
22
LIVES LOST DUE TO
FALLS NEAR FACE
UNDER GOOD SUPPORT

Calculations for Estimate for Fatal Roof Fall Accident in Early 1970's

	PERMANENT AND TEMPORARY OK	UNSUPPORTED AND TEMPORARY WITH VIOLATION	TOTAL
1966	24	67	91
1967	27	50	77
1968	24	56	80
1969	24	41	65
1970	25	42	67
Total 1966-1970	124	256	380
Average	24.8	51.2	76
Estimate for Early 1970's	24	41	65 Fatal Accidents
Reduction Factor for Hopeful Trend	$\frac{24}{24.8} = 96.8\%$	$\frac{41}{51.2} = 80\%$	$\frac{65}{76} = 85\%$

Adjustment Factor = 1.085 Fatalities Per Accident 1966-1970

Direct Dependencies
$\frac{38 \text{ Fatal Accident}}{5 \text{ years}}$ x .80 trend x 1.085 (Fat./Accid.) = 6.6 Lives

Indirect Dependencies
$\frac{77 \text{ Fatal Accidents}}{5 \text{ years}}$ x .80 trend x 1.085 (Fat./Accid.) = 13.4 Lives

Permanent Support and Adequate Temporary Support
$\frac{10 \text{ Fatal Accidents}}{5 \text{ years}}$ x .968 trend x 1.085 (Fat./Accid.) = 2.0 Lives

Net Potential Lives Saved Annually = 22.0

V. COST TO IMPLEMENT RECOMMENDATIONS

Assuming no increase in worker productivity, it is estimated that the annual, industry-wide cost of the mobile truss system would be about \$1.5 million. This figure is derived from the following calculations:

- (1800 continuous sections nationwide) x (2 modules per section) x (\$1500 per module) = \$5.4 million
- (1800 conventional sections nationwide) x (1 module per section) x (\$1500 per module) = \$2.7 million
- \$8.1 million total cost ÷ 5-year amortization = \$1.62 million annual industry cost

Further calculations result in an estimate of the increased cost per ton of coal produced per estimated life saved

- Estimated annual cost per life saved -
  \$1.62 million÷360 million tons÷22 lives saved=.02¢/ton/life saved

Based on the outlined increase in worker productivity due to a decrease in fatal accidents, it is very likely that the rate of return on investment would be higher than most alternative capital investments available to commercial operators. This assumption, however, can only be validated in the field on a controlled basis.

No calculations have been offered on the potential productivity increase associated with driving 60'-80' under support provided by a string of modules. Although a similar system, in which the trusses are raised individually for jack insertion, is currently being used successfully in module form, serious advancing problems may arise as each module is added. On the other hand, if the support system fulfills its safety potential and there is a corresponding increase in productivity, it is probable that the industry will be eager to adopt the system.

CHAPTER 8

PERMANENT SUPPORT INSTALLATION

I. STATEMENT OF THE PROBLEM

Installation of permanent support is a difficult and hazardous operation that is directly tied to the problem of temporary support, which was discussed in the previous chapter. The separation of these two functions is somewhat arbitrary since there is a considerable overlap of worker functions. In this discussion the permanent support topic will be limited to roof bolting, which accounts for the overwhelming majority of approved permanent support plans.

Present permanent support equipment and procedures accounted for 46 fatal accidents during the period 1966-1970. Numerous other fatal accidents were undoubtedly the direct result of faulty roof bolting procedures.

The permanent support function is somewhat unique in the mining system in that it is not only physically demanding and personally hazardous, but it carries with it the responsibility for the safety of all other underground workers. For these reasons, it would seem logical to assume that personnel performing this function are the highest paid and the most qualified people in the mine. This assumption is wrong on both counts. Because of a lower pay scale and the job bidding system common in most mines, this difficult and dangerous task frequently falls to an entry level worker. He is less able to recognize personal danger, less likely to do an adequate job of roof bolting, and unable to provide the accurate assessment of changing roof conditions that an experienced man "feels" through his drill steel and overall machine performance.

The permanent support problem is further complicated by the inefficiency of current equipment, which creates a bottleneck situation in most mines. The time-related roof sag of newly cut places is another important consideration in some mines. Some roofs will fall if not promptly supported, and the effectiveness of permanent support in many roofs can be seriously impaired by delayed bolting.

In summary, the single most important function in underground coal mining is effective support of the roof. Present systems do not necessarily contribute to the effectiveness of this function.

II. ANALYSIS OF THE PROBLEM

Exposure Problems

The real problem is removing the operator, his helper and "visitors" from the area under unsupported or temporarily supported roof. Over 70% of the roof fall accidents while roof bolting occurred under these conditions. In addition to the 46 fatalities previously cited, there were 62 fatal accidents while setting or removing timbers and 24 fatal accidents while scaling roof or removing a previous roof fall. Roof bolters respectively accounted for 12 and 3 of these fatal accidents.

Industrial Engineering observations made during this study indicate that the majority of roof bolters are not adequately schooled in the procedures that would minimize their exposure. Helpers often expose themselves without materially contributing to the productivity of the operation. Observations indicate that helpers and "visitors" often stand unnecessarily under unsupported roof while waiting to hand an assembled bolt to the operator or just keeping company. The visitor or helper is often a student whose training environment is less than satisfactory -- proximity to a dangerous machine while under unsupported roof. Removal of the operator from the unsupported roof area will also remove the exposed visitor in most cases.

One situation observed during the study had an operator working alone after only one week underground. Needless to say, this procedure does not contribute to safety or productivity in this key function.

Numerous examples of incorrect procedures were witnessed in a variety of mines. One operator placed three safety posts directly against the face and proceeded to bolt under a 10' open span while the mine safety director and an industrial engineer were present. The safety director was obviously unaware of the function of safety posts since this procedure added almost five minutes of exposure time while making only a small contribution toward subsequent roof bolt installation. Knowledge of good procedures and training practices is not widespread in smaller mines. Erratic spacing and "hurry-up" bolting can be found in many mines, both large and small.

Man-Machine Interaction Problems

Roof bolting machines have sudden control responses with a great deal of bumping and jerking. Control of the machine appears to be a battle between a determined operator and an almost uncontrollable, convulsive machine. Equipment-related fatalities are not a full measure of the problem since this machine also produces far more non-fatal injuries than any other single piece of face equipment. Together with industrial engineering observations, the fatalities and injuries pinpoint this piece of equipment as the machine with the greatest need for redesign.

Solution Concepts

Solution concepts will be discussed below beginning with the most ideal, long-range solutions and progressing through less than optimal, but more practical, possibilities which might be implemented in the short run.

A. Continuous Miner Mounted Automatic Roof Bolter

This is a difficult technical feat which would ideally "float" a high capacity automatic roof bolter directly behind the cutting head. Predicated on potential gains in productivity, the industry could afford the very high price of this solution. A 10% gain in continuous miner operating time would probably yield 35% more coal while reducing the number of workers required by 12 to 14%. Assuming an applicability in seam heights over 42", this machine could potentially eliminate almost all unsupported and temporary support fatal accidents, which are expected to total over 30 each year in the early 1970's. A mechanically/hydraulically driven pin system appears to have the fewest obstacles to be overcome.

Placing the roof bolters at the side or rear of the machine presents additional problems which may or may not be solvable. It is conceivable that semi-automatic or even manual bolters could safely be used at the rear of the continuous miner if the machine provided roof support for the operator(s). With an automatic design, two operators could be located on the machine in a back-to-back configuration. The operator facing rearward would operate the automatic roof bolters and control the action of the loading boom. The key to this type of configuration, both automatic and manual, would be the use of limiters and proximity switches for integration of the bolter and loading boom.

In addition to canopies, a free standing, floating truss would be necessary to provide protection for the operators. The truss support might be a relatively simple canopy that could be expanded laterally and raised off the miner by long stroke hydraulic pistons. No mechanical umbilical cord would be required since the unit could be retracted laterally and vertically to rest on top of the continuous miner for advancing or tramming. The width of the miner would be increased only by the width of the pistons on each side of the machine. When raised, the absence of mechanical connections would provide maneuverability limited only by the roof bolting function. The truss support and integrated roof-bolter concepts are shown in the following illustrations.

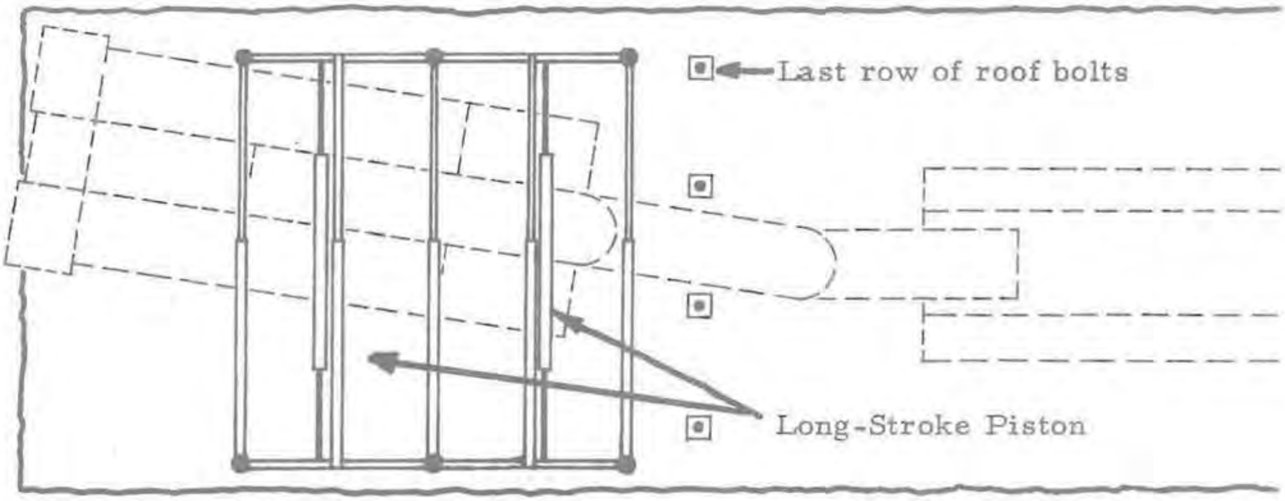


Fig. 1A Top View of Truss System

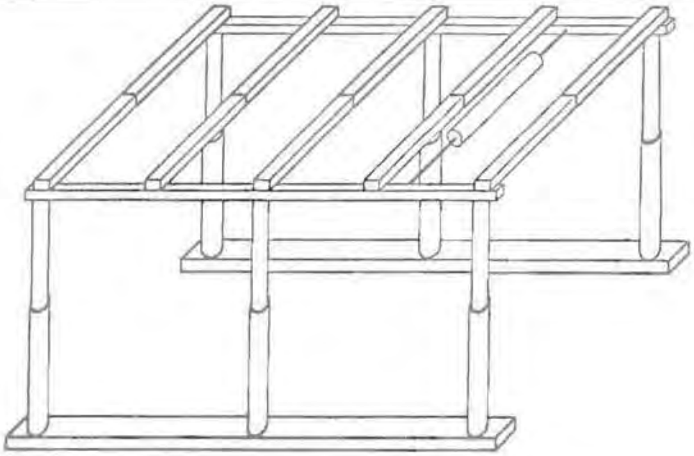


Fig. 1B Isometric View of Truss System

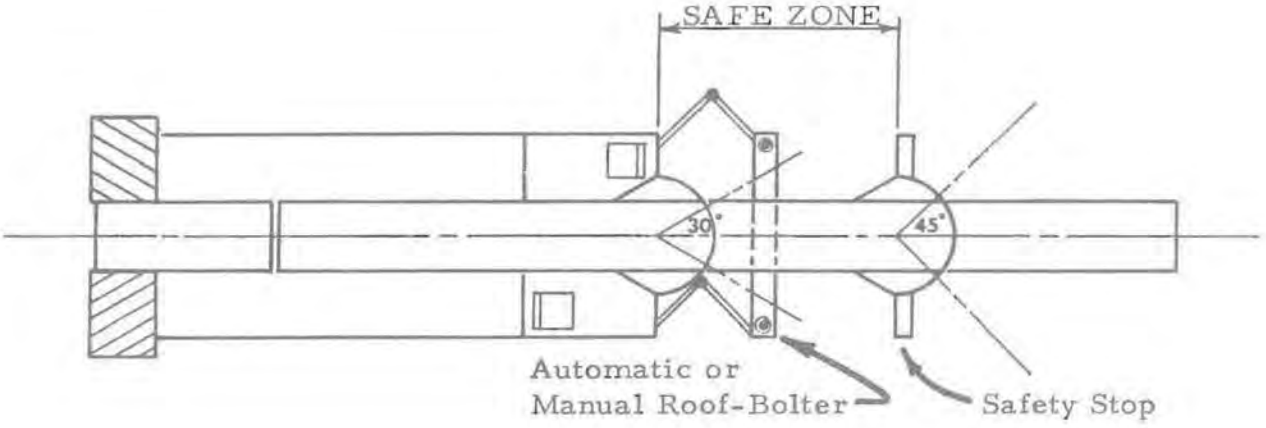


Fig. 2 Integrated Roof Bolter System

An interesting near-term possibility is the use of present equipment in the safety zone behind the miner. There are several obvious requirements such as a boom extension, hydraulic or pneumatic takeoffs, noise suppression for pneumatics, proximity switches and limiters, and interlocking boom controls operated simultaneously by the 2 roof bolter operators. This alternative might be safer than using temporary supports and a separate roof bolting machine. As we have learned from auger type continuous miners, however, men in proximity to machines must be protected from unexpected movements. Any attempt to place men near a machine without a safety zone could result in an increase in machinery accidents that would cost more lives than it would save.

B. Fail Safe Bolters and Improved Controls

The obvious alternatives are:

1. Completely automate the roof bolting operation with remote controls. A better platform, lateral tram capabilities, improved transitional control, and thus greater efficiency are assumed. This difficult but far from impossible technical feat would remove personnel from unsupported or temporarily supported areas. The advantages offered by hydraulic roof pin insertion could revolutionize roof support procedures if development is successful.

2. Equip present machines with a machine-mounted canopy or truss, and relocated and improved controls for greater efficiency. This alternative requires greater capacity to be practical. The roof bolter must be able to follow the continuous miner or loader instead of being pushed in a production sense. The bolter must also be capable of rebolting developed areas that experience roof control problems while the normal cycle is in progress. The alternative is two roof bolters per section, a practice growing in populatiry for high production sections.

C. Better Roof Bolting Procedures

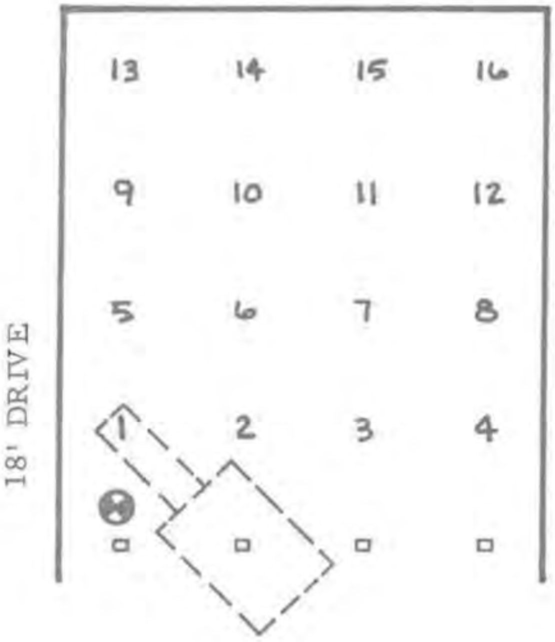
This is a "now" item that has immediate potential. The biggest obstacle – communication of known techniques to individual workers – could be overcome by the education of management, supervisors and workers.

An example of what can be done under adverse conditions was provided by an experienced roof bolter. This man was installing bolts in a roof that had been falling constantly during the night and morning shifts. The section had the worst roof conditions ever witnessed by several management personnel who had more than 30 years of experience underground. The roof bolter operator did not have temporary support that would reach the height of the place and elected to bolt without temporary support. The operator's experience and awareness enabled him to bolt safely while an industrial engineer measured his exposure time as less than 10% of the cycle time.

Subsequent discussion with the operator revealed a rational decision against using temporary support even if it had been available. The size and weight of the very long supports needed would have exposed 2 men for a far longer period of time than the careful approach that was used. Significantly, the management of this captive mine voluntarily paid the top section wage to keep this experienced bolter at his job. An inexperienced operator would have had at least 2 opportunities to kill himself during roof falls on that single cycle.

The procedure used by this experienced operator was a simple one used in a few safety conscious mines. The roof bolter is trammed into the place at a 45° angle in order to place the controls close to the last roof bolt on the left side of the place. The operator steps back under permanent support after centering and starting the bit and is exposed for only a few seconds while adding drill extensions and inserting the bolt. The place is then bolted from left to right so that the operator can benefit from the bolt just installed in the new line of support.

OPERATOR STEPS
BACK UNDER
SUPPORTED ROOF



OPERATOR
UNDER
TRIANGLE OF SUPPORT

With current equipment the temptation to bolt straight ahead is encouraged by the clumsy maneuvering necessary to position the machine in a lateral fashion. Straight ahead and random bolting sequences were frequently observed.

D. Better Training in Roof Support

Fatality analysis of task experience suggests that the first week on the job is many times more dangerous than any single week in the third year of task experience. This relationship seems even more pronounced in small mines and for roof fall fatalities.

There are 4 key factors in effective training: procedures, experience, incentive, and supervision. An excellent formal training program can be ineffective if the worker does not have the incentive to stay on the job and gain professional level experience at the task. Several of these four ingredients were not present in the majority of mines studied. In the case of the young operator working alone after one week in the mine, all four ingredients were missing.

E. Re-evaluation of Roof Bolter Job

The position of Roof Control Specialist, having the responsibilities, rewards, and prestige equal to that of the section foreman, could be created for certified miners. Combined with an automatic roof bolter, which would remove some personal hazards and demanding physical labor, the position upgrade might attract experienced men who previously "bid out" to a safer and easier job. The overall compliance level of this pivotal job would, therefore, be upgraded.

III. SUMMARY OF RECOMMENDATIONS

The optimal solution to the permanent support problem is an efficient automatic roof bolter mounted on both the continuous mining machine and the mobile loader. However, present efforts in this direction have not developed as rapidly as had been expected.

Current continuous miner roof bolter designs appear to be hang-ons that have not received industry acceptance for a variety of reasons. The hydraulically driven pin system, however, satisfies many of the requirements and its development should be given high priority.

In the absence of a readily available "best" solution, we will focus on practical, "sub-optimal" solutions which show promise of near-term payoff. Roof bolting is not rated as an extremely dangerous job from an industrial engineering viewpoint if the activity is correctly performed. This correct procedure includes the use of temporary supports and a good knowledge of safety techniques, both of which are entirely missing in many mines. This situation can be improved by:

A. Better Procedures

This is not likely to be a rewarding approach to safety due to lack of management expertise and motivation in those very mines where improvements are most needed.

B. Better Training

Again this approach is likely to be only marginally rewarding due to lack of management expertise and motivation in the offending mines.

C. Inherently Safe Bolter Machines

If the roof does fall, the operator should be either protected or a safe distance from the fall. This suggests either a remote operation or a machine-mounted canopy or truss.

D. Better Controls

Over 1/3 of the fatal accidents are equipment related, a function of machine control.

1. Tramming is dangerous because of the position of controls at the front of machine. The operator either faces backward to the direction of travel or operates controls "blind" while facing forward.
2. Actual bolting is a "hand" operation with manual drill centering, drilling and extension additions. Extensions fit loosely on the drive chuck and against the drive bit.

E. More Efficient Machines

Roof bolting is presently a bottleneck in most mines, both continuous and conventional. This situation encourages out-of-cycle face activities to maintain production pace (e. g., undercutting an unbolted place).

F. Re-evaluation of Roof Bolter Job

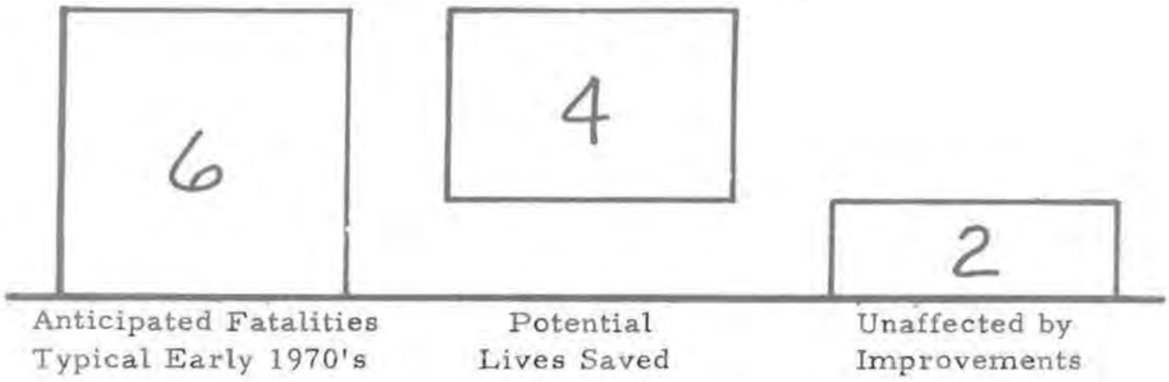
A re-evaluation is needed of union practices that encourage bidding off this vital assignment. Perhaps new contracts that establish this position as the most important function in the mine in terms of rewards and prestige should be negotiated and the position of Roof Control Specialist or a similar career opportunity should be created.

IV. POTENTIAL LIVES SAVED ANNUALLY

Potential Lives Saved: 6

The annual fatality rate for roof bolters is expected to be approximately 9, unless improvements are made.

ROOF FALL ACCIDENTS



EQUIPMENT ACCIDENTS

There will be approximately 9 fatal roof bolter accidents annually in the early 1970's. The suboptimal solutions outlined in the previous section could potentially prevent 2/3 of these accidents. This estimate is based on seams over 3' and under temporary or unsupported roof. The solutions would be directionally helpful for accidents under permanent support and would reduce these fatalities also.

Separation of the analysis of temporary and permanent support is useful for descriptive purposes in this report, but may not lend itself fully to a helpful discussion of the benefits from more effective means of roof control. The real payoff lies in the total of all the lives which could be saved as a result of an integrated support system. A total of 46 fatal accidents during the period 1966-1970 occurred while the victim was performing directly related support functions such as roof testing, scaling, setting or removing supports and resupporting after a fall. An analysis of the potential lives to be saved should include most of these victims.

Solution 1 - Integrated Continuous Miner (or Loader)/Roof Bolter System

1. Roof Fall Accidents

This system is estimated to eliminate 75% of the temporary support related activities in seam heights above 42" (roof falls only).

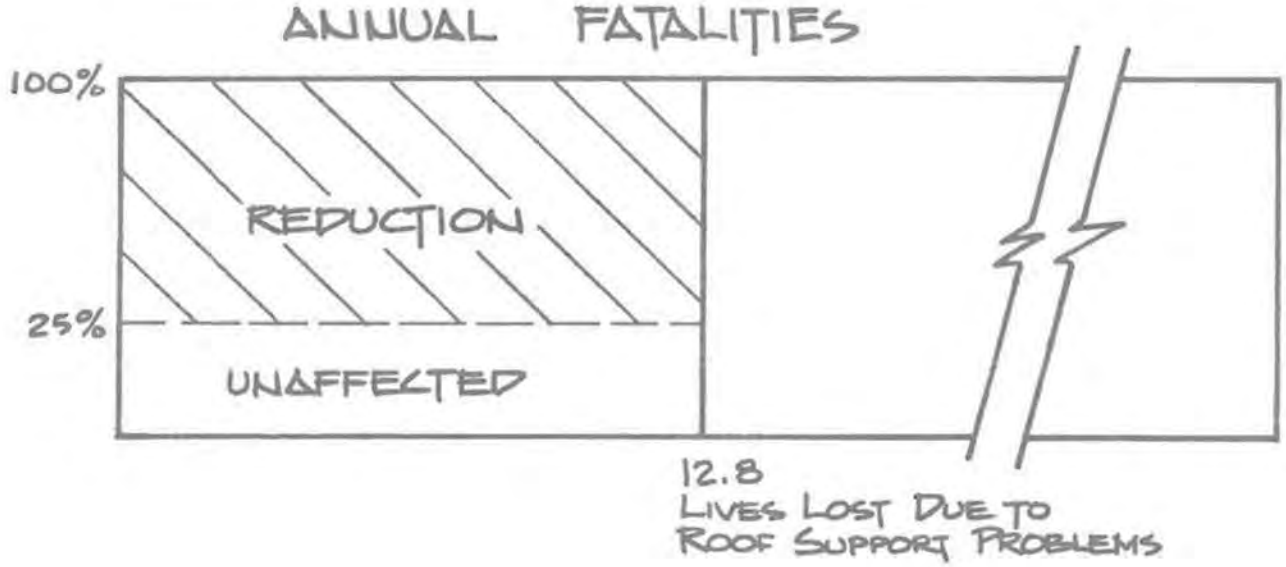
- Temporary Support-Related Fatalities (including fall removal) = 114 total fatal accidents - 45 accidents under permanent support or in seam heights above 42" = 69 fatalities

- Adjusting for the decline in roof fall fatal accidents in the 1966-1970 period yields a trend factor of .85. The trend factor can be used to convert fatal accidents into "lives lost" based on the following formula:

$$.85 \times \frac{69 \text{ fatal accidents} > 42'' \text{ seam height}}{5 \text{ years}} \times \frac{422 \text{ roof fall fatalities}}{388 \text{ fatal r.f. accidents}} =$$

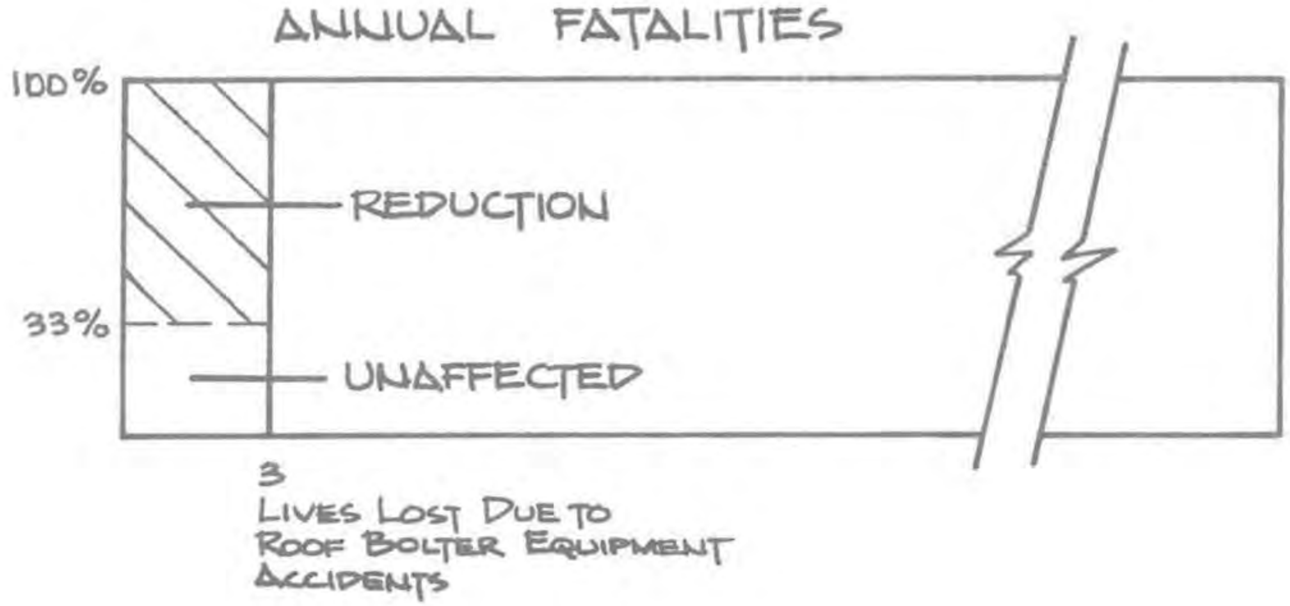
12.8 lives lost/year

12.8 lives lost/year x 75% system effectiveness = 9.5 lives saved



2. Equipment Accidents

It is estimated that 2/3 of the approximately 3 fatal equipment accidents expected annually for the roof bolt support activity could be prevented by using an improved roof bolting system.



Solution 2 - Fail Safe Bolter

Assuming that the improved roof bolter will be capable of immediate bolting of all unsupported roof, the payoff would be very close to Solution #1. The roof will not be supported as rapidly, but no temporary support would be used.

Solution 3 - Safer Procedures

This is an extremely subjective analysis and cannot be documented with available data. It is widely accepted that good procedures are the key to safety, but safe procedures are not necessarily the most productive method in the short run. If all managements were motivated and could enforce safe operating procedures, a majority of the fatalities in all categories could be prevented. This is not an easily obtainable goal, since even the best management cannot gain 100% compliance. Results, however, can be achieved by dedicated people, as evidenced by the very low fatality ratio in one of the largest captive mine companies.

Solution 4 - Better Training

Again the payoff is a subjective estimate based on individual assessment. Hopefully the improved physical environment generated by better machinery will have even more impact when combined with new training emphasis.

V. COST TO IMPLEMENT RECOMMENDATIONS

Fail safe bolters, improved control, and improved production efficiency have associated expenses which can be estimated for the industry by multiplying the number of roof bolters by the estimated cost of modification. Published coal mine data and recent survey results suggest the existence of over 2,500 rotary or rotary-percussion mobile roof bolters underground in addition to approximately 1,000 percussion drills. If we assume that modifications to existing equipment would total about $6,000 per machine, then industry costs could be computed as follows:

- Estimated annual industry cost - $\dfrac{2,500 \text{ bolters} \times \$6,000/\text{machine}}{10\text{-year amortization}}$
- Estimated cost per life saved - $\dfrac{\$1.5 \text{ million}}{360 \text{ million tons} \times 6 \text{ lives saved}} = .07¢/\text{ton/life saved}$

In determining these cost-effectiveness figures, we are assuming that the prescribed improvements only reduce fatalities occurring during the performance of roof bolting. There are, in fact, many other individuals underground who would be affected by these recommendations which would reduce the cost per life; i.e., improved roof bolting would prevent various other roof fall accidents. Moreover, increased machine efficiency could result in a modification yielding a very high positive rate of return on investment because of the current production bottleneck.

Expanding the analysis to include better procedures, training and job revaluation is subjective at best. Taking typical training costs for the industry is just a starting point since on-the-job training must be a continuing feature. Rough estimates can be made only as an exercise in formalizing the type of analysis that is necessary. The following estimates are made on a per-man basis.

- Estimated industry costs -

Formal training (1st year)-2 weeks at full pay	$800
Monthly technical meeting - 1 day at full pay (USBM or other guest speaker = 12 x $50)	600
Additional contracted salary (240 days x $3.00/day)	720
Continuing on-the-job training	0
TOTAL FIRST YEAR	$2120

- Estimated industry cost - subsequent years

Monthly technical meeting (11 x $50.00)	$550
Annual review class - 2 days at full pay	200
Additional salary	720
Continuing on-the-job training	0
Total Subsequent Years	$1470

- Estimated total industry cost
  1st year: 8,000 men @ $2,120 = $16,960,000
  Subsequent years: 8,000 men @ $1470 = $11,760,000

- Estimated cost per ton of coal produced
  1st year - $16,960,000 ÷ 360 million tons = 4.7¢/ton
  Subsequent years - $11,760,000 ÷ 360 million tons = 3.3¢/ton

Benefits

1. Contribution to reduction of 4 lives lost per year while roof bolting and an unknown number of lives saved both under temporary and permanent support.

2. Lower bolting cost in terms of manhours saved due to greater productivity of more qualified men. It would require approximately a 15% increase in roof bolter productivity to completely offset the yearly cost. This improvement may not be possible, but there would be additional savings in supervision and section productivity if this bottleneck operation is improved.

CHAPTER 9

MAINTENANCE AND REPAIR ACCIDENTS

I. STATEMENT OF THE PROBLEM

Repairman fatalities accounted for 10% (71) of all mine fatalities other than disasters from 1966 to 1970. Seventy-three percent (52) of these fatalities were job-related; the remainder occurred while the repairman was performing other than maintenance-oriented tasks. Only 1.6% (12) of the fatalities, the lowest figure for any job classification, were caused directly by mine conditions such as roof falls and rib rolls

II. ANALYSIS OF THE PROBLEM

The number of repairman fatalities has been increasing slightly each year since 1966. Those repairman fatalities which occurred while actually performing a repair-related function have remained static since 1966, while the number of repairmen killed during the performance of tasks normally outside the repair function has increased. Similarly, the fatalities which are experienced by equipment operators while operating their prescribed equipment are decreasing, but those fatalities that occur while they perform other than their normal tasks are increasing. We conclude from this that a fatality is more likely to occur when a miner is performing non-job related tasks than when he is engaged in his regular tasks.

The total mine work experience of the repairmen involved in a fatal accident has increased significantly each year since 1966. At the same time, there are an increasing number of fatal accidents involving repairmen with little task experience. This may indicate that the repair job is considered more and more desirable, and miners with greater total mine experience and related seniority are bidding onto repairman jobs for which they have no experience. The frequency of fatal accidents involving repairmen declines rapidly with task experience, thus suggesting a value in training and experience on the job.

There are theoretically two ways to develop a good repairman -- hire a good mechanic and teach him the rudiments of mining procedures, or permit an experienced miner with mechanical aptitude to be a repairman, which is the common practice. Because of the increasing amounts of task overlap of repair jobs in production operations, repairmen must be competent in many job tasks that are not strictly repair tasks. For example, either the repairman should know how to set props or jacks around a broken-down machine under unsupported roof, or he should not be allowed to work on the machine until someone else sets the props. Similarly, the repairman should know how to operate partially disabled equipment, especially in regard to tramming. These two situations are typical fatal accident situations for repairmen performing non-repair tasks.

Proper support must precede repairs under unsupported or under hazardous roof areas and similarly, the operation of equipment in order to remove it from a hazardous roof area must be delayed until the hazardous roof area is properly supported. The repairman should be trained in basic roof support procedures, so that he can recognize a poorly supported roof and know how to bring the support to the level of the approved roof control plan, or to exceed the plan when appropriate.

Restrictive measures, with the objective of confining the repairman to repair tasks, are unenforceable and therefore probably ineffective in reducing fatalities. Required training and certification of repairmen should be especially effective if direct job-related task skills are tested as well as key indirect task skills such as roof control and equipment operation. Presumably, after two years of mining experience, a miner bidding for a repairman job would be qualified on most of the indirect repair tasks he should know, but it should not be just assumed that he does. Certification for the job should test rudimentary knowledge of mechanics and electricity, safe equipment operation procedures, roof support procedures, and knowledge of a minimum number of "do's and don'ts" of typical repair situations.

A formal training program combining classroom, shop, and underground practice sessions would be the most ideal training environment. We believe that attendance in safety meetings and classroom training sessions are worthwhile, but that testing the application of knowledge provides assurance that safe procedures are understood and can be applied. Physically doing or practicing a task often provides more real learning than reading or listening to a lecture.

Repairs at or near the face, whether supported or not, are hazardous in high coal. In high seam height mines a rib roll could fill the entire width of the entry, leaving the miner(s) nowhere to run. Therefore, repairs in high coal should be performed in crosscuts which provide escape from both ends of an impending rib roll.

It is the responsibility of the mine operator to provide safe and efficient tools for various repair tasks. Tools include everything ranging from special equipment jacks to insulated needle-nose pliers.

Electrical fatalities are high for repairmen (11 in a 5-year period) and contribute to fatalities in all job categories except undercutting and drilling. The most practical way to eliminate the greatest number of these fatalities would be a permissible quick-disconnect coupling between the power cable and the equipment. When the power control point is out of the line-of-sight of the repairman -- as is presently most often the case -- a hazardous environment is automatically created. As an analogy, no TV repairman would consider working on a TV set unless he could see it was unplugged. The permissible quick-disconnect coupling would provide a convenient and reliable method of assuring the repairman that the power is disconnected.

There is a great need for a cost effectiveness analysis of underground machine maintenance to verify the benefit to be derived from and the need for preventive maintenance programs. Such a program would do the following:

A. Reduce the number of repairs and create the ability to plan, schedule and implement repairs with a minimum of interference with production operations.

B. Shorten the time spent repairing. Long repairs contribute to broken production sequence and equipment interference as well as hazardous situations.

C. Increase production up-time and reduce the pressure by production personnel to get the equipment running again, however poor the repair effort.

D. Provide the needed parts on time by anticipating what will be needed and ordering with sufficient lead time.

E. Provide the proper tools to do the job safely and efficiently.

A preventive maintenance system requires an implementation plan to make the system more readily available to all mine operators. Whatever the system is, it must be uncomplicated. It must provide the maximum useful information with little time spent administering the program. The system must be geared toward the small operator who has a small maintenance force and cannot justify an administrative clerk to maintain maintenance records.

Equipment manufacturers can make a significant contribution to better preventive maintenance programs with equipment designed for more convenient maintenance and repair, and recommended maintenance programs and schedules. In some areas there is a need for a service which apparently does not presently exist -- contract repairing of underground coal mining equipment underground. The heavy construction industry has used this type of service for many years, but with the difference that the construction equipment usually is taken to the dealer's facility for overhaul. It is impractical to remove equipment from the face area and transport it to a repair facility. Hence, many mining operations suffer excessive downtime from both long repair time and lack of well designed preventive maintenance programs.

Considering the relatively high downtime on mining equipment and the large dollar investment in mine development and mine equipment, it is surprising that more mine managements do not invest more in maintenance programs and repair training internally. The dollar return on increased repair productivity and quality from the investment in these programs should be very high, not to mention the saving of lives and injuries.

III. SUMMARY OF RECOMMENDATIONS

A. Repairman Training and Certification

Several alternative solutions to the problem of repairman accidents appear to be feasible.

1. Institute a certification system requiring miners to have a minimum knowledge and demonstrated skill in performing direct repair job tasks and key indirect job tasks -- e.g., operating and tramming face equipment and roof support procedures.

2. Encourage management to restrict repairman tasks to those required by the job or for which the men have demonstrated competence.

B. Roof Support in Repair Situations

1. Provide roof support equivalent to the approved temporary support plan in the area where the equipment is to be repaired before attempting any repair.

2. Tram all equipment to be repaired to a supported roof area after providing additional temporary support over the area in which vehicle is to be operated and trammed before beginning to tram. Additional support must be equivalent to the approved temporary support plan.

C. Proper Repair Tools and Use of Tools

1. Provide proper jacks and blocks which always remain with each machine. Design new lifting and blocking equipment as required after analysis of present tools.
2. Train repairmen in correct (safe) methods of lifting and blocking.
3. Establish a formal tool control system and immediately replace lost or damaged tools.

D. Equipment Repair Accidents

1. Train repairmen in safe equipment operation and require certification of minimum proficiency.
2. Park equipment either far enough from brattice or halfway under brattice (visible from both sides) so that any operator will have sufficient time to stop upon seeing the parked equipment.
3. Provide all equipment with reflectors on all four sides.

E. Haulage Accidents Involving Repairmen

1. Have parts and supplies delivered to the repairman, or
2. Have repairman certified on the safe operation of haulage equipment.
3. Store frequently needed parts within mine near section.

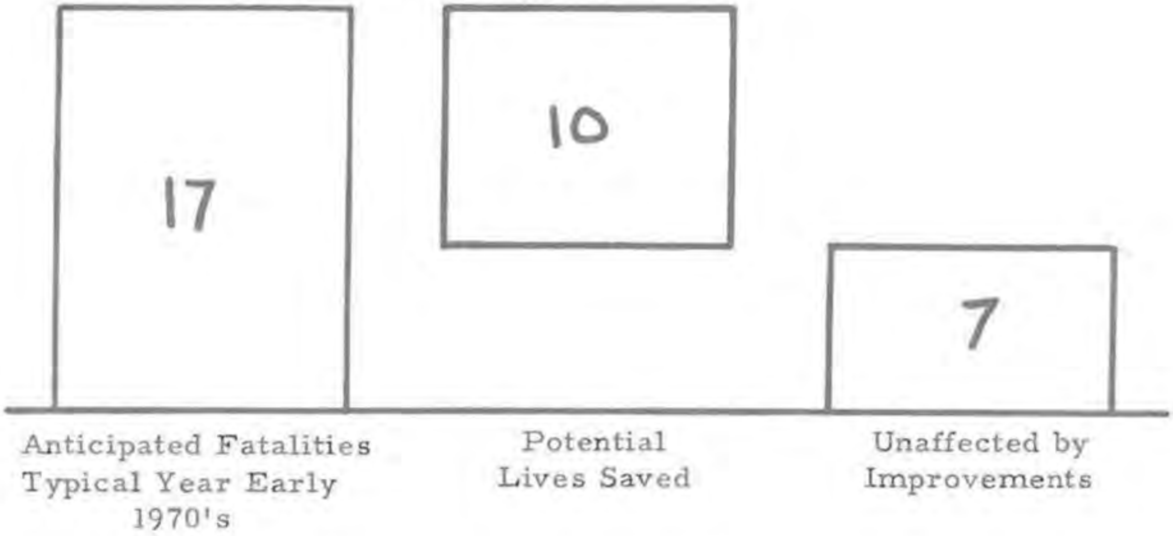
F. Electrical Repair Fatalities

1. Provide permissible quick-disconnect plug between cable and equipment.
2. Provide permissible sections of cable which can be removed and replaced quickly without removing entire cable.
3. Provide training and certification for repair of electrical systems on each piece of equipment.
4. Enforce use of and frequent inspection of insulated personal clothing such as gloves and boots.
5. Use only hand tools with sufficiently insulated hand grips.

IV. POTENTIAL LIVES SAVED ANNUALLY

Potential Lives Saved: 10

POTENTIAL FATALITY REDUCTION:
MAINTENANCE



In a typical year in the 1970's we expect 17 repairmen to be killed. Implementation of the recommendations discussed in the previous section should save approximately 10 of these lives each year.

V. COST TO IMPLEMENT RECOMMENDATIONS

1. Roof Support in Repair Situations

- Estimated cost of working under supported roof - 0
- Estimated potential lives saved annually - 2
- Cost per life saved - 0

Repairmen must work under supported roof. No cost will be incurred by the repairman by placing additional temporary supports. When the repair performed by both operators and repairmen is combined, the total time is less than the repairman's available time and allows him sufficient time to add support to the roof. The following table illustrates that the typical repairman has sufficient actual working time during an 8-hour shift -- approximately 6.5 hours -- to handle all repairs as well as maintain roof support in the repair area:

REPAIR TIME AVAILABLE TO REPAIRMAN: 6.5 HOURS

Job Classification	Repairing		
	Estimated Hours Spent Repairing*	Continuous	Conventional
Undercutter Operator	0		0
Face Drill Operator	.72		.72
Machine Loader Operator	.20		.20
Continuous Miner Operator	.20	.20	
Roof Bolt Operator	.26	.13	.13
Shuttle Car Operator	.26	.10	.16
SUBTOTAL		.43	1.21
Repairman	4.74	4.74	4.74
TOTAL Hours/day spent repairing		5.17	5.95
Time available to provide additional support in non-supported or inadequately supported area		1.33	.55
		6.50	6.50

*Time estimates based on percentage of fatalities of each job classification which occurred while repairing, 1966-1970.

2. Proper Repair Tools

Proper lifting and blocking devices and hand tools should save at least 50% in labor costs over most present methods.

Estimated Labor Savings

- Labor savings/day/section - 20 minutes;
  .33 hours x 250 days = 83 hours saved/year/section
- Annual savings
  83 hours @ $4.00/hour = $332/section/year
- Savings for 1-shift operation
  $332/section/year 1 shift x 1,000 sections = $332,000
- Savings for 2-shift operation
  $664/section/year 2 shift x 7,000 sections = $4,650,000
- TOTAL annual savings ~ $5,000,000

Estimated Tool Costs

- Total tool cost/section -$1,500
- Annual tool costs
  $1,500 x 8,000 sections = $12,000,000

Payback Period

- $12,000,000 ÷ $5,000,000 = 2.5 years

Estimated Annual Cost per Life Saved - unknown

3. Equipment Training

- Forty hours training @$4.00/hour = $160/repairman
- Estimated training costs -
  - (2 repairmen/2-shift section) x 7,000 sections = 14,000 repairmen
  - (1 repairman/1-shift section) x 1,000 sections = 1,000 repairmen
  - 15,000 x $160 = $2.4 million

4. Equipment Reflectors

- Estimated cost/reflector = $1.00
  20,633 machines x 10 reflectors/machine @ $1/reflector = $206,330

3. +4. Equipment Training + Equipment Reflectors

- Estimated total industry cost = $2,600,000
- Estimated cost per life saved =
  $2,600,000 ÷ 3 lives saved annually ÷ 360 million tons = .24¢/ton/life saved

5. Haulage Equipment Repair Training

- Eight hours training @ $4.00/hour = $32/repairman
  15,000 repairmen
- Total industry cost - 15,000 x $32 = $480,000
- Cost per life saved =
  $480,000 ÷ 3 lives potentially saved ÷ 360 million tons = .04¢/ton/life saved

6. Electrical Repair

a. Add a permissible quick-disconnect connector to each cable-powered piece of equipment.

Estimated Labor Cost

- Labor to add new permissible connector to equipment - 1 day
- Labor to add new permissible connectors to 2 cables (1 regular, 1 spare) - 1 day
- Typical labor rate @ $40/day x 2 days = $80/equipment connector conversion

Estimated Material Cost

- Number of Cable Powered Machines

Machine			Cable Power		
Mobile Loaders	2,560	x	90%	=	2,304
Shuttle Cars	9,950	x	80%	=	7,960
Continuous Miners	1,775	x	100%	=	1,775
Roof Bolters	5,223	x	100%	=	5,223
Undercutters	2,775	x	100%	=	2,775
Mobile Face Drills	1,000	x	100%	=	1,000
TOTAL Est. # of Cable Powered Machines				=	21,037

- A permissible connector set (1 male, 2 female) is conservatively estimated at $200 per set.

Estimated Total Cost

- Total cost per machine = $200 + $80 = $280
- Total Cost to Industry = 21,037 machines x $280/machine = $5,890,000

b. Cable Sections

- On a replacement basis - no cost

c. Training

- 80 hours training @ $4.00/hour = $320/repairman
  Estimate 15,000 repairmen
- Estimated total industry cost - 15,000 x $320 = $4.8 million

d. Insulated Clothing

- Estimated total industry cost - 15,000 x $100/man = $1.5 million

e. Use Only Insulated Hand Tools - nominal or no additional cost

6a - e. Estimated total industry cost of recommendations relating to electrical fatalities = $12.1 million

Estimated cost per life saved =
$12,100,000 ÷ 2 lives saved annually ÷ 360 million tons = 1.7 ¢/ton/life saved

CHAPTER 10

OPERATOR PROTECTION ON FACE EQUIPMENT

I. STATEMENT OF THE PROBLEM

During the period 1966-1970, 168 miners were killed while operating, assisting or tramming continuous miners (65), machine loaders (64), undercutters (23), and hand and mobile face drills (16), (excluding those killed in explosions and electrical accidents). The single largest killers of these men were roof and rib falls, accounting for 136 deaths. The rest were killed by bumps, collisions and equipment accidents.

The most direct and obvious solution to the problem of operator safety is the use of canopies or cages to protect the operator from rib and roof falls, bumps, and the lateral incursion of ribs and other equipment. Despite the fact that the transition to canopies is already in the advanced planning stage within the USBM and that canopies are soon to become mandatory, there is strong resistance to the incorporation of canopies on face equipment. In addition, there are major canopy design problems -- especially for use in low coal mines (see Chapter 14). This chapter will discuss these design and implementation problems.

II. ANALYSIS OF THE PROBLEM

Operator canopies and cages offer a sensible and cost effective approach to equipment operator safety. We say this with the full realization that canopied equipment is viewed by a significant segment of the industry as impractical. Major points of resistance to or criticism of canopies within the industry are: 1) they impede operator visibility; 2) they make ingress and egress tiring and difficult; 3) they are impractical in low coal; 4) they give the operator a claustrophobic feeling of being "trapped" in an emergency. Each of these points should be addressed in considering an approach to canopy design which will prove acceptable to the industry.

Caution must be exercised in designing canopy systems for face equipment to make sure that the design does not create a more hazardous situation than the one it was intended to prevent. While a completely enclosed canopy roof, for example, offers maximum protection against roof falls, it may restrict observation of the roof. In this case decreased visibility is certain to expose the operator to roof hazards which would otherwise be avoided. In other cases the operator may not be able to see the boom and shuttle car while loading, thus increasing the danger of equipment accidents.

Operator comfort is crucial for acceptance of canopies. A design made uncomfortable by a canopy would encourage the operator to climb out at every opportunity, increasing non-operating exposure to hazardous roof conditions. In addition, a canopy which is difficult to enter and exit will increase operator resistance to the canopies and encourage removal of the canopies.

The use of canopies in low coal is the most difficult problem to address. The auger type continuous miner, customarily used in low coal, presents unusual equipment hazards not common to other continuous miners. There are usually two helpers working at the front of the machine who are endangered by the machine itself, by the jacks forced into the roof to winch the machine, and by constant exposure to temporary support. This already dangerous position would be made even more hazardous by any decrease in the operator's visibility or in his ability to effectively control his machine over long periods of time (comfort/fatigue factor). Consequently, when designing canopy protection for the operators of auger miners, the safety of both the operator and the two helpers must be considered explicitly. This problem is discussed in more detail in Chapter 14.

Many of the miners interviewed said that they did not like canopies because the canopies made them feel trapped in the event of an emergency. Almost all of the miners stated they would run rather than seek protection under a canopy. The fatality reports confirm this tendency but cannot shed light on the miners who made a successful escape versus those who survived by taking cover. A detailed reading of a group of 1966-1970 fatality reports suggests that miners may often be better off in overcoming their instinct to run, since some miners under canopies have survived sizeable falls that killed personnel close to the machine.

On the other hand, there is a strong possibility that operator exposure to roof falls may actually be increased by canopies if reliance is placed on the canopy for protection. A foreman, whose continuous miner canopy was obviously damaged by a roof fall, felt that there is a tendency for operators to pay less attention to the last row of bolts if the piece of equipment has a solid roof. While the canopy may be effective in many cases, the high frequency of roof falls in newly cut, unsupported roof might increase the overall hazard. In addition, the helper, who, in practice, spends a great deal of time in front of the bolts, would not have any additional protection from this increased exposure.

The question of solid roof canopies has been discussed widely in the industry. Most operators would prefer a slotted or crossbar canopy roof to allow roof visibility. Experiments with solid canopy doors have likewise been viewed with extreme hostility in some mines, and doors are often removed.

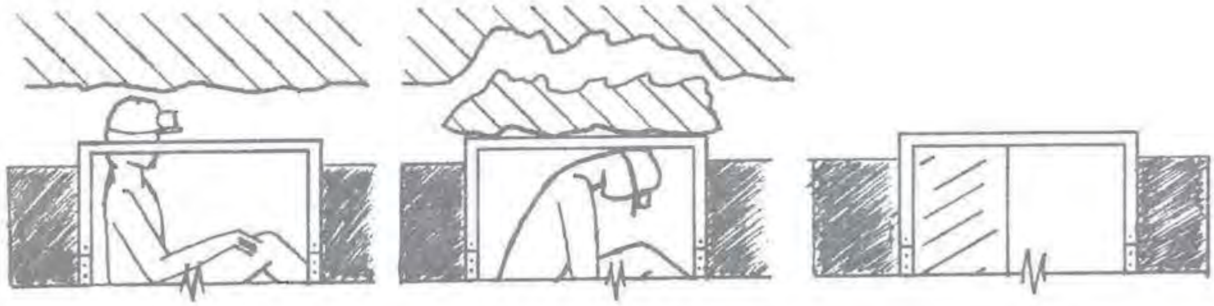
Although a solid canopy theoretically provides maximum operator protection, it would appear that a compromise solution which maintains most of the safety benefits in order to gain maximum acceptance by equipment operators would be preferable. The top and sides could be fairly open down to the top of the machine for greater visibility, and a solid shield could be used to protect the torso of the operators without drastically impeding entry and exit.

Solid canopies over the operator on equipment in low coal severely limit the vertical space available for the operator, forcing the operator either into a severely cramped space or into a prone or semi-prone position. The canopy thus virtually eliminates the operator's ability to see around him as he operates the machine and creates other problems such as now providing alternative operating visibility and more horizontal machine space for the operator.

In mines with low roof heights, a practical cage design might be a cage that permits the operator's head to project above the cage if necessary for clearance reasons. This concept is illustrated in the sketches below. We realize this concept is controversial because of its sub-optimal nature -- i.e., it is quite likely that there would continue to be some injuries and perhaps fatalities resulting from roof falls after the implementation of the concept. But, the solid canopy alternatives on existing equipment may be more dangerous. During the field observation portion of this study TB & A consultants found strong and even emotional resistance to the prospect of full canopy protection on all face equipment among operators of middle and low coal mines. The partial cage provides a workable tradeoff between the ideal safety of a full canopy and the practical necessity of achieving operator acceptability of the system.

Many fatality reports suggest that the victim has a few seconds of visual or audible warning of an impending roof fall. If equipment in low coal were fitted with low coal designs as described, the operators may have time to duck below the protective level of the cage to avoid serious injury from most falls. In addition, we believe that in some cases in low coal, roof falls may not have the time to accelerate to strike the victim's head with killing impact. With a partial cage, the victim may be pushed below cage level, with the cage frame absorbing the full impact of the fall. The seat in the cage also might be designed to break away in impact situations.

We believe careful engineering research on the above concept is worthwhile. Careful theoretical investigation of the fatality reports covering low coal roof fall accidents on equipment would help resolve the debate over the feasibility of the so-called low coal cage design concept. The fatality reports usually describe the size of the fall, the equipment, and the dimensions of the situation. Given the physiological parameters of the human body, the energy absorbing characteristics of the helmet and the support characteristics of the operator's seat, an expected theoretical injury response curve needs to be developed for the likely range of roof fall sizes, shapes, weights, and velocities that the cage concept would encounter on each piece of equipment.



NORMAL

VICTIM DUCKS
(OR IS PUSHED)
BELOW CAGE LEVEL

TORSO SHIELD

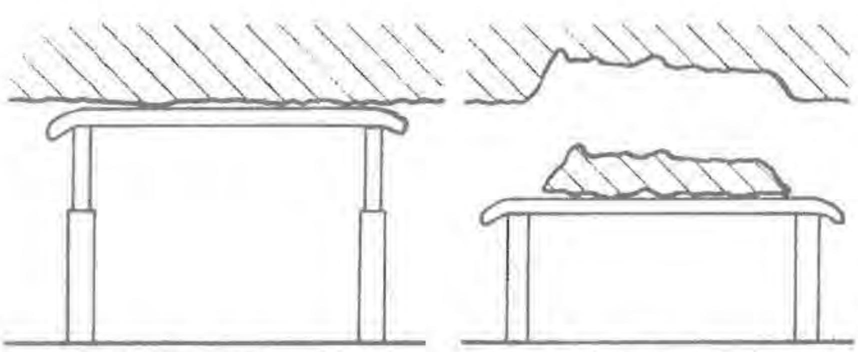
SIDE VIEW

Canopies adjustable for height variations would be necessary in many seams if roof, floor, or seam variability is a problem. This would be a necessity in marginal seam heights subject to floor heaves or roof and floor convergence in pillaring operations. Hydraulic and spring-loaded canopies are the most effective means of coping with variable heights. These can be considered together since they operate in a similar fashion.

A skid-controlled spring-supported canopy provides more protection for the miner and may be superior to a hydraulically actuated automatic canopy. The sensor or feeler on an automatic would not provide maximum canopy height since clearance must be allowed for an irregular roof that may be lower than the spot normally contacted by the feeler. Furthermore, an automatic hydraulic canopy must be built more strongly than a spring-loaded model because the additional clearance needed allows more room for roof falls to accelerate before striking the canopy. There is also a greater potential for mechanical failure of hydraulic components, particularly during strains imposed by roof falls.

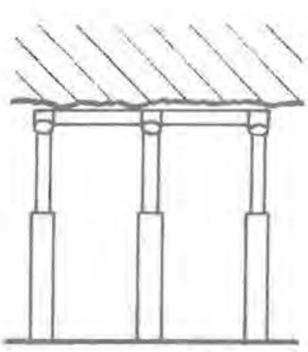
Spring-loaded canopies would rely on enclosed shock absorbers to adjust the canopy heights. The springs would support only the weight of the canopy with an adequate margin to overcome shock absorber resistance to movement. Ideally the shock absorbers would have some type of locking mechanism that would be activated by a threshold level of acceleration. This option might be a mechanical device or a chemical with dilatant qualities. The dilatant material would become a near solid when impacted by a roof fall but would provide only minimal resistance to the springs at lower than threshold speed.

The shock absorber canopy would require a manual override control and a set of "stops" for limiting lower movement. The manual control might have to be hydraulically actuated if mechanical leverage is insufficient for control.



NORMAL POSITION COLLAPSED POSITION

SIDE VIEW



END VIEW

In summary, regardless of the protection system chosen, the key to the practicality of the system is its applicability to low and medium-seam height coal. The two most feasible approaches to the solution of the low coal canopy problem have been incorporated in the various alternatives discussed above: 1) adjustable but rigid systems, in which the operator's head can rise above the top of the canopy rails during normal operations; 2) variable systems in which the canopy "floats" up and down as roof height changes but protects against the instantaneous impact of roof falls through a mechanical, hydraulic, or dilatant system.

III. SUMMARY OF RECOMMENDATIONS

A. Incorporate a Workable Canopy or Cage System on All Face Equipment.

We believe a number of practical design alternatives exist:

1. Canopies rigidly mounted on equipment. This is the cheapest and best solution for roof heights that permit free movement -- roughly, seam heights 5 feet and above.

2. Canopies adjustable mechanically with "pins" or "stops" to allow for variable roof heights in the higher seams and consistent roof heights in lower seams.

3. Canopies hydraulically actuated by a roof "feeler" or "sensor" for use in all seam heights; this system allows for minimum human containment and maximum comfort and visibility.

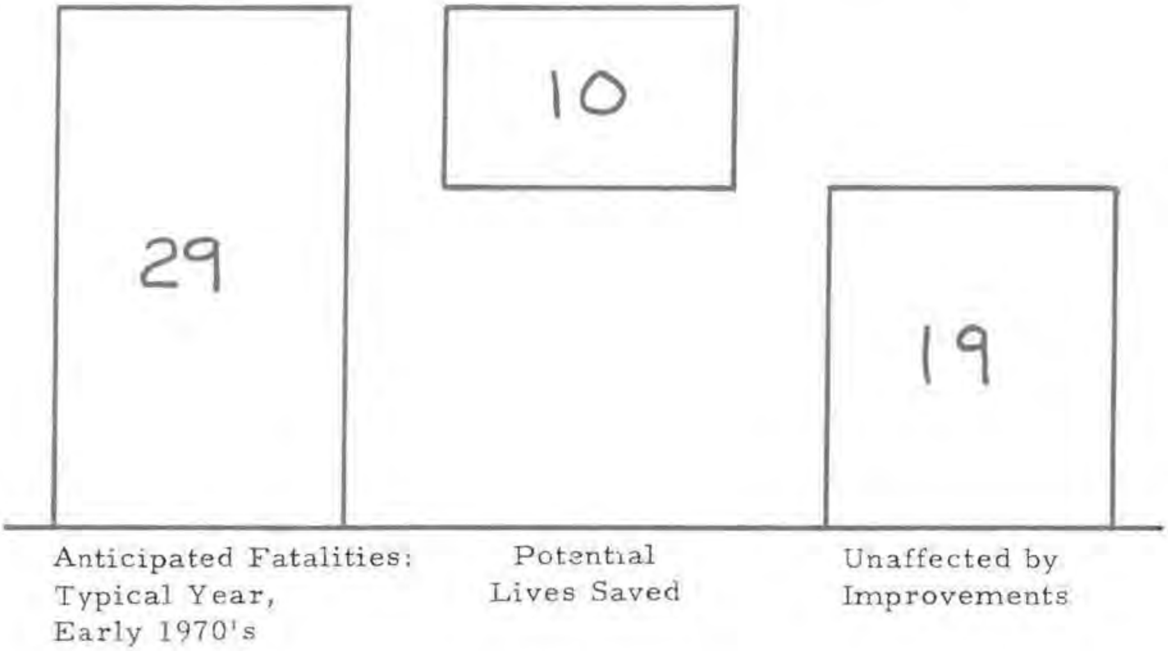
4. Automatically adjusting canopies which are adjusted by the roof pressing against skids on a lightly spring-loaded canopy equipped with hydraulic or mechanical shock absorbers. An interesting alternative in terms of cost and efficiency would be a research effort in the area of dilatant materials that become comparatively solid when threshold acceleration is reached. Floating supports in a suitable material, instead of using shock absorbers, might result in significant cost savings and improved efficiency of the system.

B. Publish fatality data in industry publications (Coal Age, UMW Journal, etc.) showing the number of operator deaths occurring during equipment operation and tramming. Industry-wide knowledge of the inherent danger of machine operations will decrease the resistance to operator protection systems. Many miners and mine operators interviewed during this study incorrectly believed that machine operator fatalities were insignificant in number when compared to other categories of accidents.

IV. POTENTIAL LIVES SAVED ANNUALLY

Potential Lives Saved Annually: 10

POTENTIAL FATALITY REDUCTION:
FACE EQUIPMENT ASSOCIATED ACCIDENTS



Direct relationships by "Victim Doing" for continuous mining, machine loading, undercutting, and face drilling (1966-1970).

ROOF FALLS, RIB FALLS AND BUMPS

	Cont Miners		Mach Load		Undercut		Face Drill		Total
	face area/tram		face/tram		face/tram		face/tram		face/tram
Gross Fatalities	44	7	49	5	15	3	15	—	138
Deduct Helpers	(14)	(2)	(22)	(1)	(7)	(1)	(3)	—	(50)
Net Probable Operators	30	5	27	4	8	2	12	—	88
Deduct 80% Hand Drills 1968 (midpoint)	—		—		—		(10)		(10)
							2		78
Deduct Estimated Non-Operating Face Time	(30%)		(20%)		(15%)		(15%)		(80%)
	21	5	22	4	7	2	2		63
Canopy Effectiveness Estimate (see below)	.59		.59		.59		.59		.59
Net Potential Fatal Accidents Avoided	12.4	2.9	13.0	2.4	4.1	1.2	1.2		37.2

Canopy Effectiveness Estimate:

Estimated Reduction Factors:

(1) Equipment operable from seated position: 80% Time Seated

(2) Roof Falls $>$ $3\frac{1}{2}'$ Thick (11% of all Roof Falls): 20% Effectiveness

(3) Roof Falls $<$ $3\frac{1}{2}'$ Thick, Rib Falls, and Bumps: 80% Effectiveness

Calculation

- (1) x (2) = .80 x .20 = .16 x .11 of all falls = .02 (Roof Falls $>$ $3\frac{1}{2}'$ thick)
- (1) x (3) = .80 x .80 = .64 x .89 of all falls = .57 (Roof Falls $<$ $3\frac{1}{2}'$ thick, Rib Falls, and Bumps)
- .02 + .57 = .59 canopy effectiveness factor

Direct relationships by 'Victim Doing" for continuous miner, machine loader, undercutter, and face drill (1966 - 1970):

EQUIPMENT AND TRAMMING
FATALITIES (NON-ELECTRICAL)

	Continuous Miner		Machine Loader		Undercutter		Face Drill		
	Tram	Eqp	Tram	Eqp	Tram	Eqp	Tram	Eqp	Total
Gross Fatalities	7	7	8	2	5	0	0	1	30
Deduct Helpers and Others	(3)	(7)							(10)
Operator Fatalities	4	0	8	2	5			1	20
Canopy Effectiveness Estimate (see below)	.68	.60	.68	.60	.68			.60	67%
Net Potential Lives Saved	2.7		5.4	1.2	3.4			.6	13.3

Canopy Effectiveness Estimate:

Estimated Reduction Factors:

(1) Equipment operable from seated position: 80% Time Seated

(2) Effectiveness of canopy in operating accidents: 75% Effectiveness

(3) Effectiveness of canopy in tramming accidents: 85% Effectiveness

Calculations

- (1) x (2) = .80 x .75 = .60 canopy effectiveness factor for equipment accidents
- (1) x (3) = .80 x .85 = .68 canopy effectiveness factor for tramming accidents

Potential Lives Saved Early 1970's

1. Roof, Rib and Bump Fatalities:

$$\text{(Roof Fall Trend) } .85 \times \frac{\text{37.2 Fatal Accidents}}{\text{5 Years}} \times$$

$$\text{1.14 (Fatalities Per Accident)} = \text{7 Lives Per Year}$$

2. Equipment and Tramming Fatalities:

$$\text{(No Trend) } \frac{\text{13.3 Fatal Accidents}}{\text{5 Years}} = \text{3 Lives Per Year}$$

Net Potential Lives Saved Per Year = 10

V. COST TO IMPLEMENT RECOMMENDATIONS

1. Rigidly mounted canopies in mines with seam heights greater than 5'
   - Estimated number of machines - 3,740 x 80% operable from seated position = 2,992 modifiable machines
   - Estimated cost fixed canopy - $500
   - Estimated total industry cost - $ 1,496,000
   - Annual industry cost = $\frac{\$1,496,000}{\text{5-Year Amortization}}$ = $299,000
   - Estimated cost per life saved
     $291,000 ÷ 4 lives saved annually ÷ 360 million tons = .02 ¢/ton/life saved

2. Adjustable canopy in mines with seam heights greater than 5'
   - Estimated number of modifiable machines - 2,992
   - Estimated adjustable canopy cost - $800
   - Estimated total industry cost - $2,394,000
   - Annual industry cost = $\frac{\$2,394,000}{\text{5-Year Amortization}}$ = $479,000
   - Estimated cost per life saved
     $479,000 ÷ 4 lives saved annually ÷ 360 million tons = .03¢/ton/life saved

3. Adjustable Hydraulic Canopy
   - Estimated number of modifiable machines - 6,280
   - Estimated canopy cost - $4,000
   - Estimated total industry cost - $25,120,000
   - Annual industry cost = $\frac{\$25,120,000}{\text{5-Year Amortization}}$ = $5,000,000
   - Estimated cost per life saved
     $5,000,000 ÷ 10 lives saved annually ÷ 360 million tons = .14¢ /ton/life saved

4. Automatic Spring Canopy
   - Estimated number of modifiable machines - 6,280
   - Estimated canopy cost - $1,500
   - Estimated total industry cost - $9,420,000
   - Annual industry cost = $\frac{\$9,420,000}{\text{5-Year Amortization}}$ = $1,884,000
   - Estimated cost per life saved
     $1,884,000 ÷ 10 lives saved annually ÷ 360 million tons = .05¢ /ton/life saved

5. Summary of Possible Combinations
   - 90% of total number of modifiable machines in mines with seam heights greater than 5'(2,693) adopt the rigid canopies of alternative #1 - $1,347,000
   - 10% of total number of modifiable machines in mines with seam heights greater than 5'(299) adopt the adjustable canopies of alternative #2 - $239,000
   - All remaining modifiable machines (3288) adopt the automatic spring canopies of alternative #4 - $84 932,000
   - Estimated total industry cost = $\frac{\$6,518,000}{\text{5-Year Amortization}}$ = $1,306,000
   - Estimated cost per life saved
     $1,306,000 ÷ 10 lives saved annually ÷ 360 million tons = .04¢/ton/life saved

CHAPTER 11

SHUTTLE HAULAGE

I. STATEMENT OF THE PROBLEM

Shuttle haulage fatalities, accounting for 11.6% of all fatal accidents in the period 1966-1970, are a major area of concern. Unlike the fatality trend in many other accident categories, shuttle haulage and tramming fatalities are not decreasing; the data for the past 3 years, in fact, indicate a slightly increasing trend. At the same time, this area offers high potential for reducing fatalities, since improvements in shuttle equipment and procedures are applicable in both continuous and conventional mining operations.

Shuttle car drivers, having the highest number of fatal accidents in the period 1966-1970, are subjected to a variety of hazardous exposures. In addition, they are often the cause of fatal accidents to other workers -- mostly due to collision. Eighty-five fatalities involving shuttle haulage and tramming were recorded for the five-year period -- 60 involving the shuttle car operator, and 25 involving a pedestrian or other machine operator. Only 11 of these 85 were the result of roof and rib falls; the remainder associated with some type of moving machine accident -- primarily crushing or pinning of the victim between the shuttle car and the rib or roof.

It is interesting to note, again based upon five-year fatality data, that fatal shuttle accidents are $3\frac{1}{2}$ times more likely to occur in seam heights less than 5 feet than in seams greater than 5 feet. The reasons for this are: 1) the increased possibility of the operator's head being pinned between the roof and the machine, 2) poorer visibility in low and medium coal, and 3) a generally less satisfactory mine environment in small, independent, low seam mines, having rough uneven floors, crooked entries, uneven pillars, etc.

II. ANALYSIS OF THE PROBLEM

The Fatality Report Analysis portion of this study reveals some significant and perhaps little known facts about fatalities occurring while operating shuttle cars: 1) shuttle haulage is an extremely hazardous activity, accounting for nearly 12% of all fatal accidents; 2) roof falls are not a major problem, as they are with the operation of other major pieces of section equipment; 3) crushing/pinning accidents against ribs, rib-roof intersections, and roof are the major hazards, accounting for over 80% of all fatal accidents involving the operator of the shuttle car during hauling and tramming; 4) shuttle haulage is dangerous not only for the operator, but for pedestrians and other equipment operators moving in the working section. During the five-year period, 14 men were crushed by secondary haulage vehicles while operating some other piece of face equipment; 11 were killed while standing, crawling, or walking in the working section.

Pinning/crushing accidents result from the operator's dangerously exposed operating position on the side of his shuttle car. He is, in effect, riding on the "running board" of the vehicle, with the consequent chance of being squeezed between the side frame of his machine and any solid object which the shuttle passes too closely (rib, another machine, etc.). In low seam mines, the operator is exposed to the danger of vertical crushing as well as lateral crushing as he may also get his head caught between the top of the machine and some irregular projection from the roof.

The pedestrian and other-operator fatalities discussed above are primarily the result of poor visibility and the lack of tailored-response controls. Guiding a massive machine through tight entries with low roof and almost moonlight level lighting is a real challenge. The degree of difficulty is compounded by the presence of other workers, machines, blind penetration of ventilation curtains, overhanging ribs and numerous roof, bolt and truss projections which are all but invisible. As mines become more mechanized and operate at a faster pace, these dangers are increasing despite the upgrading of present equipment.

The visibility problem is mainly generated by inadequate vehicle lighting. Equipment lights observed by TB & A consultants during their underground observations were most often covered with thick layers of rock and coal dust. Often lights had been broken-out and left unrepaired; several workers admitted that lights are often broken "accidentally-on-purpose" in order to reduce the nuisance of glare for other section personnel.

Most shuttle cars encountered by TB & A consultants lacked tailored-response controls. Consequently, control response is abrupt and results in almost convulsive movement. (In fact, the controls problem applies not only to shuttle cars, but to most major pieces of section equipment.) For the reader who is unfamiliar with the technical and mechanical aspects of underground mining equipment, it may be difficult to visualize the problem being described here. An analogy which helps in understanding the difficulties and dangers associated with present controls may be useful. Imagine the difficulty of attempting to park a large, stick-shift automobile in a one-car garage, with the accelerator stuck at full throttle. In such a situation, the driver's only available power control lies in engaging and disengaging the clutch. The driver's problem is not too unlike the shuttle operator's problem in negotiating 90° turns in narrow entries and attempting to maneuver his vehicle with some precision into a 20-foot wide working face area behind the continuous miner or mechanical loader. Shuttle cars with direct-drive provide almost an on/off response, with consequent wheelspin when starting. Convulsive control response is not only a tramming problem, but applies to boom and conveyor movement as well.

In dealing with all of these problems -- operator protection, visibility, sensitive controls -- another major variable must be considered in order to prevent it from becoming an additional problem -- operator comfort. An uncomfortable position will tend to fatigue the operator, possibly cause him to hurry in order to minimize his discomfort, and tempt him to get out of the car or tractor unnecessarily. Ease of operation also includes ease of entry and exit since the operator must help with a variety of other work functions such as setting posts, dusting, etc. Some of the almost prone position, fully enclosed canopy designs now being considered by manufacturers would fail all of these tests and might result in a shortage of experienced operators if they "bid out" from the operator position in order to avoid discomfort. This situation is already present in the roof bolting operation which is fast becoming an entry level job despite its personal danger and the dependency of others on the quality of performance.

The solution concepts that address these problems are:

A. Articulated Shuttle Car Concept with Central Seating

The most significant potential safety improvement in shuttle car design is the use of articulated sections which permit a central seating arrangement for the driver. Central seating dramatically improves visibility while moving toward the face from the belt over that obtained in a conventional shuttle car with rear corner seating, with some visibility impairment moving in the opposite direction. In addition, the operator is protected from: 1) potential pinning/crushing accidents from ribs, posts, and other vehicles; 2) the danger of rib falls. Because of the articulated movement of the vehicle made possible by the "joint" in the middle, the vehicle is much more maneuverable and less likely to "round-off" the corners of pillars at intersections, even in narrow room widths. It offers some lateral adjustment while loading without back and forth movement, and has the potential for faster unloading which may compensate for the extra 180° maneuver needed to position the load for dumping. A residual benefit is the elimination of the metal on metal conveyor -- a maintenance and noise level improvement.

Centered seating offers substantial improvement in riding qualities when compared to the cantilever seating in many cars. Aside from the increase in riding comfort, this location tends to mitigate the effect of running over bumps and other large objects left on the floor. These obstacles tend to project the operator toward the roof causing head and neck injuries and a potential loss of machine control. The up and down movement of most cars is quite harsh, and any improvement in this area would increase control and operator safety.

Perhaps the most practical advantage of this type of shuttle car is that it is an off-the-shelf item requiring no R & D investment or lead-time. At least one equipment manufacturer -- Jeffrey -- currently produces a car with this design.

The following illustrations show the principle advantages of the articulated shuttle car with central seating:

FIGURE 1

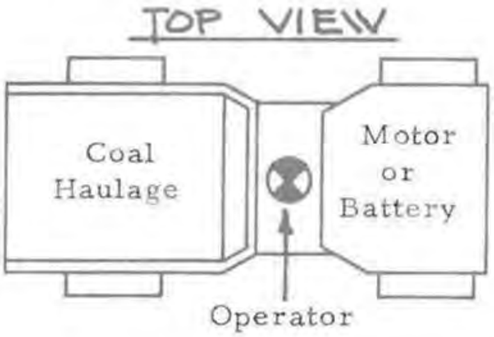
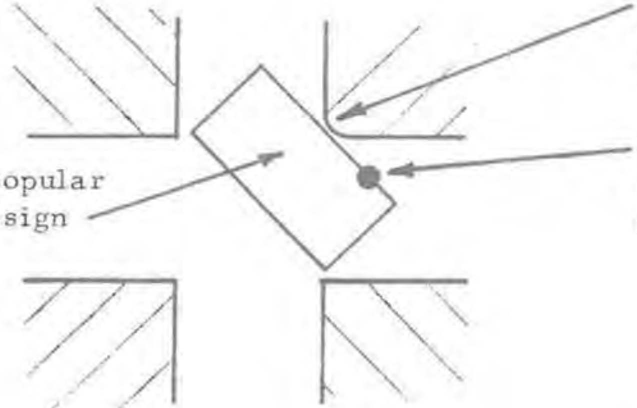


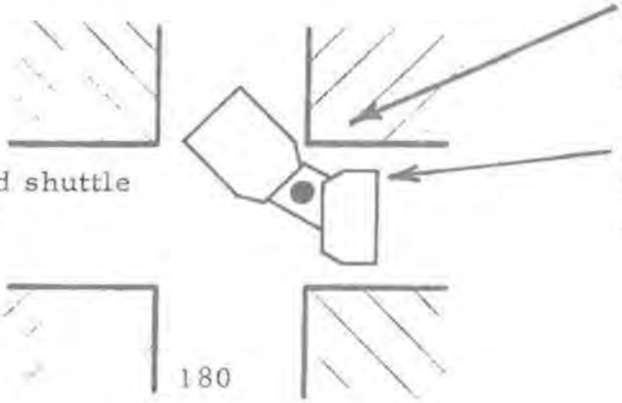
FIGURE 2



Shuttle often bangs into pillar while cornering, rounding pillar off.

Operator can be crushed against rib, post, other machines.

FIGURE 3



Shuttle "bends" or articulates, allowing easier cornering.

Operator is protected from crushing/pinning accidents.

B. Cage Protection on Shuttle Cars

As discussed before, roof fall fatalities represent less than 15-20% of the accidents on shuttle cars. Lateral collisions with ribs and other equipment, and low overhanging roof, headers, and rib-roof brows represent the major hazard. Only very strong lateral protection on shuttle car operator corner or side positions will prevent the majority of shuttle car accident injuries. Central seating, even without any protection, would have avoided injury in many of the fatal injury accidents.

In low coal, canopy or cages added to existing designs of shuttle cars represent a difficult problem because of limited vertical space. A low coal compromise cage design may be the best answer available as discussed in the previous chapter. An additional aspect of the low coal operator protection problem is the warning time available to the operator to avoid a collision. Shuttle car speed, although not great, lessens the time to react to obstructions or low overhangs. Because of visibility problems, some operators killed in collision accidents with rib or roof were likely not aware of the clearance problem until impact. An effective advance feeler or warning device, even ten feet ahead of the operator, might have saved some of the operators. Needless to say, checking clearances on shuttle car routes prior to runs also might have helped avoid some of these collision accidents, but such procedures would not be reliable considering that roof and floor often are continually converging near face areas as mining proceeds.

A conceptual sketch of a low coal cage design with a warning feeler device is shown in Figure 4. The design with an open top is controversial, but may provide sufficient protection to a high percentage of potential fatal shuttle car accident victims without sacrificing visibility or creating extremely cramped or uncomfortable operator space.

FIGURE 4

CONCEPTUAL SKETCH
OF LOW COAL CAGE DESIGN
FOR CENTER-SEATED SHUTTLE CARS

We believe it is important to be practical and carefully investigate the cage/ canopy issue. Based upon the sample of mines encountered in this study, we believe that strong and even emotional resistance exists throughout the industry with regard to canopy requirements for shuttle vehicles in medium and low coal. Much of this resistance undoubtedly grows from management's natural desire to avoid non-productive investment in new or modified equipment. We feel part of their resistance, however, stems from the possibly accurate belief that canopies create even greater hazards than those they protect against. Only 2 of 17 shuttle haulage accidents anticipated yearly in the early 1970's would be expected from roof falls. Is there a possibility that severely reduced visibility from adopting canopy designs would increase the number of collisions and cause 2 or more fatal injuries? Only careful research will resolve the issue.

One more point about cages is worth making. Assuming the comfort obstacle in cages can be overcome with good design, a miniature wide-angle periscope might restore the visibility lost by lowering the operator's head below the cage. Combat vehicles sometimes must rely exclusively on this type of visibility under certain conditions, so this concept is not new. The wide-angle periscope would only be supplementary underground and would provide object identification, not depth of field. The designs could pivot to provide maximum height and avoid damage from roof projections.

C. Improved Control Response and Improved Lighting

These problems have been noted and described in earlier sections. We do not know the technical problems involved in developing tailored-response controls but feel that a variable power lever is not technologically infeasible. Miners who break out headlights to reduce the glare have probably created an even greater hazard to machine operators and pedestrians than the hazard created by the glare of current equipment lighting designs. In this regard, directional beam lamps or indirect lighting designs may prove a useful concept in an attempt to compromise the conflicting hazards of poor lighting and glare. In addition, USBM inspectors should strive to ensure that vehicle lighting conforms to already existing requirements in the law.

D. Miscellaneous Improvements

There are a number of other modifications that might contribute to haulage safety. Factory painted roof bolt plates would ensure better visibility, increase depth perception and, in the case of face equipment, make the last row of bolts more apparent. White plates would be visible even after rock dusting since the surface would be white on white and reflect more light than white on the typically black roof. The paint would not add significantly to the cost of the plate if applied on the production line. (Note: This plate should also be lubricated at the point of contact with the washer type bolt head. A "halo" of sparks usually accompany final torquing and the resistance of metal on metal probably makes torque readings more variable. These two small washer changes are oriented toward explosion and roof hazards.)

Battery-powered shuttle cars or tractors eliminate a major safety and maintenance problem of trailing cables, but at the same time have some technical problems. Batteries have limited operating time, are expensive, and need to be changed on-shift. Maintenance of battery housings is another problem because of the high humidity and rapid oxidation of metals near the battery. An inert enclosure might overcome this obstacle. If the technical problems of heat gain and permissible quick charging can be solved, the battery-powered equipment would be safer and more efficient than cable machines. A typical shuttle car requires approximately 30 seconds to dump to a feeder or railcar. It may be possible to develop an automatic quick charge station which would provide power for the unloading conveyor and charge a relatively small tramming battery for round trips to the face. The battery could also provide power for minor load adjustments required by the machine's conveyor while loading. The quick charge station would have to be automatic to avoid delays and ensure permissibility and personal safety.

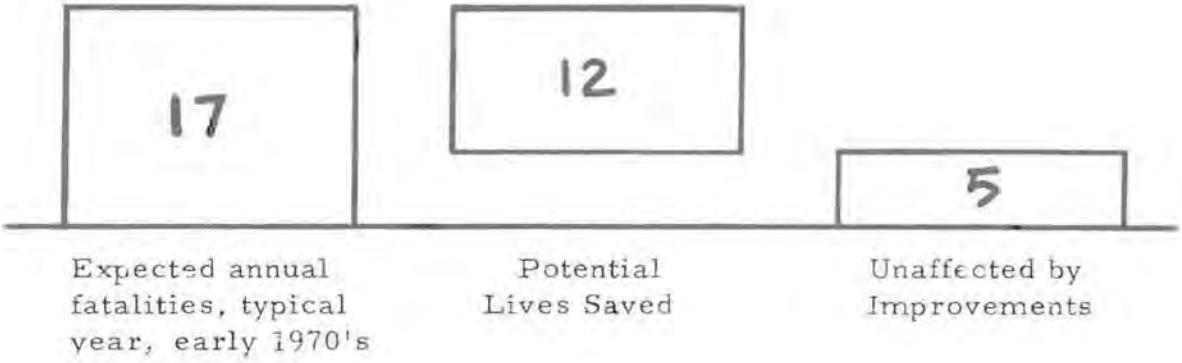
III. SUMMARY OF RECOMMENDATIONS

Two major equipment improvements can reduce shuttle fatalities dramatically. The first is the use of shuttle cars employing central-seating, thus eliminating crushing/pinning-type fatalities against ribs and rib-roof intersections. The second is the use of operator cages or canopies in low and medium coal to reduce roof pins and roof fall fatalities.

Improvements in several other areas will reduce pedestrian and machine operator fatalities caused by collisions with shuttle cars: 1) tailored-response controls, 2) improved lighting, and 3) a move toward internally powered (battery) shuttle cars.

IV. POTENTIAL LIVES SAVED ANNUALLY

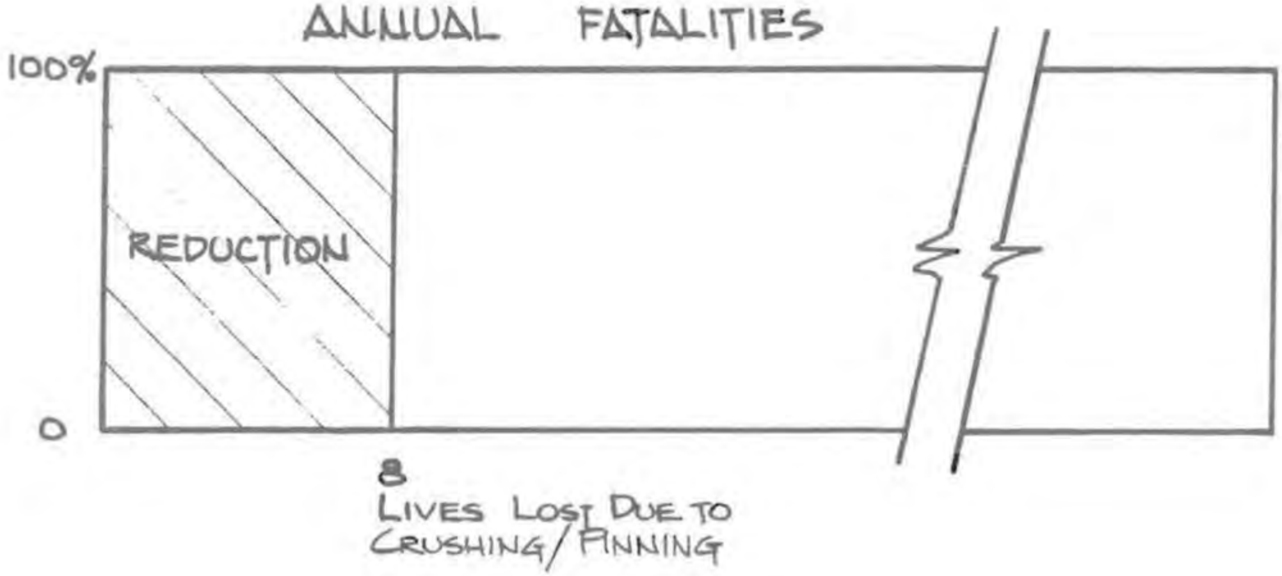
Potential Lives Saved: 12



Based upon the slightly increasing trend in fatal accidents occurring during shuttle operations, we can expect 17 fatalities annually -- 15 equipment accidents and 2 roof falls. Of the 15 equipment accidents, 10 will involve fatal injury to the shuttle car operator, while 5 will involve fatal injury to a pedestrian or other vehicle operator.

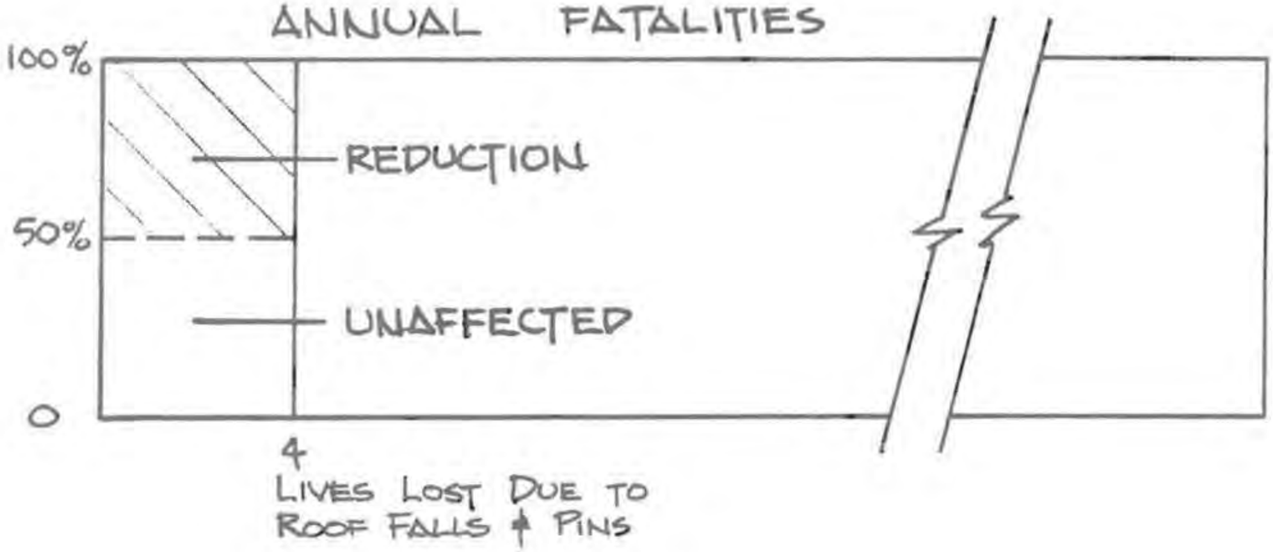
Central-seating could eliminate all fatal rib, rib-roof, post, and machinery crushing injuries to the shuttle operator by removing him from the point of collision -- saving approximately 8 lives/year.

POTENTIAL FATALITY REDUCTION:
NON-ROOF CRUSHING/PINNING ACCIDENTS -
SHUTTLE CAR OPERATOR



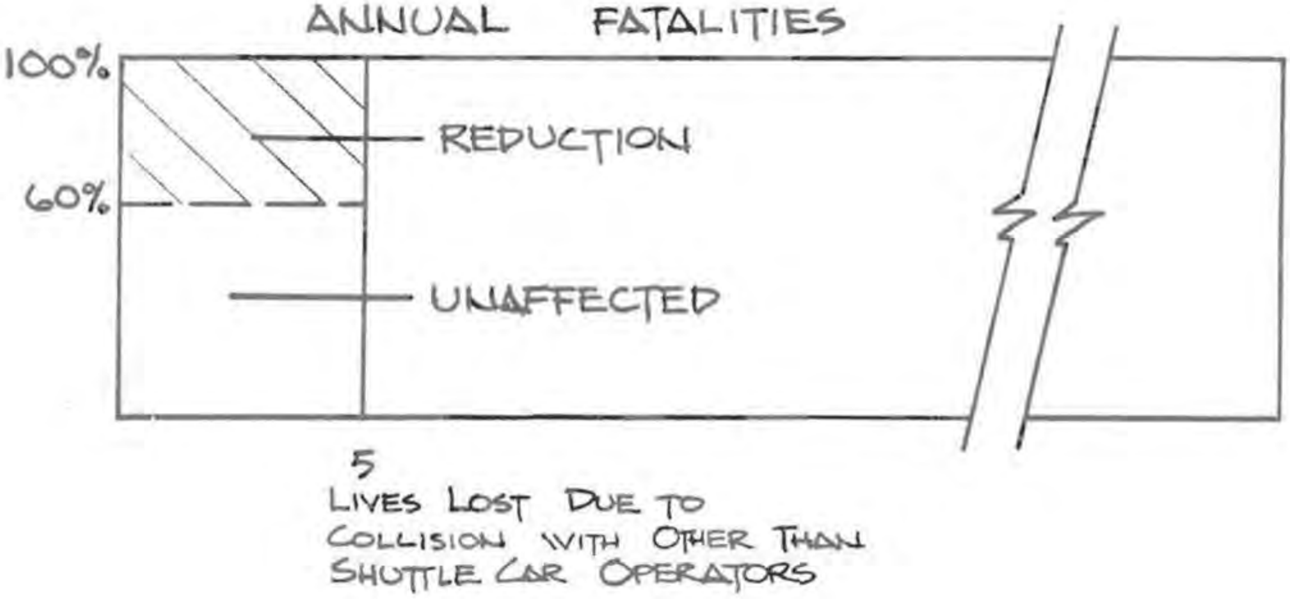
We estimate that cage protection on the center-seated shuttle could prevent 1 of 2 fatal roof fall fatalities and 1 of 2 fatal roof pinning fatalities.

POTENTIAL FATALITY REDUCTION:
ROOF FALL AND ROOF PINNING ACCIDENTS -
SHUTTLE CAR OPERATOR



The improved visibility inherent in center-seating, combined with improved control response and better lighting, could save 2 of 5 non-operator fatalities -- i.e., pedestrians and other equipment operators -- resulting from shuttle collision.

POTENTIAL FATALITY REDUCTION:
SHUTTLE COLLISION WITH PEDESTRIANS AND OTHER OPERATORS



In summary, we estimate that 12 of 17 annual fatalities could be prevented by the recommendations discussed in this project.

V. COST TO IMPLEMENT RECOMMENDATIONS

1. In the case of the center-seated, articulated shuttle, implementation of the recommendation is more difficult than solving the technical aspect of the problem. Assuming that there are approximately 8,000 shuttle cars in active use, the total cost of complete, industry-wide use of the articulated shuttle would be:

$50,000 per shuttle (approximate) X 8,000 = $400,000,000

This works out to about $40,000,000 annually based upon a 10-year amortization, or about 11¢ per ton of coal. These figures indicate that a massive, "all-at-once" shift to this type of vehicle is probably impractical.

A more realistic approach would be a required "phase-in" of the center seat design as old equipment is depreciated or as a particular mine is worked out, with a final deadline date for required use. USBM has utilized a similar approach before with permissible equipment. The effect on fatality reduction would not be as immediate or dramatic using this approach, but industry resistance would be minimized.

2. The cage concept requires little or no R & D or design investment. The degree of technical complexity does not appear to be significantly greater than that involved in installing a roll-bar on a sports car. A workable cage could probably be installed on most shuttle cars for about $500.00 per vehicle. As an interim measure, cages installed on present, side-seated shuttles would save some, but not all, of the lives which could be saved using the center-seated car. The approach to cage utilization in low and medium coal is dependent upon the system of implementation required for use of center-seated shuttles, since the two concepts are closely related.

   In summary, we estimate that 10 lives annually could be saved through the combined use of central-seating and cages. But the industry cost of such changes depends upon the system of implementation. Therefore, cost effectiveness estimates -- i.e., cost of implementation per life saved -- are not possible at this point.

3. The cost of improved control response and improved lighting is unknown. A move toward battery-powered vehicles might affect shuttle fatalities indirectly by reducing hazardous maintenance situations caused by the need for cable repair, etc. The elimination of cabled vehicles, however, would not directly affect shuttle fatalities. (Note: Elimination of cabled vehicles would obviously affect fatal electrical maintenance injuries; see Chapter 9, Maintenance Fatalities.)

CHAPTER 12

MACHINE LOADING ROOF FALL ACCIDENTS

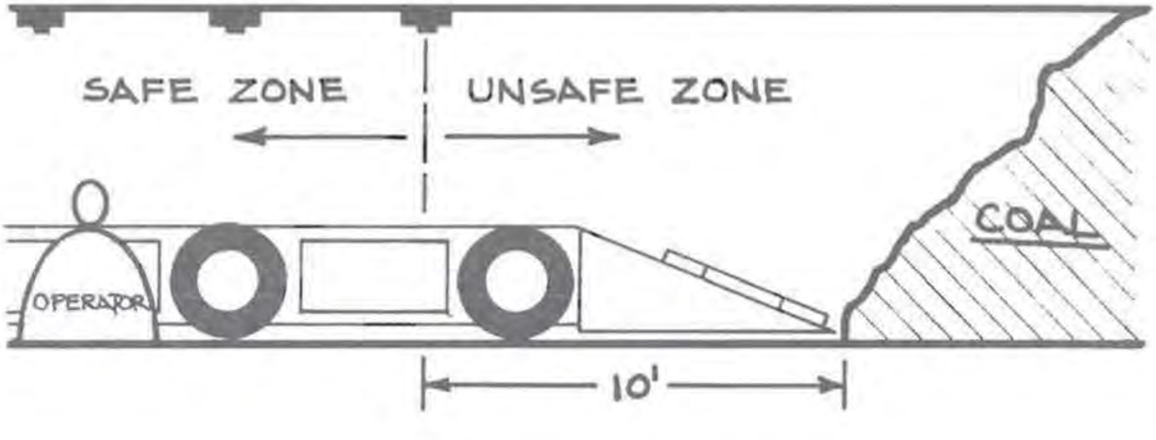
I. STATEMENT OF THE PROBLEM

Forty-two men lost their lives during 1966-1970 from roof falls while they were operating loaders in conventional type mines. Half of these men were killed working under unsupported roof; one-fourth were killed working in areas incorrectly supported (in violation of the support plan); and one-fourth were killed working under approved roof support.

II. ANALYSIS OF THE PROBLEM

A. Unsupported Roof

POTENTIAL MOVEMENT UNDER UNSUPPORTED ROOF



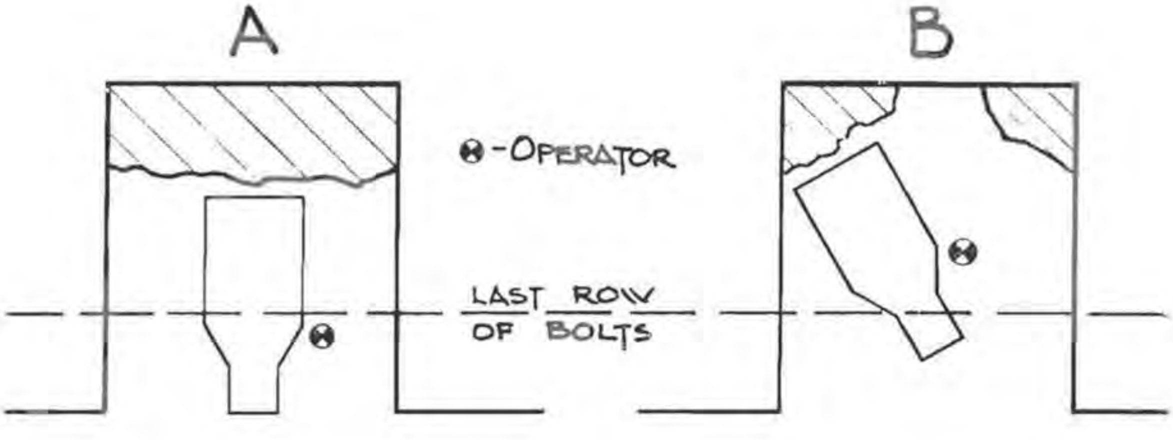
Half of the fatalities while operating a loader were experienced by persons other than the regular loader operator. An analysis of the fatality data shown on the next page indicates that there is no difference in the factors shown between the "other" operators and the regular operators with regard to the percentages of roof fall accidents while operating loaders.

JOB TITLE	FALLS				VICTIM UNDER ROOF				Total Fatalities	
	Approved plan*		Violation of plan*		Unsupported Necessary		Unsupported Unnecessary			
Regular Operator	6	14 %	6	14 %	1	2 %	9	22 %	22	52 %
Other than Regular Operator	4	10 %	5	12 %	0	–	11	26 %	20	48 %
TOTAL	10	24 %	11	26 %	1	2 %	20	48 %	42	100%

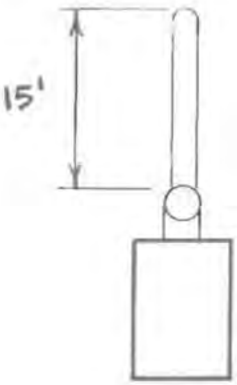
*Roof control plan

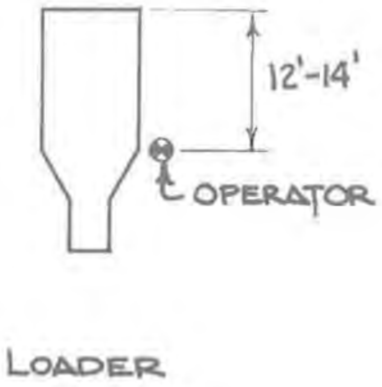
1. Undercutter Operator

The undercutter operator determines the depth of the face cut by his sump, and establishes the penetration required to load out the coal during the subsequent loading cycle. The safe penetration distance of the undercutter is therefore that which allows the loader operator to remain under supported roof at all times. For example, a loader operator may be able to load safely as long as he loads perpendicularly to the face (see A); but when he positions the loader to load coal at either corner of the base, the penetration depth required increases 20 %. At this time the operator is frequently beyond the last permanent support and is exposed. (see B)



In other cases the undercutter blade (which may range from 9-15 feet on different models) may cut a section of coal which, if completely shot out, puts the loader operator under unsupported roof as he draws near the end of his loading cycle, even if the loader is kept perpendicular to face. This case is diagrammed below.





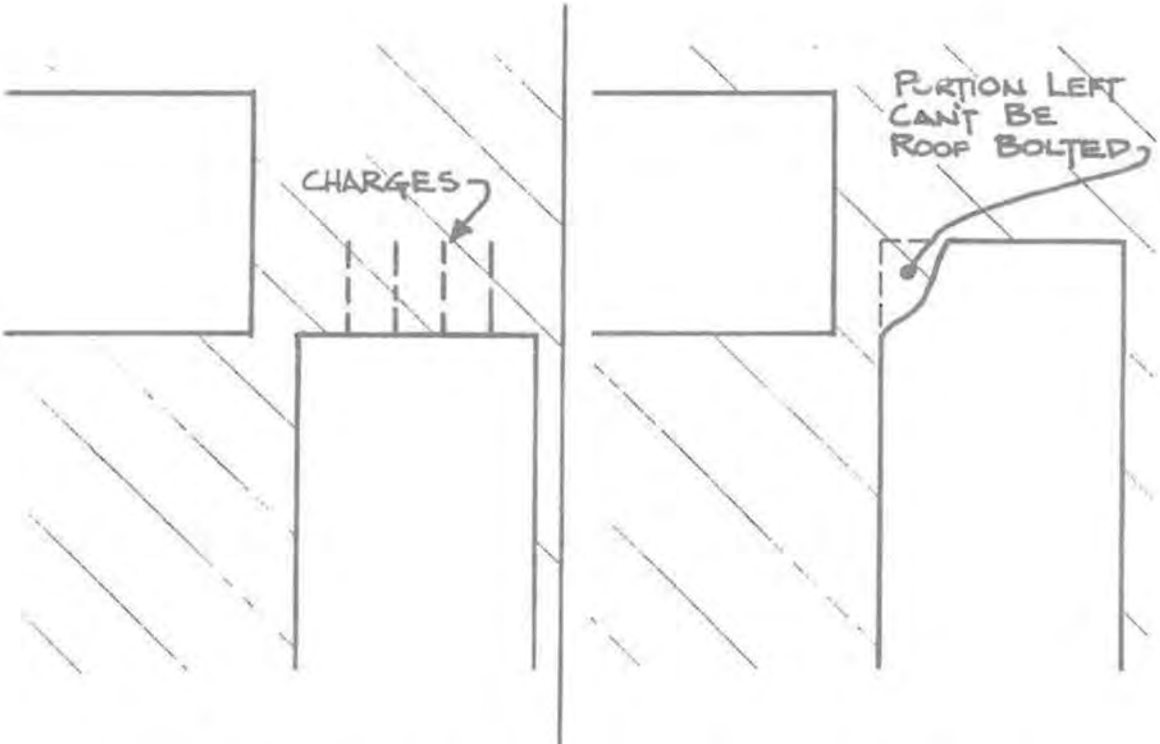
2. Coal Shooter

The coal shooter also affects the penetration required to load out the coal during the next loading cycle by the size and location of the charges. An example of this was observed during the field study:

The left corner of a face was butted to a new break with a thin partition of coal between the break and the face. The face was undercut and shot. A 10-foot section of wall and face was left after shooting, and the roof bolter was unable to position his equipment in the 10-foot area to drill and insert roof bolts. The loader operator was, therefore, tempted to work under unsupported roof. This situation can occur in varying degrees of severity every 4-6 cuts, whenever a new break occurs.

In theory, the safer procedure in this case would be for the roof bolter to enter and bolt after a partial loading cycle, followed by re-entry of the loader. However, during the underground observations conducted during this study, this safe procedure was never seen.

Hence, a more practical procedure may be to rely on matched equipment to minimize the number of times this situation would occur.

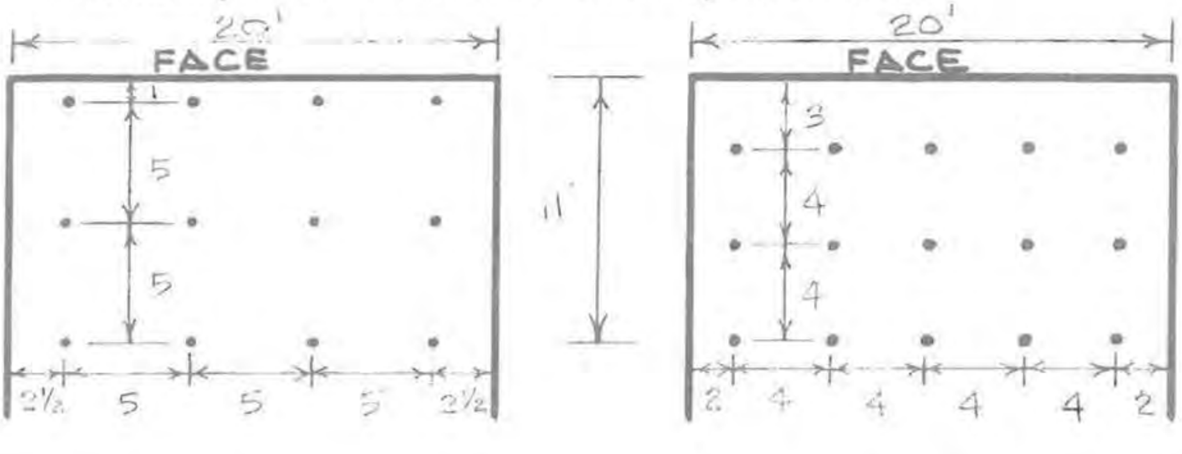


BEFORE SHOOTING

AFTER SHOOTING

3. Roof Bolter

When the undercutter penetration is not matched to the approved roof bolt plan, the loader operator is further endangered. An 11' cut with a 4'x4' roof bolt pattern, for example, leaves a 3 foot unsupported area at the face. But a 13' cut with a 4' bolt pattern, or an 11' cut with a 5' pattern leaves a safe one-foot unsupported area at the face. Two examples are shown in the following illustration.



SAFE PATTERN

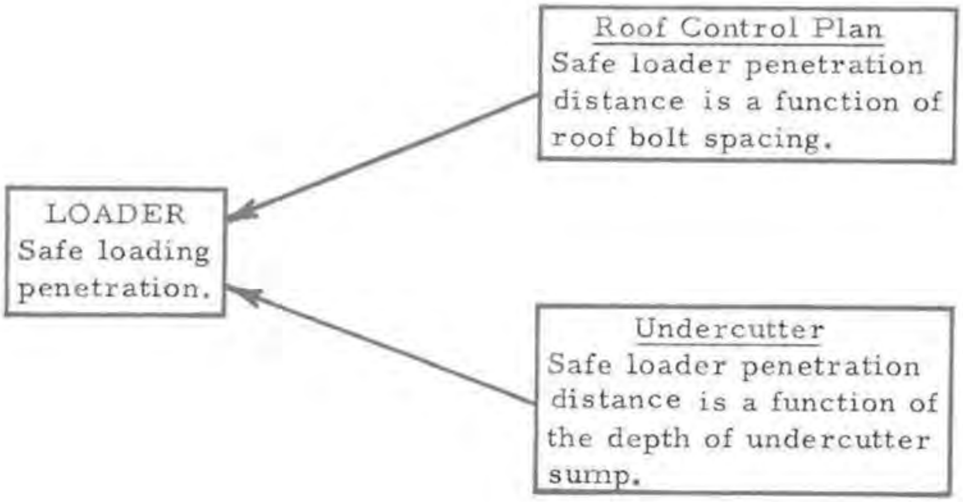
HAZARDOUS PATTERN

We have observed some coal operators increasing the number of roof bolts required in an attempt to insure compliance with the approved roof control plan. This can change the distance to the face of the last row of roof bolts, creating a hazardous exposure situation for the loader operator.

4. Loader

The loader operator sometimes needlessly exposes himself to unsupported roof conditions. He frequently trams from the face just loaded directly to a new break joining that face. When he trams directly instead of performing the proper tram out and tram around to the supported area of the break, he advances the loader directly to the break under unsupported roof and repeats the loading cycle under the unsupported roof.

In summary, loading, undercutting, and the roof bolt plan are interrelated and must be considered concurrently when trying to ensure loader safety.



Roof Control Plan
Safe loader penetration distance is a function of roof bolt spacing.

LOADER
Safe loading penetration.

Undercutter
Safe loader penetration distance is a function of the depth of undercutter sump.

If this is not done, the loader operator either works under unsupported roof conditions or a loss of production results as the loader endeavors to remain under supported roof.

Choice of equipment is presently a management function, and modifications to equipment which can affect production operations are largely voluntary. Miners' refusal to work under unsupported roof can be a powerful lever in generating modifications which will prevent hazardous exposure to the miners (e g., stops on undercutter blades to control sump depth).

Alternatively, there may be some safety benefit in regulating (i.e., USBM regulation) equipment matching. For example, a 15 ft. cutting bar would be permissible only when used with certain machine loading equipment; it could not be used in conjunction with any machine loader whose physical dimensions put the operator under unsupported roof during any part of the loading cycle after a 15 ft. cut. Equipment matching tables would be easy to develop. An example is given below.

TYPE LOADER	MAXIMUM CUTTER BAR LENGTH
GOODMAN 970-L	9 ft.
GOODMAN 870-LW	9 ft.
GOODMAN 968	13 ft.
JOY 14BU10-41	11 ft.
JOY 14BU10-11A	9 ft.
JOY 14BU10-41B	11 ft.
JOY 14BU10-41C	9 ft.
JOY 14BU10-11C	11 ft.

B. Support Plan Violation

All fatalities from roof falls attributed to support plan violations have decreased steadily from 1966-1970. Roof fall fatalities caused by temporary support violations have dropped dramatically, while the decrease in fatalities due to permanent support violations has been more gradual. (Note: While legal "violations", *per se*, were not possible until USBM approval of roof support plans became a requirement in 1970, "violations" of company roof support plans were noted in 1966-1969 fatality reports.)

Roof fall fatalities experienced by machine loaders followed the same trend. 1970 showed no temporary support violation fatalities and only one permanent support violation fatality. Increased knowledge, better training, and stronger law enforcement are responsible for the reduction in this category of fatalities.

The roof fall fatalities that occur while operating loaders under roof in violation of the approved support plan can be further reduced through increased efforts by the USBM inspectors to recognize roof control plan violations and enforce compliance. Although inspectors presently have sufficient enforcement capability, some inspectors have told us that they sometimes lack either familiarity with specific roof control plans or the time to measure deviations from the approved plans.

Miners also must be trained to recognize support plan deviations, must be taught to avoid deviations themselves, and must be discouraged from working within violation areas.

C. Approved Roof Support

All categories of roof fall fatalities decreased during the 1966-1970 period except for the approved permanent support category, which increased. The same relationships hold when broken down for machine loading fatalities from roof falls.

When roof fall fatalities from violations of permanent support (which decreased) are added to the approved permanent support roof fall fatalities (which increased) there is a slight increase in the total number of fatalities resulting from roof falls of supported roof. If the slight fatality increase is normalized by annual tons produced to arrive at fatalities per million tons, however, there is a slight improvement in the fatality record.

Although the analysis of fatality data indicates that fatalities from roof falls are declining, the category -- approved roof support fatalities -- is increasing. (See note on the changed definition of violations, preceding page.) This is true in spite of the in-depth attention given to roof support research by the USBM. TB & A consultants were concerned by the lack of awareness of USBM research efforts and USBM technical information regarding roof support on the part of many management personnel -- particularly small, independent operators. This fact seems to indicate that dissemination of existing data to the operating industry should be as important a goal for the USBM as additional research.

III. SUMMARY OF RECOMMENDATIONS

A. Unsupported Roof

1. Encourage loader operators to refuse to work under unsupported roof.

2. Regulate depth of undercutter sump to insure that loader penetration depth does not put loader operator under unsupported roof; this may include putting stops on undercutter blades.

3. Match the penetration depth of the loader to multiples of the established roof bolt pattern to minimize the distance between the last line of support and the face, thereby reducing the loader operator exposure to unsecured roof during the second loading cycle.

B. Support Plan Violation

1. Emphasize USBM inspector enforcement of approved roof control plans. This may take the form of both additional inspections, and more thorough inspections of roof control compliance and roof control problems.

2. Encourage loader operators to refuse to work in roof control violation areas.

C. Approved Roof Support

1. Inadequate Support

Increase training of USBM inspectors in roof control problems and correction techniques so that they can recognize and transmit roof control inadequacies to the respective sub-district offices for prompt remedial action.

Disseminate information on roof control from USBM Research Laboratories to all coal operators and USBM inspectors.

2. Non-Controllable

Non-controllable refers to supported roof falls which can not be anticipated nor prevented with local area knowledge of roof control and lithology.

a. Determine level of local area knowledge of roof control and lithology.

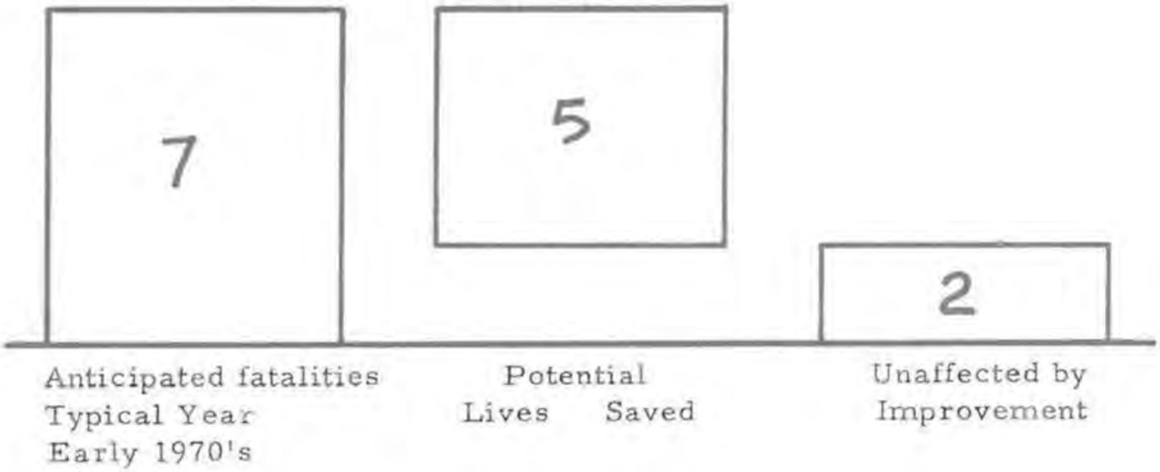
b. Determine level of usable research information and whether the level is sufficient to contribute to a reduction of non-controllable supported roof falls.

c. Up-date USBM inspectors in new roof control technology.

d. Review and upgrade approved roof control plans of mines with a supported roof fall history.

IV. POTENTIAL LIVES SAVED ANNUALLY

Potential Lives Saved Annually: 5



Installation of the recommendations in this chapter are estimated to result in the saving of five of the seven loader operator lives expected to be lost each year in the 1970's. We feel that proper matching of equipment can save three lives; closer attention to approved roof control plans, one life; and the dissemination and implementation of recent research findings on roof support, one life.

V. COST TO IMPLEMENT RECOMMENDATIONS

1. Unsupported Roof

There is no immediate cost if coal operators match equipment to the best of their abilities within their specific equipment array.

2. Support Plan Violation

There is no true additional cost for compliance to the approved support plans.

3. Approved Roof Support

It is estimated that three man-years at $15,000 per man-year would be required to gather, collate and distribute roof control research on roof support technology to the operating industry.

$$\frac{\$45{,}000 \text{ for study}}{(1 \text{ potential life saved annually} \times 360 \text{ million tons})} = \begin{array}{l} \$45{,}000 \text{ estimated} \\ \text{cost per life saved,} \\ \text{or } .01¢\text{/ton/life saved} \end{array}$$

CHAPTER 13

ALTERNATIVE EQUIPMENT MODIFICATIONS

I. STATEMENT OF THE PROBLEM

There are many equipment modifications which can contribute to fatality reductions by eliminating the hazard itself, reducing the exposure time of the operator, or eliminating the need for an operator to be exposed. The modifications presented here are mainly low cost changes, which should be considered as alternatives to implementing the major equipment changes outlined in other sections.

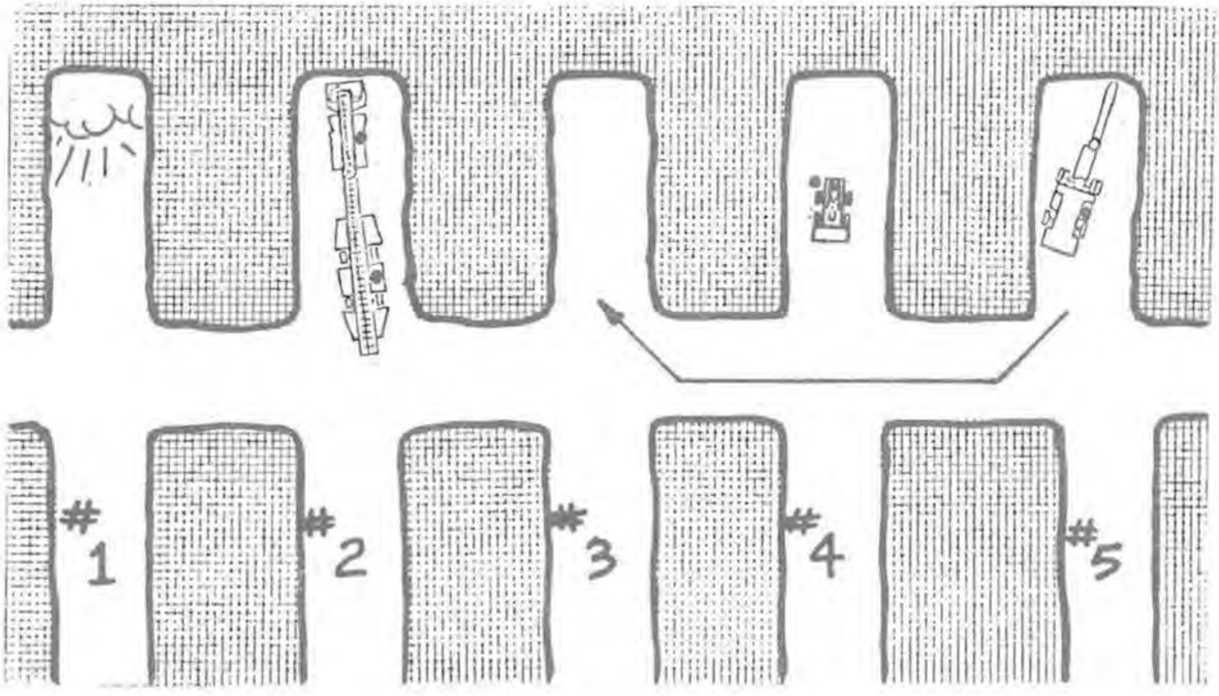
II. ANALYSIS OF THE PROBLEM

The problems and solutions contained in this chapter weave in and out of other projects. The reason for repetition of some items is to add emphasis to the severity of the problems, and to show that the causes for some high frequency fatalities may have simple solutions.

A. Undercutter

The undercutter should theoretically be a very safe face machine. The operator should never need to be under unsupported roof since he follows the bolter in sequence. However, in fact there have been six fatalities where the victim was needlessly killed by a roof fall under unsupported roof.

In these cases it was found that the undercutter sometimes skipped ahead of the bolter because of the slower bolting cycle and undercut in a face area which the bolter had not yet secured. This situation was observed by TB & A in several mines.



Description: Loader has finished in #3, moves to #2; bolter is still bolting in #4; cutter has finished in #5; cannot move to #4 because of RB; wants to get out of way so shot fireman can move from #1 to #5.

The most effective way to reduce these undercutter roof fall fatalities is to design greater efficiency into the roof bolter to shorten the bolting cycle time, and reduce the temptation for the undercutter to skip ahead.

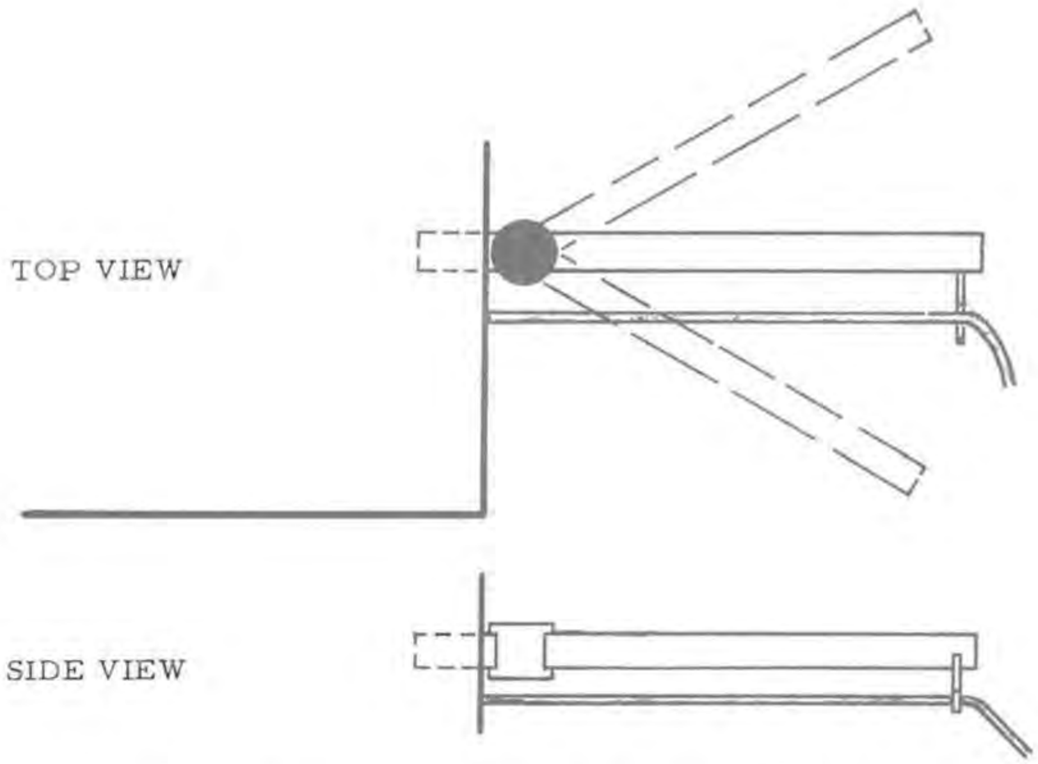
B. Loader

1. Flexible Arm Extension

The addition of a flexible arm extension at the rear of the loader (also the continuous miner) and cable takeup and payout reels would eliminate the primary function of the high-risk job of helper. An illustration of the arm extension is shown below.

FLEXIBLE* CABLE EXTENSION

*Arm Gives Under 30-40 Pound Resistance

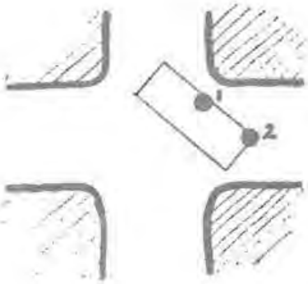


The major task of the helper is to move cables and hoses while the operator is changing location of the equipment within the face area. Because the operator cannot see the helper who is at the rear of the machine, the helper is frequently pinned or struck by the machine. Cable devices that will perform the same functions as the helper are the logical way to reduce the helper fatalities.

There were 27 fatalities of helpers who were performing tasks directly related to the equipment, and 34 fatalities while the helper was performing tasks indirectly related, for a total of 61 fatalities from 1966-1970. The argument for using helpers so they can be trained as operators is a very costly rationale in terms of lives lost. Based on our 50-mine sample, we estimate that only 30% of the loaders utilize helpers. (Virtually 100% of the continuous miners, however, utilize helpers.) We estimate 2/3 of these positions could be eliminated on an industry-wide basis.

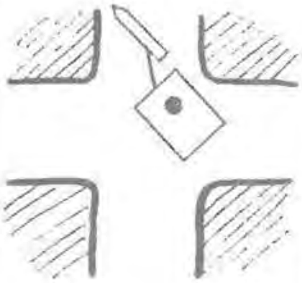
The impact of machine dimensions upon safety should be considered on all future loader designs, as the loader usually has the greatest width and height dimensions of any face equipment. The loader is difficult to negotiate around corners. This difficulty contributes to the destruction of ribs at intersections, which contributes to rib falls and roof falls because the area of the intersection is enlarged.

SHUTTLE CAR



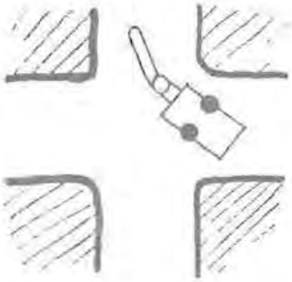
Shuttle car, typically about $24\frac{1}{2}$' long by 9' wide, clears corner easily. Operator has some protection -- since he is protected in recess near wheels, usually at 2 , sometimes at 1 .

FACE DRILL



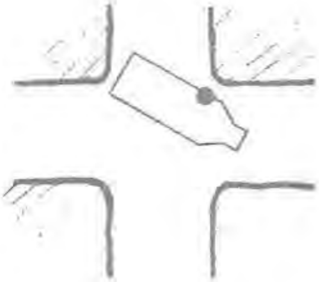
Although 11' wide, face drill frame is usually only 15'-16' long. Corners easily turned. Operator has protection in recess between wheels, as shown.

FACE CUTTER



Cutter frame usually only 9'-10' wide by 15'-16' long. Corners easily turned. Operator protected on either side in wheel recess.

LOADER



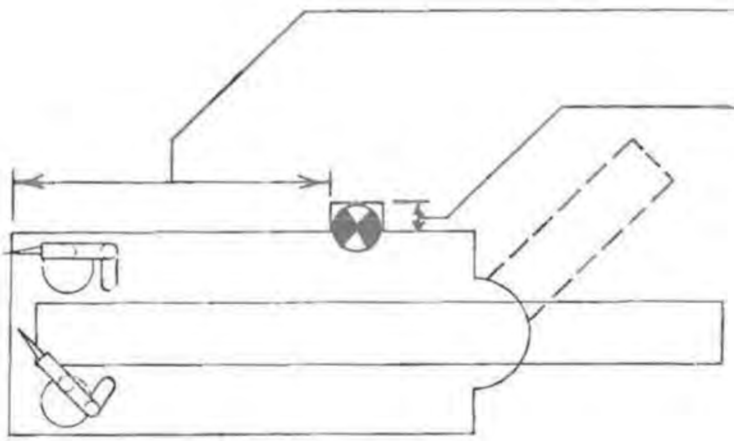
Loader dimensions typically about $28\frac{1}{2}$' long by 9' wide. Operator sits facing in (on other machines operator normally sits facing front or rear (to face). He sits outside tracking gear on small, unprotected flat seat, about 18" wide. Two hazards compounded:
1) size of machine necessitates close rib clearances.
2) operator position is highly exposed.

2. Operator Protection

The machine loader is inherently the most dangerous piece of face equipment to tram or operate. The operator's silhouette extends 8"-10" beyond the frame of the machine, making him highly vulnerable to crushing lateral forces (machines, ribs, etc.). Fifty-seven miners were crushed in the period 1966-1970 because their equipment had no side protection or no seat at all.

A solution to the crushing fatalities experienced by the loader operator is to locate the operator further back on the machine so that his silhouette lies completely within the frame width -- then to build a cage around him. This places the operator in a location where he is able to escape both over and under the conveyor. In addition, the extra 5'-7' of linear distance from the front of the loader allows him to penetrate further under unsupported roof during the loader cycle without actually exposing himself to unsupported roof. The diagram on the following page illustrates this suggestion.

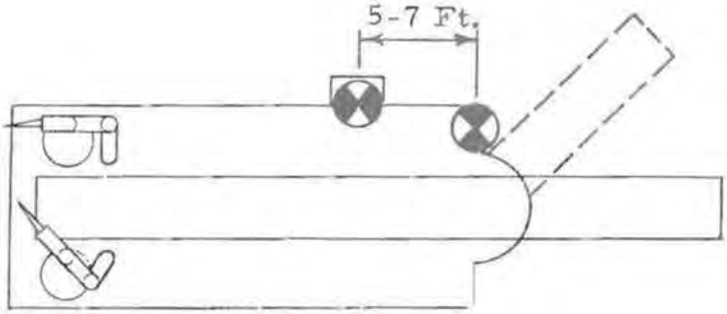
PRESENT



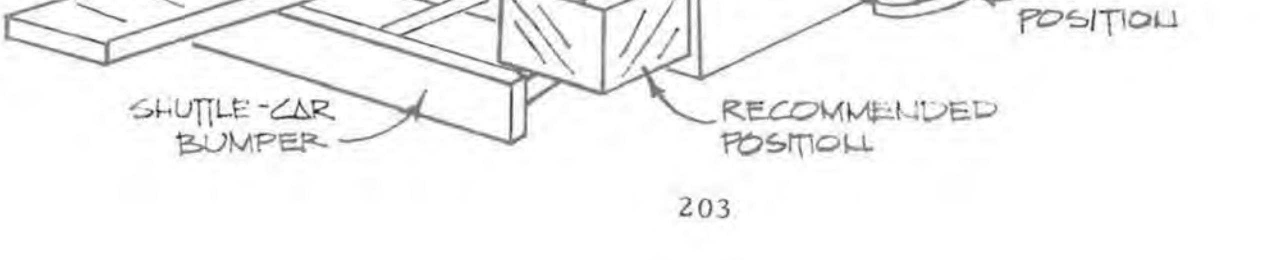
Operator only 12-14' from front of machine

Operator sticks out 8-10" from frame of machine.

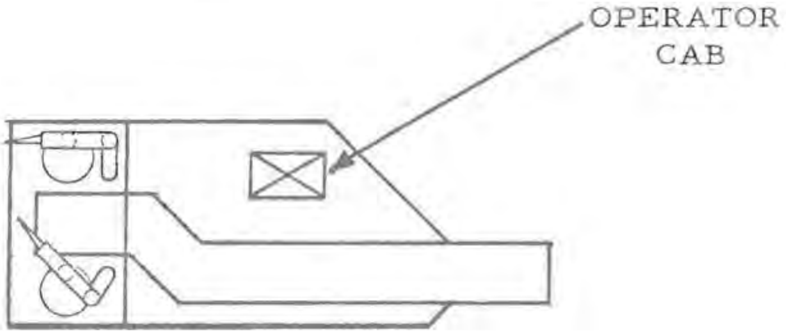
RECOMMENDED



Operator position is moved from side to rear of frame, giving him 5'-7' more for safer angle-loading, and moving him inside frame-width of loader. Conveyor still can be rotated to its 45° limit without interference.



The ultimate solution to the machine loader problem is complete redesign. The loader's silhouette greatly impedes the operator's visibility. A lower silhouette which slopes forward will contribute greatly to the safety of others near the loader. Furthermore, there is no functional reason why the conveyor has to be centered on the machine. An ideal loader, from a safety standpoint, might be totally re-configured as shown below:



C. <u>Continuous Miner</u>

1. The addition of a flexible arm to the continuous miner is similar to the situation of adding one to the loader.

2. An extendible brattice attached to a brattice support at the front side of the miner offers several improvements to the present method of hanging brattice at the face. First, the miner can continue to mine coal during the time presently required to advance the brattice. Second, the need for a helper is further reduced when the brattice-setting task is eliminated. This means the helper and others do not need to be near the cutting head nor under possibly unsupported roof, both high risk positions.

It is felt that the brattice support and the cable and hose modifications will so reduce the tasks of the continuous miner helper that the position will no longer be required. A true saving is possible by using the helper to perform those other mine tasks such as rock dusting, clean-up and general utility for which an additional person is usually hired.

3. The continuous miner has a methane monitor which becomes fouled with dust and must often be cleaned 2 to 3 times per shift. Often the operator cleans the sensor under unsupported roof because it is too much trouble to tram back from the face to a safe area. The solutions are to have a retractable sensor, or a sensor that will foul less often, such as by having a dust filter ahead of the sensor.

D. Shuttle Cars

1. There are several features which should be built into future shuttle cars.

   a. Future shuttle car designs should incorporate slow-rise shock absorbers to reduce the present high bounce when a car climbs out of a sudden dip in the floor. Canopies will prevent the operator from injury against the roof, but the improved shock absorbers can prevent the operator from momentary loss of control over his vehicle as he is thrown about within the protective canopy.

   b. The high drive whine alerts other miners to an approaching shuttle car. It has the opposite value to the shuttle car operator, however. The modulating frequency and high decibel rate prevent the operator from hearing commands, other equipment, or the mine itself and is a real hazard. Damping could be affected through either isolation or insulation of the main drives.

   c. Excessive coal spillage during loading of shuttle cars creates extra hand loading and clean-up activities. These hand activities are hazardous because the men often walk under unsupported roof without realizing it.

2. Forty shuttle car and battery powered utility vehicle operators were killed during 1966-1970 in accidents caused by crushing against ribs and other vehicles and running into appendages of parked vehicles such as cutter bars and loader booms. Shuttle cars and utility vehicles should be provided with side protection devices for operators.

III. SUMMARY OF RECOMMENDATIONS

A. Loader

1. Provide a flexible arm extension at the right rear of the loader to raise the power cable and water hose from the floor. This will greatly reduce the need for a loader helper.

2. Change the loader operator's position by:

    a. Moving the machine controls back 5 to 7 feet so that the operator can: 1) operate the machine from a position inside the frame width, thereby reducing his exposure to crushing by ribs and other equipment, 2) penetrate further under unsupported roof during the regular loading cycle. (See the discussion of safe loader penetration, Chapter 12, Machine Loading.)

    b. Providing a protective side canopy or bar around the operator to prevent injury from rib and vehicle collisions. The canopy would remain within the loader frame width.

    c. Lowering the loader machine silhouette forward for increased visibility by the operator.

B. Continuous Miner

1. Provide a flexible arm extension at the right rear of the continuous miner to raise the power cable and water hose from the floor. This will reduce the need for a continuous miner helper.

2. Provide a support at the front of the continuous miner to which an extendible brattice can be attached. This will further reduce the need for a miner helper (see Chapter 18).

3. Design the methane sensor of the methane monitor so that it does not need to be cleaned so often nor cleaned under unsupported roof if machine is not trammed out.

4. Provide a protective side canopy or bar around the operator to prevent injury from rib and vehicle collisions.

C. Shuttle Cars

1. The design of future shuttle cars should incorporate the following features:

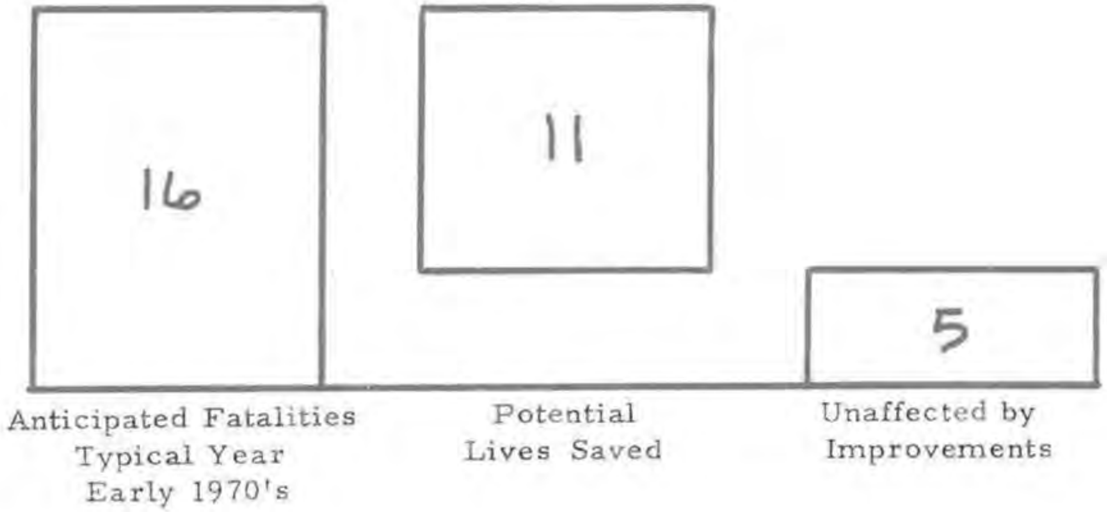
    a. Shock absorbers which have a much slower expansion rate than compression rate to significantly reduce the bounce when a car climbs out of a sudden dip in the floor.

   b. Reduced high drive whine of shuttle cars to improve the ability of the operator to hear warnings from the mine and miners and to hear other equipment which might be converging upon the shuttle car.

2. A protective side canopy or bar around the operator to prevent injury from rib and vehicle collisions should be provided.

IV. POTENTIAL LIVES SAVED ANNUALLY

Potential Lives Saved: 11



V. COST TO IMPLEMENT RECOMMENDATIONS

A. Loader

1. Cable and Hose Modification
   - Estimated additional cost per machine - $2000
     $2000 x 2560 loaders = $5,120,000 total gross cost to industry
   - Estimated lives saved annually - unknown, but reduced helper tasks and hazardous task location contribute to fatality reduction.

2. Change Loader Operation Position
   a. Relocate Controls
      - Estimated cost to relocate controls - $500
   b. Side Canopy
      - Estimated cost for side canopy - $500
        Total cost per machine - $1000

$$\$1000 \times 2560 \text{ loaders} = \$2,560,000$$

$$\frac{\$2,560,000}{\text{5-year amortization}} = \$512,000 \text{ per year}$$

$$\frac{\$512,000}{2 \text{ lives saved} \times 360,000,000 \text{ tons}} = .07\text{¢/ton/life saved}$$

   c. Estimated cost to lower loader silhouette and slope silhouette forward for maximum visibility by the operator.
      - Estimated additional cost per machine - unknown
      - Estimated lives saved - unknown, but better visibility should contribute to a reduction in fatal accidents.

C. Continuous Miner

1 and 2. Cable and Hose Modifications; Brattice Support
   - Estimated additional cost per machine
     Cable and hose modifications - $1000
     Brattice support - $1000
     Total cost per machine - $2000
     $2000 x 1775 continuous miners = $3,550,000
     *Less: $10,000/year/helper x 1185 continuous miners = $11,850,000
     Annual Savings = $ 8,300,000
   - Estimated annual savings

$$\frac{\$8,300,000}{3 \text{ lives saved} \times 360,000,000 \text{ tons}} = .77\text{¢ savings/ton/life saved}$$

3. Better Integrated Methane Monitor
   - Estimated additional cost per machine - unknown
   - Estimated lives saved - unknown, but less hazardous exposure should contribute to a reduction in fatal accidents.

4. Provide Operator Side Protection for Protection Against Rib and Vehicle Collisions
   - Estimated cost for side protection - $500
     $500 x 1775 Continuous miners = $887,500

$$\frac{\$887,500}{\text{5-year amortization}} = \$177,500 \text{ per year}$$

$$\frac{\$177,500}{1 \text{ life saved} \times 360,000,000 \text{ tons}} = .05\text{¢/ton/life saved}$$

---

* Estimate that 2/3 of continuous miner helper jobs can be eliminated.

D. Shuttle Car

1. New Design Features
   Slow rise shock absorbers
   Reduced drive whine
   Increased conveyor speed
   - Estimated additional cost per machine - unknown
   - Estimated lives saved - unknown, but new features will contribute to safer shuttle haulage.

2. Provide operator with a side protection against rib and vehicle collisions.
   Note: This is a sub-optimal solution; the ideal solution is discussed in Chapter 11-- the recommendation that the industry move toward sole use of center-seated shuttle cars. During the transition period, however, "add-on" side protection will save some, though not all, of the lives which can be saved by central seating.
   - Estimated cost for side protection - $500
     $500 x 10, 000 vehicles = $5, 000, 000

$$\frac{\$5,000,000}{\text{5-year amortization}} = \$1,000,000\text{/year cost to industry}$$

$$\frac{\$1,000,000}{\text{5 lives saved} \times 360,000,000 \text{ tons}} = .06¢\text{/ton/life saved}$$

CHAPTER 14

AUGER-TYPE CONTINUOUS MINING ACCIDENTS

I. STATEMENT OF THE PROBLEM

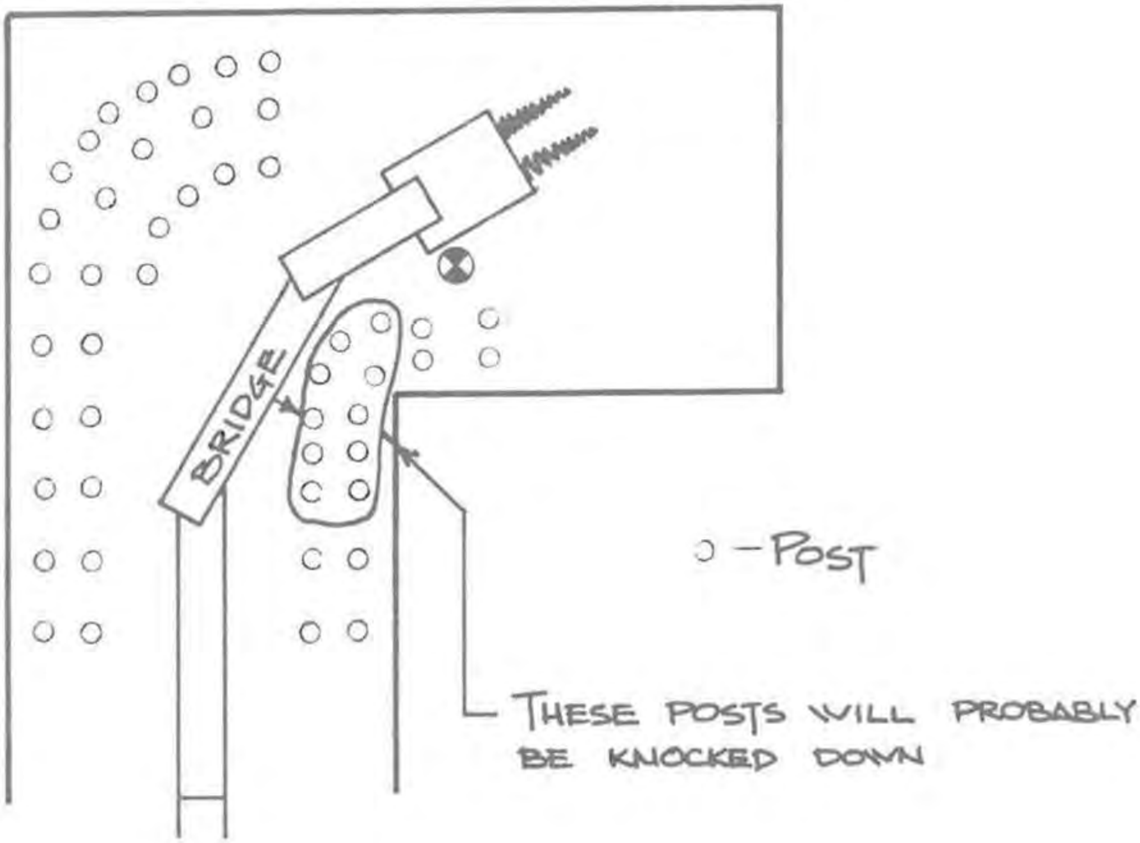
During the period 1966-1970, 25 fatal accidents resulted from roof falls (13), and machine-related (12) accidents in mines worked with auger-type continuous miners. The auger mining environment, characterized by low -- 24-36" -- coal, presents some unique safety problems both in terms of roof control and equipment safety. Compounding the inherent hazards is the nature of the mining process itself which requires 6-9 crew members working simultaneously in close physical proximity (within a 20' x 20' square) during most of an 8-hour shift, thus increasing the probability of a multiple fatality accident.

II. ANALYSIS OF THE PROBLEM

Two major conditions combine to make auger-type continuous mining hazardous: 1) the high incidence of roof falls resulting from the wide-rooming technique of the auger miner and the lack of continuous roof support; and 2) the inherent danger of the continuous interaction between a 6-9 man crew and a constantly moving machine operating in an irregular pattern.

A. Roof Support Problems

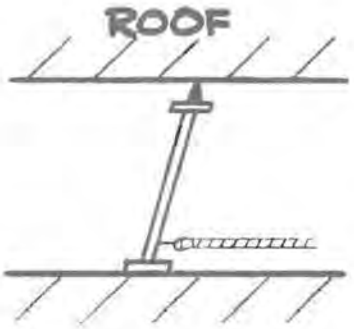
TB & A consultants often observed unsupported 80-90 ft. mined spans in auger-type mines during the field observation portion of this study. In addition, where support was used near the working face, the timbers were constantly being removed and replaced in order to allow for the movement of the miner boom and moveable bridge. The posts were either removed intentionally by a timberman or knocked out by the movement of the boom and bridge. Timbermen often got behind in post-setting if the miner boom and bridge were in a position to knock out a large number of posts very quickly, as for instance, in turning an entry:


BRIDGE
○ – POST
THESE POSTS WILL PROBABLY BE KNOCKED DOWN

One theory of roof support holds that roof left unsupported for a long period of time, e.g., overnight, loses its cohesive integrity and can never be safely supported. (This is called roof "flexing".) The continual withdrawal and replacement of support in an auger mine may flex the roof and leave it in a similarly weakened condition, although there is no empirical data to prove or disprove this theory.

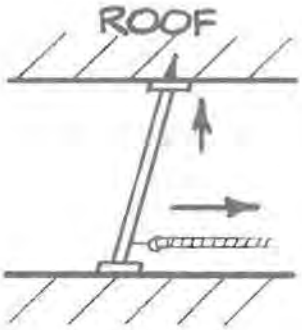
Adding to these roof hazards is the danger created by the miner's winch jacks as they gouge into the roof under tension. A majority of the auger section crew members interviewed felt that this winch pressure against the roof was one of the major safety hazards in auger mining. The jack acts, in effect, as a high powered roof scaling tool, often penetrating the roof several inches and levering down a thick section of rock, as shown:

I



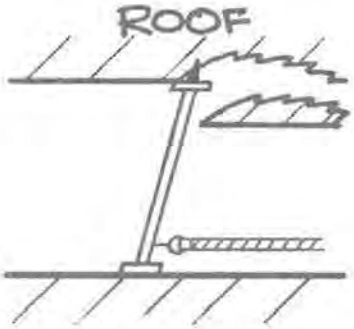
Jack is set

II



Tension cable moves jack; force is exerted against roof

III



Possible roof fall

Adding to the total system of auger mining roof fall hazards is the close proximity within which nearly the entire section crew works. As many as 6-9 crewmen may be working within a 400 sq. ft. area centered around the mining machine. A substantial roof fall in the face area can kill the entire crew. This very kind of disaster was prevented in an auger mine visited during this study by fortunate circumstances. A large, 6 ft. thick, rib-to-rib fall occurred, permanently burying the auger mining machine, but fortunately causing no injury as it was the lunch break and no men were in the area.

In summary, four characteristics of auger mining interact to create a hazardous roof environment: 1) wide-rooming techniques; 2) roof flexing caused by noncontinuous roof-support, i.e., constantly removing and replacing timbers; 3) roof hazards created by winch jacks under high tension; and 4) close crew proximity, i.e., the "two or more birds with one stone" effect.

Wide-rooming and timber removal and replacement are an inherent part of the auger system of mining and are unavoidable, short of outlawing or significantly limiting this mining method. It, therefore, seems to follow that the hazard level generated by potential roof falls will be unavoidably higher in auger mines. We feel that the most sensible way of dealing with this problem is to:

- Reduce the concentration of personnel in the immediate area of the miner through procedural changes.
- Recognize that the percentage of roof falls caused by winch jacks can be avoided and seek to eliminate them through the use of different equipment.
- Recognize the unavoidability of a certain percentage of roof falls and seek to minimize their danger through the use of a practical canopy system.

1. Procedural Changes

We believe a large payoff both in terms of cost effectiveness and the absolute number of lives saved lies in restructuring the typical hand loading and clean-up cycle. As pointed out in Chapter 16 on Hand Operations, Sections 75.400-1 and 75.400-2 of the Health and Safety Act of 1969 are vague regarding specific clean-up requirements. Whatever the intent of the Act regarding clean-up, common sense suggests that clean-up activities should not in themselves create new hazards. In the case of auger mining, it is common practice for the two jackmen to double as clean-up men on either side of the main augers, shoveling loose coal directly into the three small "clean-up" augers while the large augers continue to mine (Illustration 1). If, instead, clean-up is conducted by shoveling onto the belt after the miner has advanced, as in Illustration 2, the danger of being caught in a roof fall near the face is reduced and one fatal accident per year can be prevented. Of course, large rocks or chunks of coal must still be removed in some situations to permit machine movement.

This procedural change will also reduce the number of fatalities due to being caught in the main augers, as discussed in a later section on Man-Machine Interaction Problems.

ILLUSTRATION 1

Jacksetters shovel loose coal into augers.

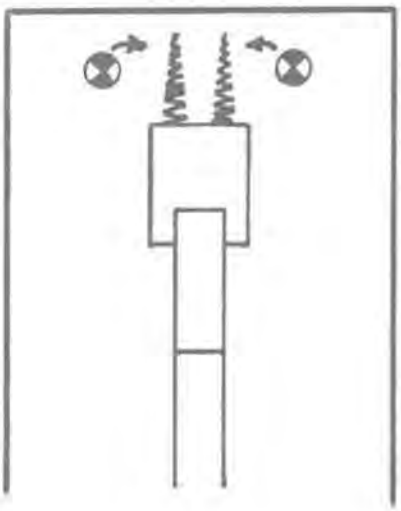
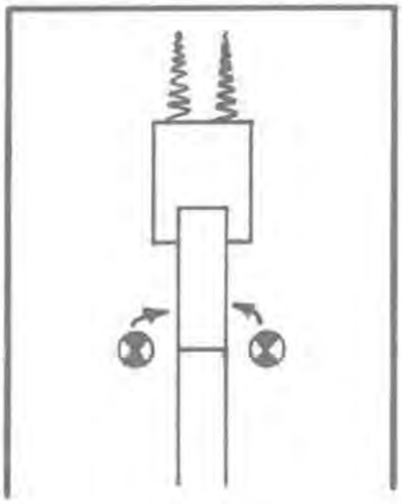


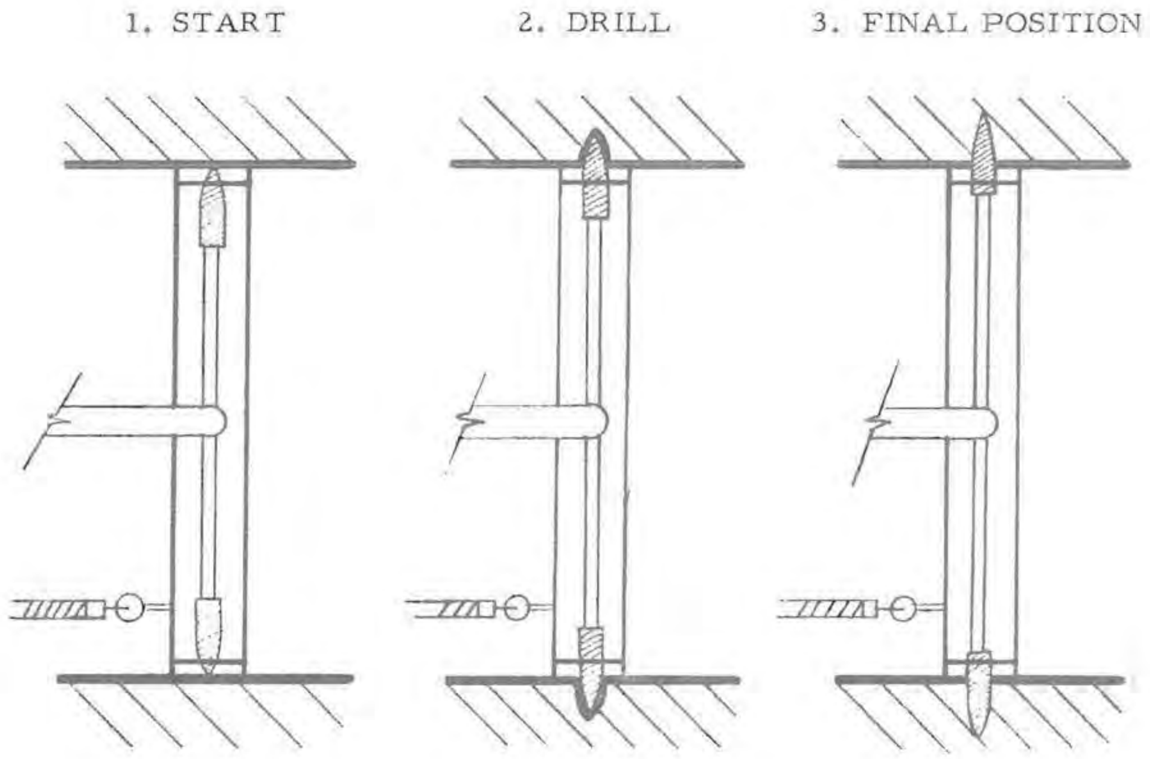
ILLUSTRATION 2

Loose coal is shoveled onto bridge after miner advances.



2. Winch Jacks

We feel that Cable Winching as a major roof control hazard can be eliminated through the development of a self-contained drill-jack unit which drills itself into the floor and roof using the miner as its source of electrical power. The unit would require no major engineering advance; the technology is essentially that of the hand-held face drill which uses the cutter as a power source in conventional mining. Equipment specialists claim that high maintenance costs make this concept infeasible and impractical. We feel, however, that the unit does merit formal study to resolve this issue.



1. START 2. DRILL 3. FINAL POSITION

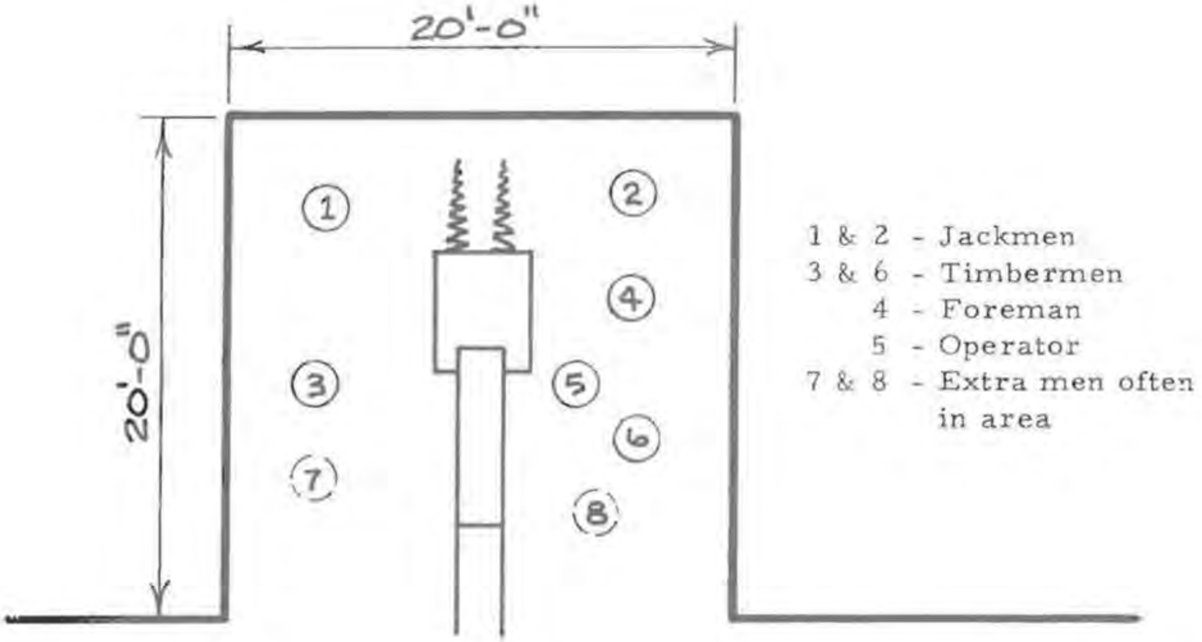
The proposed change in winch jack design has two important benefits:

a. It insures the jack being in a static position before the cable tension is applied. With the present system, the cable tension pulls the jack into the final position, often with unpredictable jack movement and jack-roof interactions. The new jack would, in effect, virtually eliminate roof falls caused by the jack-winching of auger miners.

b. It allows the jacksetter to leave the winching area before cable tension is applied. Under the present system the jacksetter stays right with the jack during the application of cable tension (i.e., the most dangerous time) to hand-guide the jack's roof spike and insure a secure "bite" by the jack.

3. Canopies

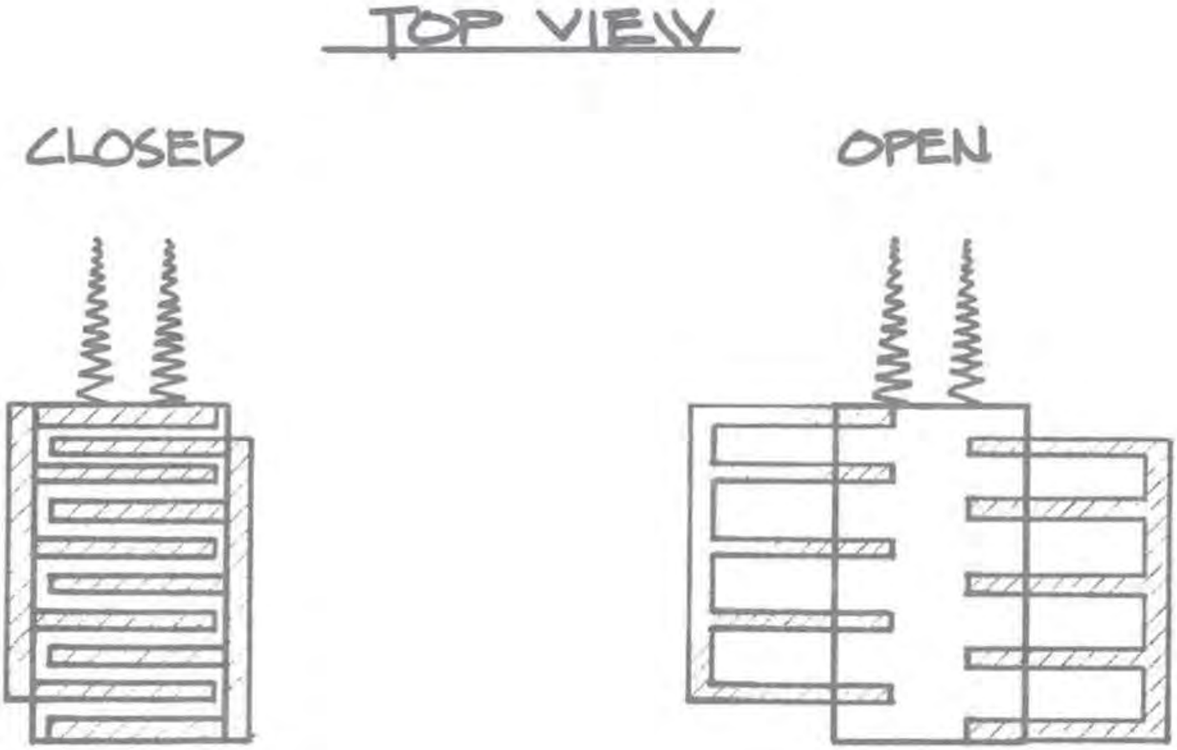
In an auger mine it is not unusual to have 6-8 men within 3-5 feet of the miner during its operation, as shown here:



The ideal protection for these men is a single integrated canopy system which covers all of them and is an integral part of the miner itself.

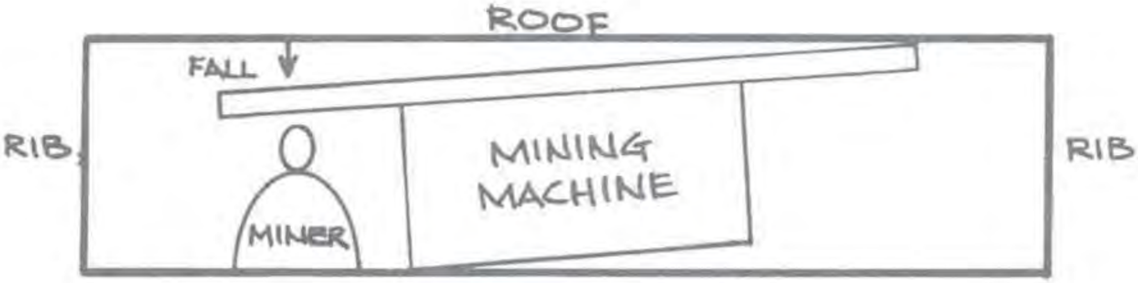
In extremely low coal -- 24-28" -- roof clearance above the miner becomes critical, and the additional height required by, say, a 4" I-beam canopy system makes a canopy solution infeasible. Only a major equipment redesign effort to integrate the canopy with the machine so that the present height of the miner is not increased will make canopies practical in extremely low coal.

In 28-36" coal, the normal height of auger mines, the single unit canopy system appears more feasible from an economic and engineering standpoint. A system of adjustable I-beams could be attached to the top of the miner, since at these coal heights the miner height is 4-10" lower than the height of the auger mining heads, exclusive of raising and lowering the augers. Schematically, a hydraulically or mechanically operated canopy system might look as presented below:



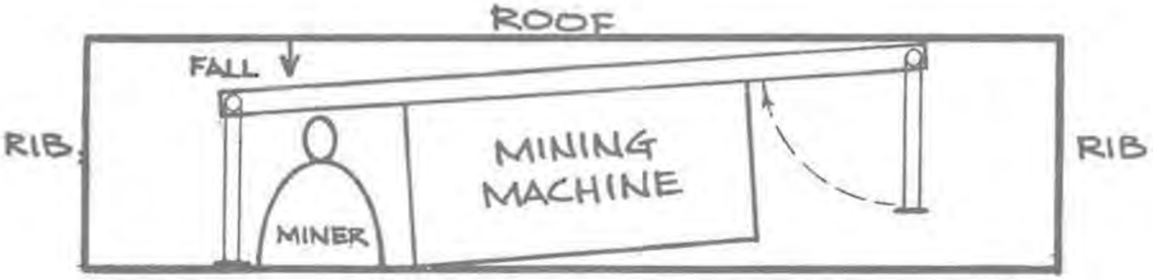
The belt conveyor could be re-routed across the top of the canopy with minimal redesign. Further, the canopy would take advantage of the low roof height to lever against the effects of a nearby roof fall:

SCHEMATIC: LEVERAGE AGAINST ROOF FALLS



Small foldable trusses could be provided at the corners of the canopy when fully extended to add additional support in case of a fall:

SCHEMATIC: TRUSS SUPPORT OF AUGER MINER CANOPY



During normal operations in 30-36" coal, most or all of the miners would operate with their heads partially or entirely above the 26" level of the canopy. Based on the accident descriptions contained in the 1966-1970 roof fall fatality reports, we believe that in most cases the operator will have some visual or audible warning of an impending roof fall, and can duck below canopy level to achieve full protection. Moreover, as pointed out in Chapter 10 concerning canopy protection on face equipment, some low roof falls might push the operator's head below canopy level, with the canopy frame receiving the full weight of the fall. There will continue to be some injuries and perhaps fatalities with this system, but there will be serious injuries and fatalities prevented as well.

B. Man-Machine Interaction Problems

The two major machine dangers associated with the auger miners are: 1) being caught in the auger itself; and 2) being crushed or pinned by the miner boom and moving bridge. Fatality data indicates that about 3 men per year might be killed by auger mining machines during a typical year in the early 1970's: two caught in the auger itself, one crushed by boom/bridge movement.

Jacksetting and clean-up shoveling near the face are the activities most often associated with being caught in the auger. Crew members in 24"-28" coal are severly limited in terms of physical mobility and flexibility. Quite simply, in this dangerous man-machine situation, the auger crew members often have neither time to move nor place to move.

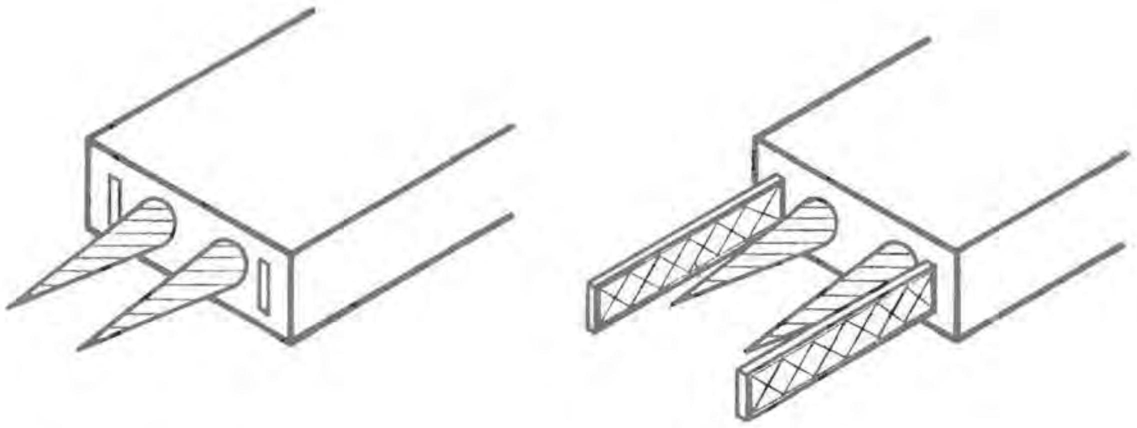
Solutions

Two major machine hazards are partially eliminated by the recommendations under roof control which: a) eliminate clean-up as much as possible at the working face concurrent with mining operations; and b) reduce jacksetter time near the front of the machine. Both of these improvements reduce crew exposure to the auger itself, and will reduce fatalities in this area as well as fatalities due to roof falls.

We believe the addition of a 4-1/2' retractable auger guard on the outside of each of the rotating augers will, in conjunction with the above recommendations, virtually eliminate the 80% of the fatal accidents caused by rotating augers.

In sump or sweep position, the operator will retract the auger guards to allow for normal mining operations. While tramming, withdrawing from sump, or repositioning, the operator would extend the auger guards.

AUGER GUARDS



RETRACTED

EXTENDED

The modification would require a minimum of equipment redesign. A few existing auger miners are already equipped with an auger guard device; however, these guards are primarily useful in shielding the small clean-up augers.

III. SUMMARY OF RECOMMENDATIONS

A. Roof Control Problems

1. Procedural Change

Eliminate the simultaneous performance of clean-up and mining operations in the face area. Clarify clean-up requirements in section 75.400 of the Federal Register, Volume 35, No. 226.

2. Winch Jack Improvement

Develop and require the use of an electrically powered drill-winch jack which eliminates jack movement during the application of cable tension.

3. Canopy Accessory

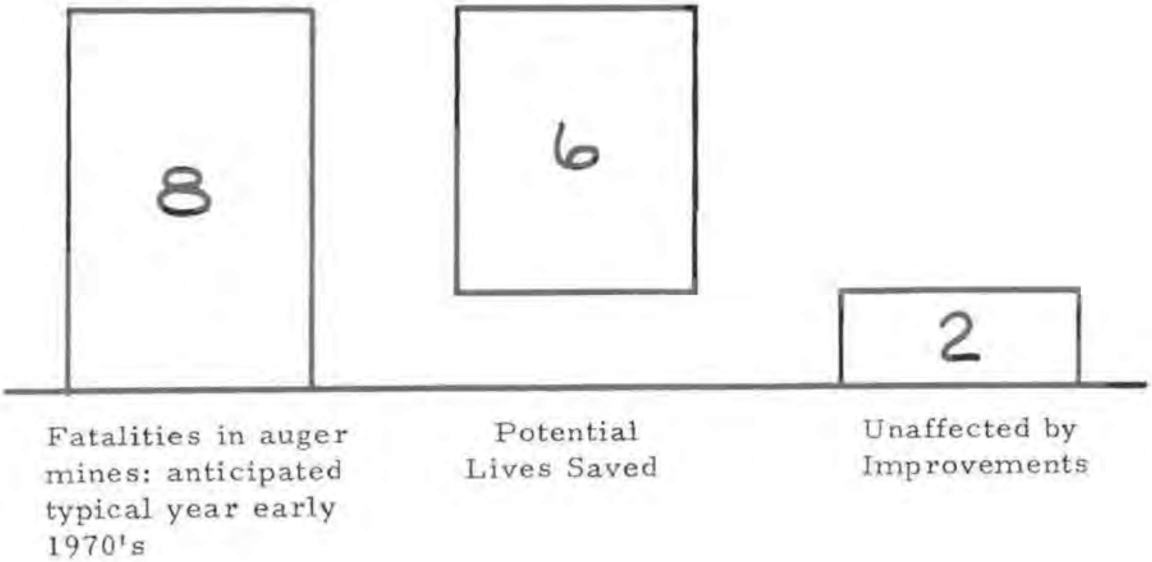
Develop and require the use of an extendible, crew-size canopy attached to the mining machine, providing protection for 6-9 crew positions.

B. Man-Machine Interaction Problems

Develop a retractable auger guard to protect crew members from being entrapped in augers during tramming, repositioning, and withdrawal.

IV. POTENTIAL LIVES SAVED ANNUALLY

Potential Lives Saved Annually: 6



1. Potential Lives Saved by Avoiding Roof Fall Fatalities

a. Procedural Changes

Elimination of clean-up occurring simultaneously with mining operations at the working face will prevent one fatal roof fall accident/year. The change in procedure will have no effect on production and will cost nothing to implement.

b. Winch Jacks

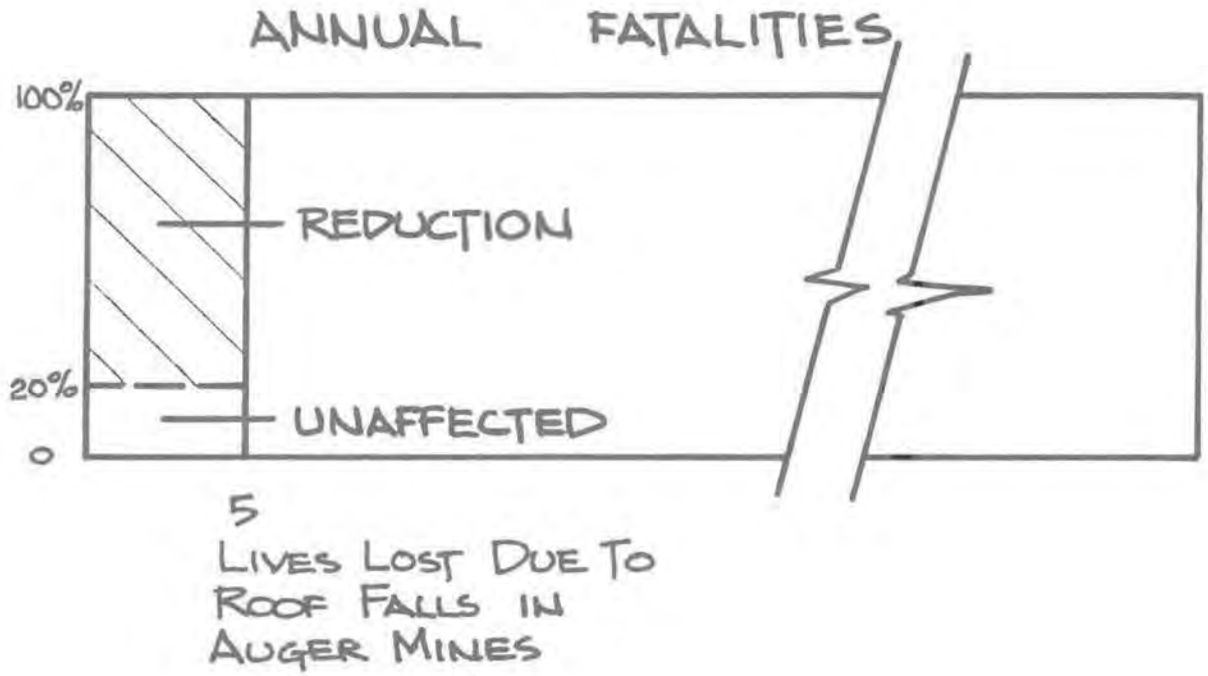
During the early 1970's about 1 man/year will be killed by roof falls while setting winch jacks. The development of a new drill-winch jack to replace current hand jacks will eliminate this fatality by removing the jacksetter from the area during cable tension.

c. Canopies

During a typical year in the early 1970's a total of 5 men/year will be killed by roof falls in auger mines. We estimate that 4 of the five fatalities occur within 8-10 feet of either side of the miner, between the face and the rear of the machine. An effective canopy will eliminate these fatal accidents. Two of the potential four lives saved annually by canopy protection have already been "saved", in effect, by the development of a safer winch jack and the change in clean-up procedure discussed above. In other words, employment of a canopy system in addition to a safer winch system and procedural changes would have the net effect of saving two lives annually.

The net effect of clean-up cycle modifications, winch system improvement, and canopy development is shown in this table:

POTENTIAL FATALITY REDUCTION: ROOF FALLS



2. Potential Lives Saved by Avoiding Man-Machine Interaction Problems

During the early 1970's three fatal accidents a year will result from man-machine interaction problems; two from being caught in a rotating auger and one from boom/bridge crushing. The two auger accidents can be eliminated by the development of an effective auger guard.

The net effect of installing auger guards is shown in this table:

POTENTIAL FATALITY REDUCTION:
MACHINE ACCIDENTS

V. COST TO IMPLEMENT RECOMMENDATIONS

1. Roof Support Problems

a. Procedural Changes

Changing the clean-up cycle sequence to eliminate simultaneous clean-up while mining will not significantly affect production and will have no effect on total production costs.

b. Winch Jack

The estimated cost of the improved winch jack described earlier is $1,000 per winch jack.

$1,000 X 150 estimated no. of active auger sections =
$150,000 total cost to industry

$150,000 ÷ 5-year amortization =
$30,000 estimated annual investment cost

$30,000 ÷ 1 life saved annually ÷ 360 million tons = .01¢/ton/life saved

c. Canopies

The suggested canopy system, while essentially an external "add-on" device requiring no significant equipment redesign, still represents a major capital equipment acquisition, the estimated cost of which is $10,000.

$10,000 X 150 estimated no. of active auger sections X .80 auger
sections in 28-36" coal =
$1,200,000 total cost to industry

$1,200,000 ÷ 10-year amortization =
$120,000 estimated annual investment cost

$120,000 ÷ 2 lives saved annually ÷ 360 million tons = .02¢/ton/life saved

2. Man-Machine Interaction Problems

The cost effectiveness of a retractable auger guard is estimated below:

$7,500 estimated cost per auger guard x 150 estimated no. of
active auger sections =
$1,125,000 total cost to industry

$1,125,000 ÷ 10-year amortization =
$112,500 estimated annual investment cost

$112,500 ÷ 2 lives saved annually ÷ 360 million tons = .02¢/ton/life saved

CHAPTER 15

HAULAGE THROUGH THE BRATTICE

I. STATEMENT OF THE PROBLEM

Ventilation control in many mines relies upon curtains (brattice) to regulate airflow. The brattice curtains often create a safety hazard both at the face, where erection of the brattice requires exposure to unsupported roof (see Chapter 18), and in the areas between the face and mainline haulage. The blind penetration of the brattice in the latter location, especially between face and first material haulage change point, is extremely dangerous. The safety problems created by brattice maintenance at the face are discussed in Chapter 18; this chapter will focus on the hazards arising from the blind penetration of the brattice in both mainline and secondary haulage.

Secondary haulage typically contains a number of pieces of mobile equipment and a large number of mine workers in comparison with mainline haulage. There are fewer brattice dangers for mainline haulage, with the possible exception of systems that utilize belt transportation for underground workers. We have noted during our underground observations that penetration of curtains while riding a belt is a hazard normally associated only with low coal operations, but the exposure for this limited number of workers is significant.

Contrary to most mine safety trends, the danger from haulage through the brattice is expected to increase in the future as increasing numbers of machines and workers function in the mines at ever increasing paces.

II. ANALYSIS OF THE PROBLEM

The problem of haulage through the brattice is one of visibility and control of large equipment. The mine environment is extremely hostile in many ways and travel constraints are quite usual. Since shuttle cars are the vehicles most often involved in haulage through brattice curtains, a description of the shuttle car operation underground may be helpful.

The operation of shuttle cars is analogous to operating an automobile with no top or windshield in an absolutely blackened parking garage. The driver must move within a very narrow lane (12-14' to make it proportional) over a 100 - 400' route that is changed constantly. The lighting is provided by two flashlights and as many as 5 other unlighted vehicles use the passageways. Pedestrians with flashlights are present, as are other unlighted machines which are parked close to blind turns. The car has 4 broken springs and the driver may be required to operate the vehicle from a small, unprotected platform at one side of the trunk. The floor is wet, slanted, and dotted with potholes and bumps. The roof is more irregular than the floor and may unexpectedly project downward within a few inches of the top of the car, which will require that the driver lean outward to avoid the obstacle while maintaining control of the vehicle. Unfortunately, the car's gas pedal is jammed and the motor runs at a constantly high (relative) speed. Movement is controlled by shifting gears to neutral, low or reverse, and the wheels spin on startups. The brakes do not always work. The driver must operate his vehicle for approximately 5 hours per day while making 50 to 100 trips between changing points to load and unload various materials

Into this system, we shall now introduce ventilation controls. Along some portions of the pathways, the narrow width is reduced another several feet by a continuous length of canvas usually supported by unyielding wooden posts. Several of the passageways may be hidden behind this stretch of unmarked canvas. The driver is required to penetrate this canvas blindly for up to 20' before determining that the hidden pathway is/is not angled, that there are no roof obstacles or overhanging walls, that no other machines are parked behind the curtain, and that there are no pedestrians or workers who might be facing away from the machine while in a kneeling position.

This is a typical situation, especially in lower seam heights. The conditions range from much better to much worse. It would appear that tractor-trailer haulage is even more dangerous than powered shuttle cars.

Penetration of curtains while riding a conveyor belt to enter and exit from the mine is more of an observed hazard than one that appeared in the fatality analysis. In the day-to-day operation of a mine, the safety devices are often in need of repair and belt riding becomes very dangerous. Often the controls for reducing belt speed are inoperative at one end, forcing one crew member to take a high speed ride to the control at the other end to reduce the speed for the remainder of the crew.

Solutions

A. Transparency Index for Curtains

Materials that permit observation of light through the curtain are available and in use. Maximum opacity would be the point where a miner's cap light, pointed away from the curtain, could be observed from a reasonable distance (25 - 30'). This would be a measure of light reflected by roof, ribs and floor. Often a miner may be kneeling while working on a piece of equipment and reflected light is all that is available.

B. Use of Machine Lights When Tramming

As a matter of policy, the shuttle car inby light is often dimmed, intentionally caked with mud, or otherwise modified to avoid blinding the loader or continuous mining machine operator. Tramming lights should be bright and clean in order to penetrate a transparent curtain. Bounce lighting from recessed spot lights directed toward the roof on an angle would be both effective in penetrating the usually small separation between the curtain and the roof and acceptable to the miners.

C. Portable Equipment Lights

Parked equipment is especially dangerous since it is often below the field of vision of other drivers or obscured in some other manner. At least two permissible battery powered lights should be used in order to define both extremities of a piece of equipment. The lights need not be extremely bright to achieve definition since only a warning is necessary. They should be easy to transport and attach, perhaps magnetically, to metal surfaces.

D. Equipment Parking

All equipment should be parked such that it can be seen from both directions. An example of a case when this was not done is the worker who parked one machine behind a curtain, immediately climbed into another machine, trammed through the curtain and crushed himself against the machine he just parked. Machines should not be left near blind corners or curtains. Intersections also appear to be a dangerous parking spot.

E. Curtain Markings

A number of fatalities have occurred as a result of the lack of definition of safe entry points. Machine operators tram themselves into angled ribs, overhangs, and concealed roof trusses or rib posts. Some mines actually construct a door to indicate safe worker passage and to provide passage definition. If doors are not actually constructed, the outline of the passage entry should be clearly marked on the outside of the brattice with reflective tape or other easily visible material.

F. Machine Projections

A number of fatalities are the result of an operator tramming himself through a curtain and into a boom or other projection. Placing projections on the floor or against a rib is standard procedure for most mines but the exceptions are deadly.

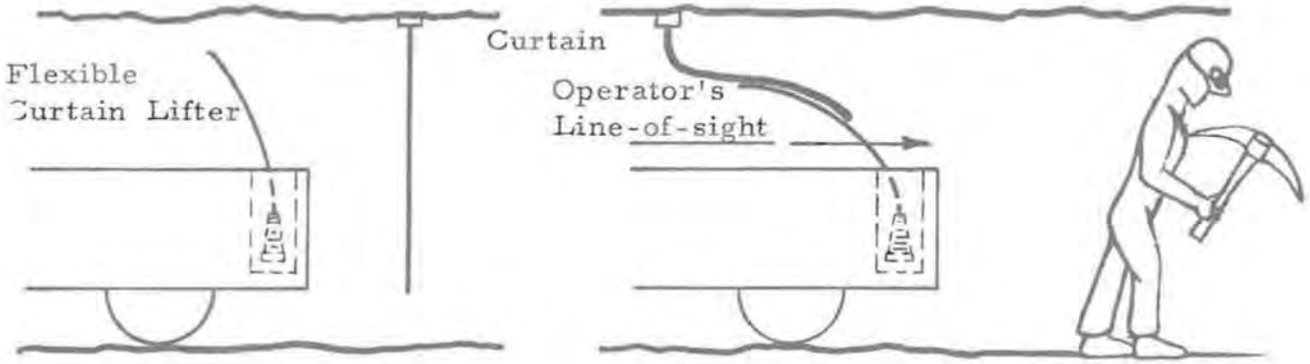
G. Angled Curtains

Brattice hung at an angle can mislead a machine operator and cause him to collide with a rib or post. Many rib squeezes are the direct result of a miscalculation caused by a crooked curtain. This is particularly dangerous when combined with a changing mine configuration behind a curtain. If the angle is absolutely necessary, a stepped curtain would be preferable.

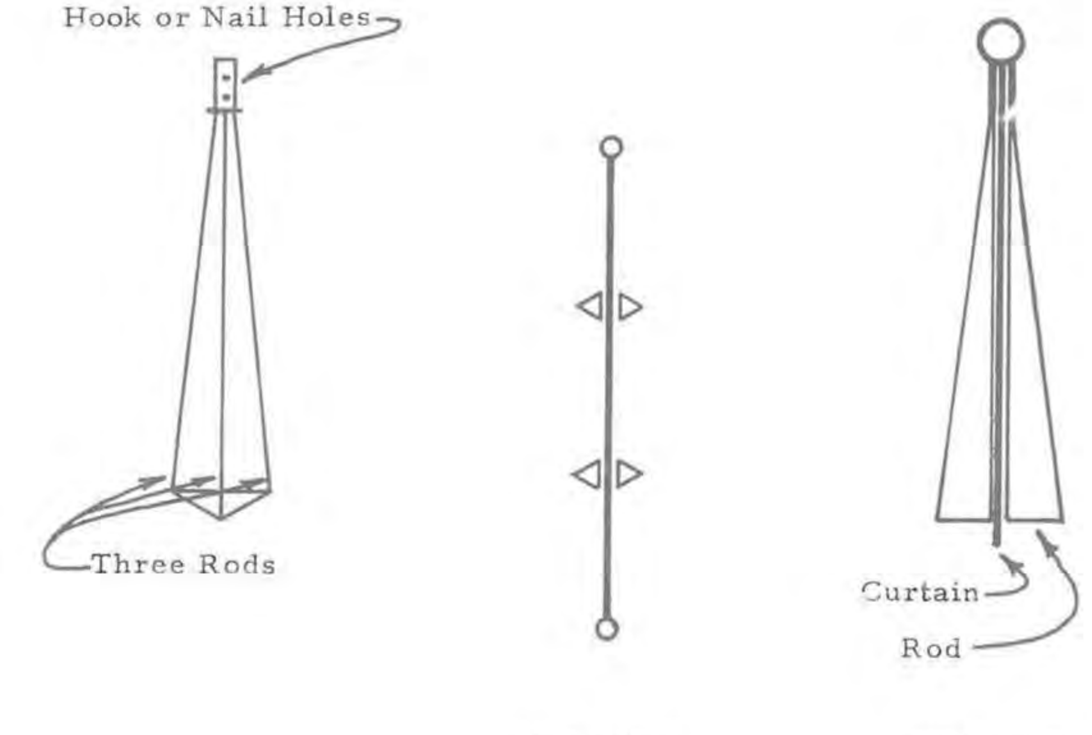
H Curtain Lifters

These could be machine or brattice-mounted lifting devices constructed of inexpensive materials. The machine-mounted devices would be more efficient but much less practical because of machine/machine and machine/mine interactions. The machine mounting would have to survive boom movements, roof abuse and constant battering from other sources. Examples are shown in the illustrations on the two following pages.

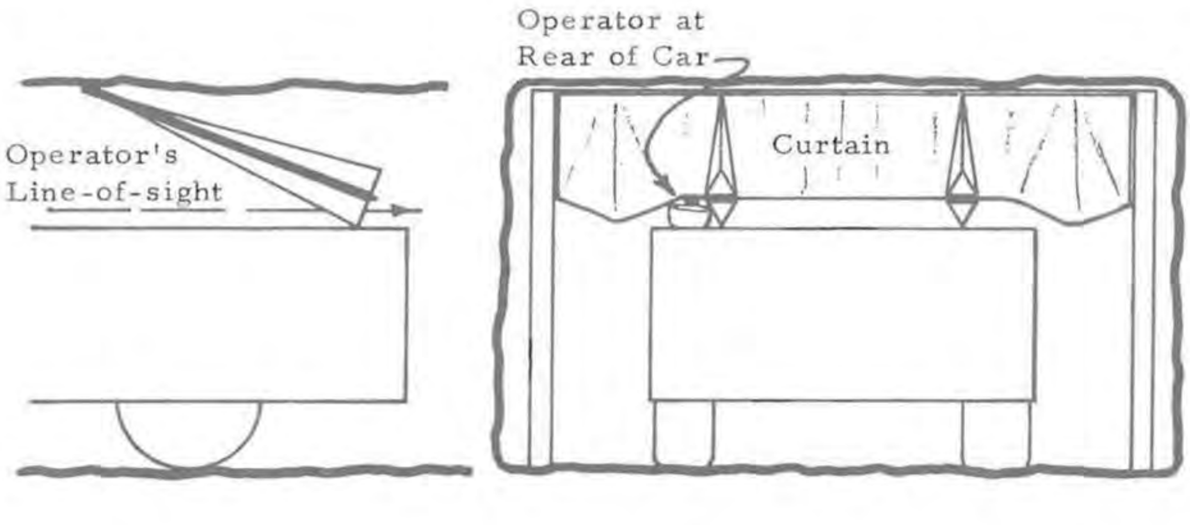
MACHINE MOUNT



Machine-mounted curtain lifters could be similar to automobile whip antennae. They must be flexible, yet strong enough to hold the brattice up to enable the operator to see beyond the brattice into the next haulageway.



TOP VIEW SIDE VIEW



SIDE VIEW FRONT VIEW

Brattice-mounted curtain lifters could be a simple lightweight plastic hanger that would lift the curtain above the top of the tramming machine. The lifter could be attached to a truss or curtain or hung by a rope to the proper height.

I. Belt Curtains

1. Relocate Belt Curtains

Provide a safety zone on both sides of curtain. This area should provide ample reaction time for a worker traveling at maximum (although illegal) belt speed to be consistent with reality.

2. Mark Safe Penetration Height

Curtains can often conceal a supporting truss or lowered roof height. All curtains should have reflective markings to indicate both the presence or absence of danger.

3. Brush Roof

On/off spots should have sufficient roof height to insure the safety of workers required to use the belt. This recommendation would also improve material handling efficiency at these points.

III. SUMMARY OF RECOMMENDATIONS

In the long run, the safety problems created by blind penetration of the brattice can only be solved by the development of new systems which obviate the need for curtains both at the face and throughout the mine. In the interim, there are a number of improvements which can be implemented to increase operator visibility while penetrating or working around ventilation curtains.

An analysis of fatal accidents, combined with underground observations, suggests the following recommendations:

1. Require a transparency index that will permit the light from a miner's cap to be seen from the other side.

2. Require full use of vehicle lights when tramming through curtains on all machines.

3. Require the use of a portable light to mark all equipment down for repair.

4. Require all equipment to be parked either at least 20' from any blind corner of brattice or so that half of the machine is exposed and lighted on each side of brattice. Keep all machines out of intersections.

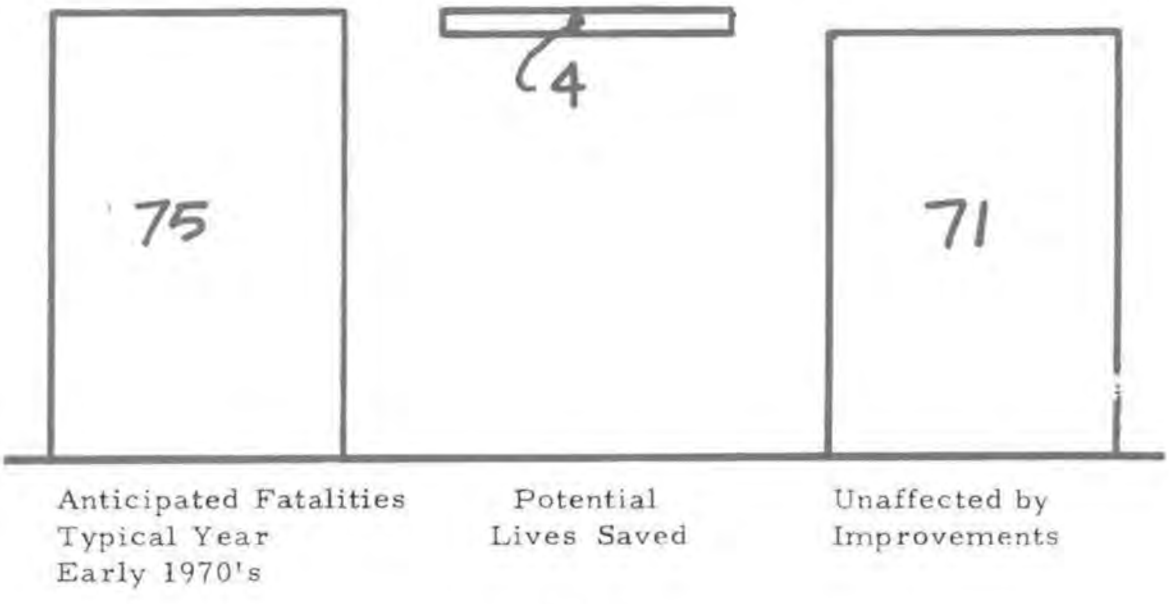
5. Require reflecting tape or other marking to outline safe passage area on curtain.

6. Require projections on parked machine to be placed on the floor or against a rib. This includes booms on face drill, roof bolters, undercutters and all projections on other equipment.
7. Require that brattice be hung only at right angles to the direction of travel whenever possible.
8. Design flexible curtain lifters which would provide visibility for equipment drivers at the time of equipment penetration.
9. Belt curtains
    - a. Relocate curtains over belts used for mantrips to modify proximity of hazards.
    - b. Mark belt curtains for safe penetration heights.
    - c. Investigate the feasibility of semi-automatic lifters for hazardous belt curtains.
    - d. Brush roof for on/off point clearance.

IV. POTENTIAL LIVES SAVED ANNUALLY

A. Potential Lives Saved: 4

POTENTIAL FATALITY REDUCTION:
EQUIPMENT ACCIDENTS



Many of the 74 fatal face haulage and equipment tramming accidents (1966-1970) could have been avoided if visibility had not been obscured by a brattice. At least 4 of the 75 total equipment accidents in 1970 alone were the direct result of obstructed vision. A number of other fatal accidents might have been mitigated through a combination of the recommendations proposed in this chapter.

V. COST TO IMPLEMENT RECOMMENDATIONS

These recommendations entail relatively inexpensive modifications, many of which are standard procedure in better managed mines. Taken individually, the cost of the recommended procedures and equipment is negligible. Taken collectively and combined with the cost of enforcement, there might be a modest increase in the cost of coal. It would appear that the residual benefits of improvements in visibility and safety would increase productivity and offset the incremental labor and material expense, but this is a subjective judgement.

CHAPTER 16

PERFORMANCE OF MISCELLANEOUS HAND OPERATIONS

I. STATEMENT OF THE PROBLEM

In the period 1966-1970 there were 77 fatalities resulting from roof falls that occurred while the victim was performing hand operations: hand loading, clean-up, removing falls and roof scaling. Fourteen of these fatalities took place in 1970 alone.

II. ANALYSIS OF THE PROBLEM

A. Hand Loading and Clean-Up

Hand loading and clean-up operations are similar except for the time and location of the task performance. Hand loading is the clean-up of loose coal from the floor of the working area when the loader, continuous miner, or hand buggy is in the face area, whereas clean-up refers to the removal of loose coal when there is no mining machinery in the area.

Hand loading fatalities from roof falls have steadily decreased since 1966. The greatest reduction has occurred in the "unsupported unnecessarily" category used to describe a miner who is working under unsupported roof when he does not need to be there.

Forty-three percent of the hand loading fatalities by roof falls were experienced by someone other than the person assigned the hand loading job as a primary task. This function is performed by all working area personnel and all levels of supervision, indicating a lack of advance planning of hand loading task assignments.

Clean-up fatalities from roof falls, while reasonably stable since 1968, have increased in the "unsupported unnecessarily" category. This may be a result of the greater emphasis by the USBM on enforcing the rock dust-coal dust ratio, and the over-compliance by the coal operators in the prompt removal of loose coal from floors -- often under unsupported roof. Many of these fatalities could have been prevented by less zealous attention to clean-up.

The 1969 law is very specific on rock dusting, allowable percentage of float dust, and ventilation requirements; however, the law is quite vague with regard to requirements for the clean-up of combustible materials. (75-400 of the Federal Register, Volume 35, Number 226.) 75.400-1 states that "...loose coal, and other combustible materials shall be cleaned up and not permitted to accumulate in active workings,..." and, 75.400-2 states "...A program for regular clean-up and removal of accumulations of coal and float coal dusts, loose coal, and other combustibles shall be established and maintained."

75.400-1 and 75.400-2 do not state that the clean-up task need not be performed if an area is unsafe to enter as is specifically stated in 75.402 on rock dusting. The implication for safe clean-up is weak because the safety clause follows two paragraphs later. Therefore, it is recommended that a "safe" clause be added to 75.400-2 similar to 75.402 and that an interpretive letter be sent to each coal operator to explain that loose coal can remain on the working area floor until it can be safely cleaned-up under permanently supported roof. Further, it is recommended that the letter stipulate that loose coal cannot remain any longer than is necessary for safety (beyond the next loading or mining cycle at each face).

B. Removing Falls

Fatalities from roof falls which occur while removing earlier falls is a very difficult safety problem. Miners will be exposed to the danger of additional roof falls during the period they are removing falls, whether the removal is performed manually or mechanically. The only way to reduce this hazard is to reduce the cause of the roof falls or to develop a means whereby the miners can position themselves under safe roof and remove the fall mechanically.

1. Roof falls of supported roof are caused by poor lithology or changes in lithology. An observed cause of weakened roof common to most mines is the roof bolter re-setting one or more jacks or posts before drilling a hole and inserting a roof bolt. This flexes the roof by removal and re-application of support and contributes to a weaker roof. Re-setting temporary supports is unnecessary if the supports are located with greater precision initially in accordance with the approved roof control plan. If the roof control plans submitted for approval properly take into account equipment mobility needs to arrive at a workable temporary support grid, no further adjustments to the temporary supports should be required.

2. Operators need to be shown that roof falls are expensive as well as dangerous. The Bureau should provide funds to:

   a. Finance a pilot study on the cost effectiveness of roof fall prevention vs. roof falls.

   b. Publish the findings of that study.

3. A study should be conducted, parallel to the roof fall prevention study, to determine the economic feasibility of a machine to remove falls such that the machine operator can remain under supported roof. Funds should be provided by the Bureau to finance this study.

C. Roof Scaling

Most of the face crew and the foremen scale at one time or another. Present roof scaling techniques are very hazardous. The miner generally places himself under unsupported roof, nearly under the rock being scaled, or both. Eighteen miners were killed scaling roofs from 1966-1970; only three of these were standing under supported roof. In 11 cases the roof did not fall back to the last support line. Thus, these 11 would probably not have become fatalities if they had been able to scale the roof from a position close to the last line of permanent support.

Most of the miners killed by roof falls while scaling roofs become victims because they feel they cannot concurrently scale and remain under supported roof. To solve this problem we recommend the development of a hydraulic roof scaling device that could be mounted on a continuous miner, a roof bolter, or a loader and operated from under permanently supported roof.

It is most logical to place this device on a roof bolter in a continuous-type mine and on a loader in a conventional-type mine. The continuous miner can pick up the rock scaled by the roof bolter at the beginning of the next continuous miner cycle. Furthermore, since the normal advance in one cut is 20 feet, the roof bolter would be able to attack bad top near the face by first bolting to within 10 feet of it. He could then safely stand under permanent support to scale the roof.

In conventional mining, scaling should be performed by the loader, because any scaling debris brought down after the loader leaves a room would present a tramming obstacle to either the face driller or the undercutter. The length of the scaling tool handle would provide a safe length for the loader operator because conventional sections, generally, undercut only 6-8' at a time.

The hydraulic roof scaling device would require a 10-12' handle of a lightweight tubular material. The scaling end of the device would incorporate a hydraulically operated, worm gear expander that would generate the required force to open the jaws and scale the roof. The hydraulic fluid could be supplied via tubing in the handle. (See Chapter 20, Areas of New Research, for further discussion of roof scaling equipment requirements.)

When this device is employed, the miner would: 1) remove the tool from its storage location on a continuous miner, loader, or roof bolter (a telescoping handle would be needed for storage purposes), 2) position himself under permanent support nearest the roof area to be scaled, 3) force the scaling end of the tool into the area of the roof to be scaled, and 4) activate the scaling mechanism.

In addition to preventing fatalities, the scaling device would also reduce worker fatigue. Our consultants have observed workers exerting enough physical force to bend a 1" steel scaling bar.

The development of a scaling tool of this nature would be the responsibility of equipment manufacturers. Development would be facilitated, however, by a USBM grant for further study and development. This tool could be made a requirement in appropriate mines based upon performance tests following development.

III. SUMMARY OF RECOMMENDATIONS

A. Hand Loading

The requirement for the clean-up of combustible materials (75.400 of the Federal Register, Volume 35, Number 226) should be clarified to exclude all mine areas where the roof is not permanently supported.

B. Removing Falls

1. We recommend that roofs be secured according to the approved temporary support plan as soon as possible after mining, and according to the permanent support plan as soon thereafter as possible. In any case, the roof should continually be supported to avoid roof flexing.

2. Research funds should be provided to study the causes of supported roof falls, determine ways of preventing them, and examine the economics of such prevention.

3. We recommend the performance of a feasibility study on the design of machines to remove falls remotely and safely.

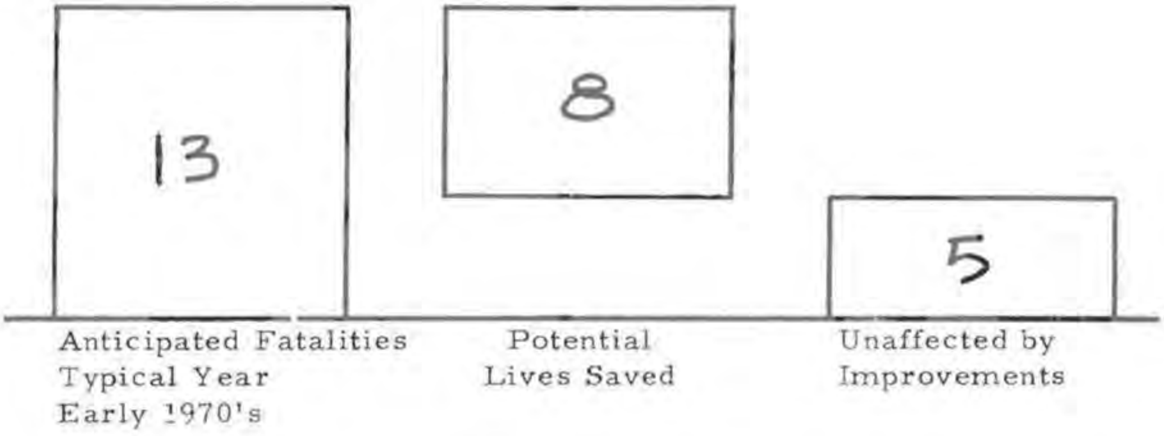
C Roof Scaling

A scaling tool to enable the miner to scale from under supported roof should be developed.

IV. POTENTIAL LIVES SAVED ANNUALLY

Potential Lives Saved Annually: 8

POTENTIAL FATALITY REDUCTION:
MISCELLANEOUS HAND OPERATIONS



Based on 1966-1970 fatality data, we estimate 13 fatal accidents will occur annually while performing hand operations: 7 hand loading and clean-up accidents, 2 fall-removal accidents, and 4 roof scaling accidents. We estimate that 5 hand loading and clean-up accidents can be prevented by procedural changes in the clean-up cycle, while 3 scaling accidents can be prevented by an improved scaling device.

V. COST TO IMPLEMENT RECOMMENDATIONS

1. Hand Loading and Clean-Up

If the helper can hand load coal left from the preceding cycle at that face, he will remain under supported roof during the entire hand loading operation for each cycle. In other words, the coal spilled by machines loading or continuous mining will remain on the floor until the loader or miner again returns to that face. There is no loss or gain in productivity, and no additional labor or cost required to change the sequence of the hand loading activity.

The clean-up operation is presently performed in the working area under unsupported or temporarily supported roof. There is no loss or gain in productivity, no additional labor required, and no cost involved in making sure that the roof is supported first so that the clean-up task will only be performed under supported roof.

2. Removing Falls

a. There is no additional cost assigned to prompt roof securing for mines that follow the approved roof control plans closely. There is a benefit to be gained from precise placement of temporary supports--the roof bolting cycle can be shortened because the temporary supports do not need to be removed and relocated prior to drilling. For example:

Remove and relocate 3 jacks unnecessarily/6-bolt cycle takes 1.50 min.

12 roof bolt cycles/shift x 1.50 min/roof bolt cycle = .31 hrs/shift

.31 hrs/shift x 250 days/year @ $4.50/hr. = $348.00/year/shift

b. The estimated cost of a cost effectiveness study on roof fall prevention vs. roof fall removal is $50,000.

c. The estimated cost of a requirements and feasibility study for a roof fall removal machine is $10,000.

3. Roof Scaling

An extendible scaling tool with hydraulically actuated, worm gear driven jaws would offer the miner a tool which would loosen and remove loose pieces of roof without expending physical energy. The extendible handle would allow the miner to stand under supported roof as he mechanically scaled the loose roof.

The estimated cost for the scaling tool is $250

$2,50 x 3,600 active sections = $900,000

$$\frac{\$900,000}{\text{5-year amortization}} = \$180,000 \text{ estimated annual investment cost}$$

$$\frac{\$180,000 \text{ estimated annual investment cost}}{3 \text{ lives saved annually x } 360,000,000 \text{ tons}} = .02¢\text{/ton/life saved}$$

CHAPTER 17

SURVEYING ACTIVITIES

I. STATEMENT OF THE PROBLEM

Surveying activities are most often conducted under unsupported roof after a fresh cut. In addition to setting spads, which is done by the company survey team, there are several other types of surveying done by the section crew. These are:

A. Measure the depth of the entry to determine where to trim for a crosscut.

B. Measure the entry width at the face to assure that the width is correct.

C. Establish a center line on the roof of the entry to assure that the entry is straight.

During the early 1970's, we expect one miner to be killed each year while surveying or performing survey-related activities -- moving to, or coming from a survey task, discussing the survey, etc.

II. ANALYSIS OF THE PROBLEM

Two men are needed to measure the depth of the entry: one man holds one end of the tape measure at the last spad, and the second man holds the other end at the face. If the roof has been supported, the man at the face is often one to three feet past the last line of permanent support. If the roof has not been supported, the man at the face is very vulnerable to a roof fall.

The face width is usually measured at the face rather than under the last line of permanent support. There is no need to go beyond the last line of support when the roof bolts are within three feet of the face. If the roof has not been supported for the last ten to twenty feet, however, then accuracy dictates hazardous exposure to unsupported roof.

The center line is established by attaching a chalk line to the last spad and sighting along the extended chalk line for two spads. When the three points are aligned, the foreman snaps the chalk line, with a resultant white line on the roof. The foreman exposes himself unnecessarily if he marks the line before the roof has been supported.

The solution consists of making two changes in the present procedure -- when the tasks are performed and who performs them.

Assignment of the depth of entry and width of entry measurement tasks to the roof bolter operator will force the "when" to occur after the roof has been properly supported. The roof bolter operator will use a retractable steel tape with a spike on the end for imbedding into rock or coal. This will permit one man to make all measurements. He will record measurements onto the right rib with a permissible aerosol white paint or dye, indicating the cumulative number of feet from the last spad. This will enable the undercutter operator and the continuous miner operator to know exactly when to make a crosscut. For example, the continuous miner operator may see a "50" at the last line of permanent support as he trams toward the face to begin his mining cycle. Since he knows that a break must occur at sixty feet, he needs to judge only 10 feet from that point.

This simple procedural change and task reassignment has the additional advantage of eliminating the common error of over-cutting, thereby creating more uniform pillars and greater conformity to the approved mine plan.

The measurement of the centerline should remain the responsibility of the foreman. As in the case above, it is the "when" of task performance which is to be modified. The foreman should only make his measurement after the roof has been supported - after the roof bolter operator has made the entry width and depth measurements.

III. SUMMARY OF RECOMMENDATIONS

A. Measure and mark the entry width, depth and centerline only after the roof has been supported and only under that portion of the roof that is supported.

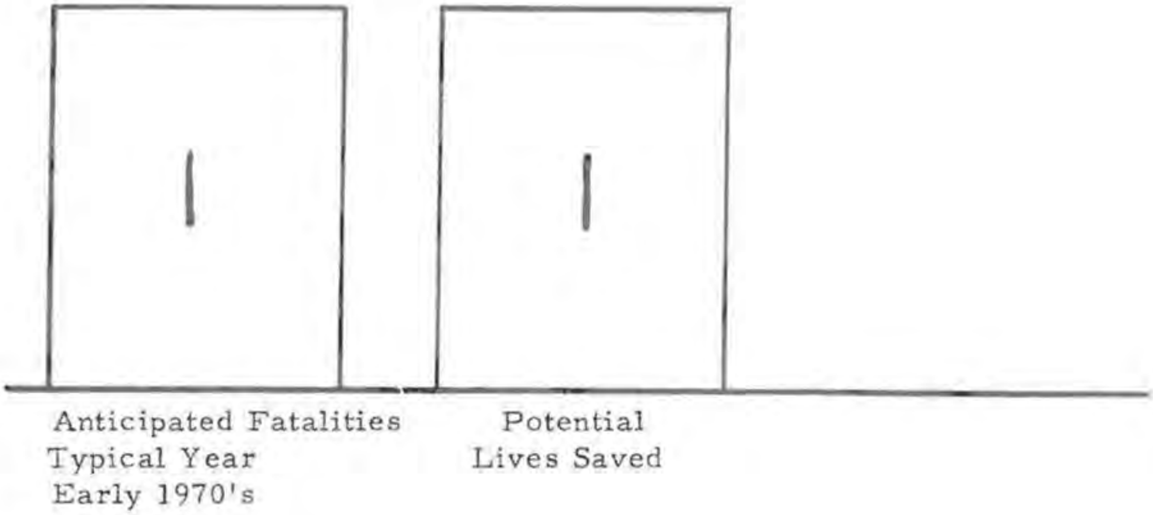
B. Assign the entry width and depth measurement and marking to the roof bolter operator as a regular task to be performed at the end of each roof bolting cycle.

C. Keep the centerline marking a task of the foreman, with the requirement that he remain under supported roof at all times while performing the task.

IV. POTENTIAL LIVES SAVED ANNUALLY

Potential Lives Saved: 1

POTENTIAL FATALITY REDUCTION



We believe that the changes in surveying procedure outlined above will save the life of the one miner each year who is expected to be killed surveying.

V. COST TO IMPLEMENT RECOMMENDATIONS

1. Measure depth of entry

Present method - 2 men x n minutes
Proposed method - 1 man x 2n minutes or less

2. Measure entry width at face

Present method - 2 men x n minutes
Proposed method - 1 man x 2n minutes or less

3. Establish center line - no change in time

Thus, the suggested changes require no increase in elapsed work cycle time and therefore can be implemented at no additional cost to the mine.

CHAPTER 18

BRATTICE MAINTENANCE

I. STATEMENT OF THE PROBLEM

One of the most exposed positions in continuous mining is that of the miner helper. He is responsible for ventilation control, which requires that he extend the brattice periodically to keep it within 10 feet of the face as the miner progresses. After the initial penetration, the brattice extension takes place in newly cut and unsupported roof which often necessitates the setting of a prop or roof jack to support the brattice. This exposure to unsupported roof is complicated by a preference for a position forward of the boom, usually in front of the operator, in order to avoid being crushed by the boom in the event of a control malfunction or operator misjudgement. This position, however, is extremely hazardous since it 1) places the helper nearer unsupported roof areas and 2) does not provide any room to escape in case of an accident.

It is estimated that the need for penetration into unsupported roof areas for brattice erection will result in at least 4 lives lost each year during the early 1970's. As continuous mining tonnage increases as a percentage of the total national underground tonnage, this number will increase proportionally.

II. ANALYSIS OF THE PROBLEM

Although they share some joint exposures, the continuous miner operator's and helper's duties are extremely varied and preclude a simple analysis of their exposure. Observations indicate that the operator assists the helper in the performance of his duties more than the helper assists the operator. During development work, the operator captains the team and is in almost constant productive motion -- cutting and loading coal, helping with props, brattice, testing, scaling and a dozen other duties. While the helper works constantly during the period devoted to support functions, he is relegated to the position of an observer during most of the mining and loading operations. The helper's duties are to protect the power and water lines which serve the equipment and to move the brattice. Brattice movements normally require two men and are usually performed during the necessary delay between shuttle cars.

The helper's position during the mining and loading operations is normally to the rear of the operator but out of reach of the boom. From this position he can tend the service cables, observe work progress, and assist in evaluating roof conditions. The helper, however, in this position is also exposed to dangers from the ribs, posts, roof, and machine -- particularly the boom as a result of constant equipment adjustments.

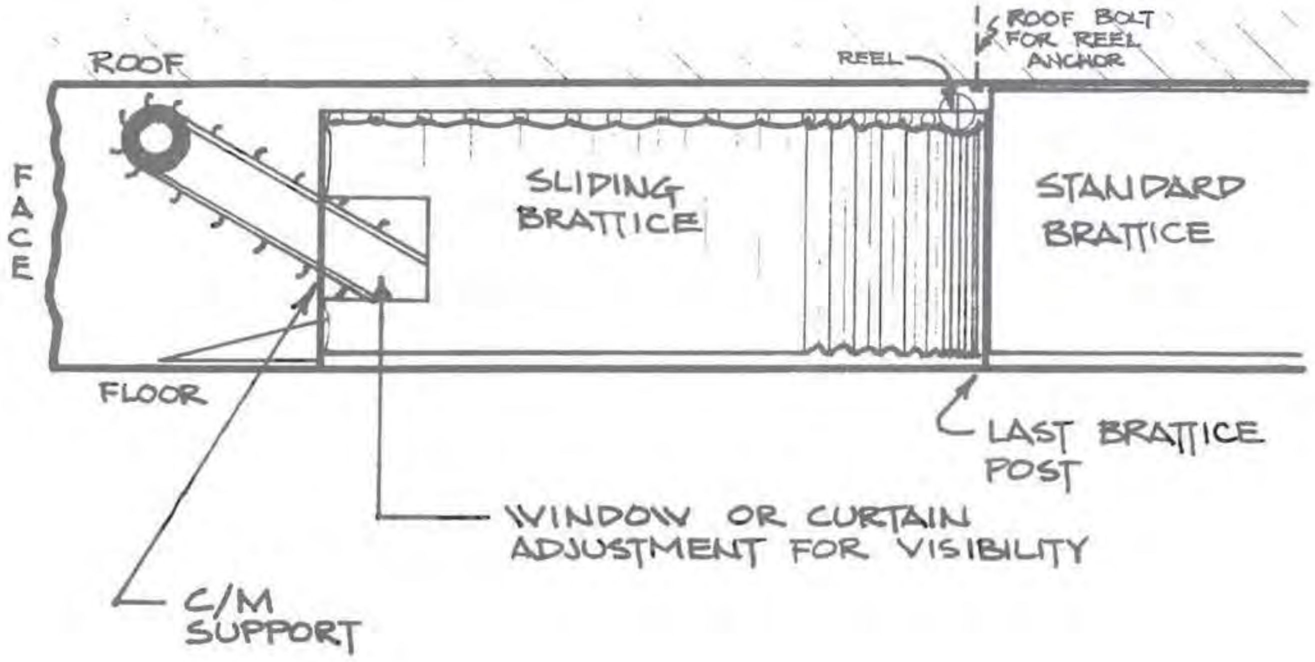
The functions performed by the helper are important but not all need to be executed manually. Most of the duties, such as roof support or the movement of supplies, must be performed by someone, so we are not suggesting that the position can be eliminated by the removal of only two duties. Face brattice adjustments and equipment cable handling, however, can be performed mechanically which would free the helper for productive labor in other functional areas. This chapter will only consider the problem of face brattice adjustment. The cable tending function was discussed in Chapter 13.

There are a number of logical approaches to the brattice problem. Elimination of the requirement for a brattice kept within 10 feet of the face would be a partial solution for non-gassy mines. Minimum airflow and dust requirements would allow greater latitude in mines not subject to methane liberation. This may be only a partial solution, because a number of mines ignore the present brattice requirements between inspections and are therefore not subjecting operators and helpers to this exposure. A typical comment in the industry is, "when the inspector comes up the hill, the brattice goes up to the face".

A second possible solution is to substitute tube-type ventilation equipment, now used in some mines to help control air movement, for the brattice. Unfortunately the tubing diameter required for high volume air movement restricts the applicability of this system in many mines with low seam heights.

The most practical approach to the problem seems to be in accepting brattice as the standard ventilation method, and attempting to redesign brattice maintenance. The simplest method of connecting the last brattice in a permanently supported area to the continuous miner is to have a "curtain rod" type tensioned cable. This will allow the brattice, supported by sliding rings, to adjust itself to the opening required. The brattice would be adjustable on the cable and could be positioned to keep both ribs visible. Although visibility would be a problem, one possible alternative, assuming one end of the brattice is connected to the continuous miner, would be a visibility "window" near the machine. This window could be a simple cut-out in the brattice to provide rib and face visibility.

1. SELF-WINDING CABLE SUPPORT

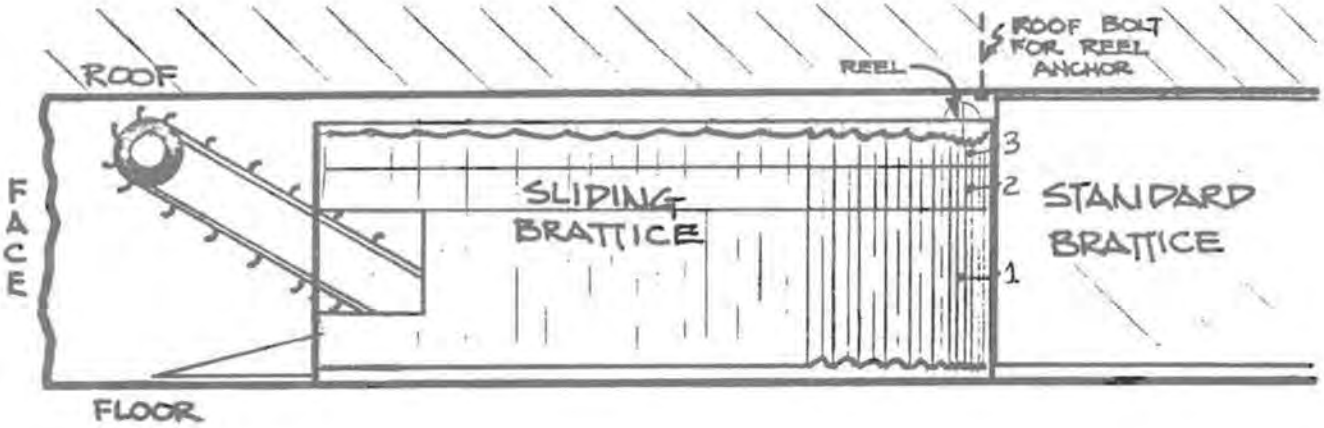


METHOD FOR EXTENDING SIDE BRATTICE

Uneven roof and the expected sag in the supporting cable would permit some air to escape between the roof and the top of the brattice. The closer proximity of the brattice to the face, however, might compensate for this loss. The miner mount would have to be both adjustable and flexible to provide maximum height, but adjustments could be made in permanently supported areas.

An alternative would be a self-winding brattice reel which would release brattice as needed from an area under permanent support. This "window shade" solution would be slightly more complicated and probably more expensive both in original cost and in efficiency. In this concept, a number of spring-loaded brattice rolls would be required to adjust for height. A typical 5' roof height would require a 4' roll and several 1' and 1" rolls to adjust to roof variations. In contrast, the "curtain rod" concept would adjust at the equipment and excess material would fold at the last brattice support and on the floor.

2. SELF-WINDING BRATTICE REEL



SELF WINDING BRATTICE REEL
(WINDOW SHADE DESIGN)

1. BASIC ROLL
2. ADJUSTMENT ROLL
3. ADJUSTMENT ROLL

Whatever system is eventually chosen, we believe that for most non-gassy mines the inherent danger of subjecting the miners involved in hanging new brattice to unsupported roof far outweighs the ventilation dangers generated by allowing brattice maintenance to lag face activity by more than 10 feet -- even 20-30 feet. A practical course of action for the USBM might, therefore, involve 3 steps: 1) as an immediate interim measure, amend the "within 10 feet of the face" regulation to specify that brattice maintenance may be allowed to lag face activity by more than 10 feet in bad or suspicious roof areas; 2) finance or subsidize a feasibility R & D study by manufacturers for a machine-mounted, cable-supported brattice system and any other potentially useful system for maintaining the brattice without exposing workers to unsupported roof; 3) require the use of a remote brattice system in most continuous mines.

III. SUMMARY OF RECOMMENDATIONS

A. As an interim measure, amend the law to allow brattice maintenance to lag face activity by more than 10 feet in areas of bad or suspicious roof.

B. Finance a feasibility R & D study of the machine-mounted, cable-supported brattice system to obviate the need for hanging brattice under unsupported roof.

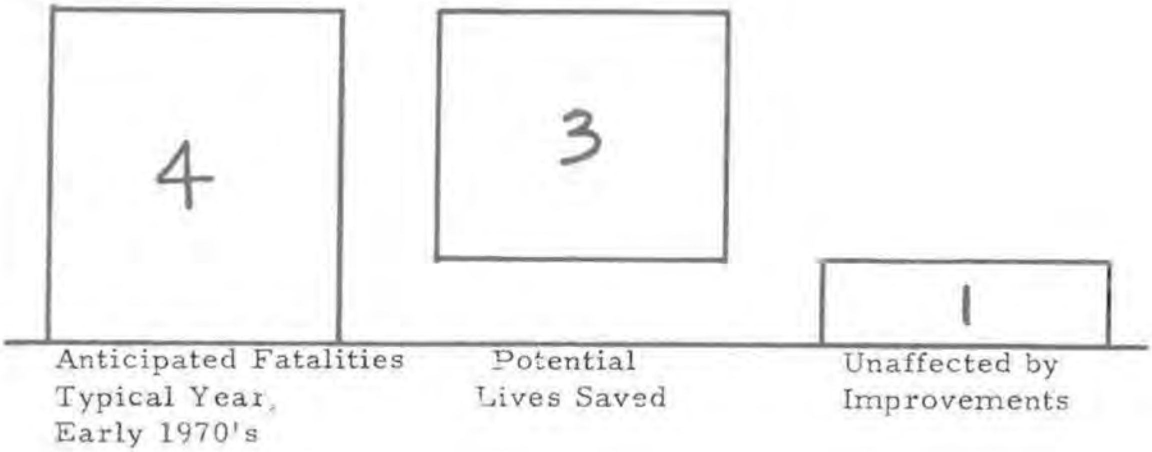
C. Require the use of a remote brattice system in continuous mines and return to the "10 ft. rule" in the Federal Register.

The remote brattice system is now being used in a few mines. It consists of a cable support fastened to the roof with quick connecting rings to attach the brattice. The rings can be moved along the cable in the manner of a shower curtain. To extend this system from the last permanent support would require a strong take-up reel and a support on the miner itself. The brattice might then be positioned directly in back of the cutting drum and provide even better ventilation control.

IV. POTENTIAL LIVES SAVED ANNUALLY

Potential Lives Saved: 3

POTENTIAL FATALITY REDUCTION



Based on 1966-1970 fatality data, we estimate that approximately 4 men will be killed annually while setting brattice under unsupported roof. We estimate that 3 of these can be saved by industry-wide use of a remote brattice system.

V. COST TO IMPLEMENT RECOMMENDATIONS

A. Cable Supported Brattice System

- Estimated cost of equipping one section with cable supported brattice = $1,500-2,000
- Estimated cost of cable, roof bolt mounted cable take-up, brattice, and continuous miner mount = $500
- Total industry cost = $1,200,000
- Annual industry cost = $1,200,000 ÷ 5-year amortization = $240,000
- Estimated cost per life saved =
  $240,000 ÷ 3 lives saved ÷ 360 million tons = .02¢/ton/life saved

Combined with a device to assist the machine operator in handling power cables in the face area, this arrangement would have the potential of eliminating the presence of a helper while driving entries, although his assistance would still be needed for tramming and other functions. In any case, the miner helper's productivity would be improved, making the real cost per life saved probably significantly less than .02¢/ton/life saved.

2. Feasibility Study

- Estimated lives saved annually - unknown
- Estimated total industry cost = $40,000

3. Change 10' Regulation in Federal Register

- Estimated lives saved annually - unknown
- Estimated industry cost - 0

SECTION IV

HUMAN BEHAVIORAL PROBLEMS, RESEARCH IDEAS, AND COMMENTS

CHAPTER 19

HUMAN BEHAVIORAL PROBLEMS: LOW JOB TASK EXPERIENCE, LACK OF TRAINING AND CERTIFICATION, LACK OF QUALITY SUPERVISION

I. DISCUSSION OF THE PROBLEM

In the broadest sense, nearly every fatal accident can be related, either directly or indirectly, to some form of human error. The Fatality Report Analysis presented in Section II shows a high correlation between inexperience, especially job task inexperience, and high fatality rates. Actually, these figures provide only a rough estimate of the significance of personal error as an accident source since the data does not exclude those inexperienced men killed regardless of their experience level. Also the data does not and cannot classify related human error factors -- fatigue, attitude, anxiety, lack of attention, faulty knowledge, etc.

One can reduce human error by either changing the individual or changing his environment. The individual's environment is composed of both social and physical factors. Most of the fatality reduction problem areas discussed in this study are concerned with improving the physical environment to reduce the likelihood of serious or fatal injuries, e.g., postponing clean-up until the roof is supported, designing better cages or canopies, designing temporary truss support systems, matching undercutting and loading equipment, etc. However, to ignore the social environment of the workers, i.e., the influence of other workers, the supervision, etc. or to ignore the characteristics of the worker, his task experience, his training or his skill level etc. would be a serious oversight in a survey of underground coal mining safety.

The I.E. study approach was not designed to investigate in detail such problems as supervision, absenteeism, job turnover, worker attitudinal problems, etc. Nevertheless, in our observations in over 50 mines, and in our conversations with mine managers and workers, these problems were observed or discussed over and over again. Moreover, our staff was convinced that many of these human behavioral problems deserve as much or more attention than the physical problems if dramatic safety improvements are to be achieved in the mining industry.

The problem areas discussed will be:

- A. Aspects of Low Job Task Experience Problems
- B. Lack of Training and Certification
- C. Shortage of Quality Supervision

A. Aspects of Low Job Task Experience Problems

Chapter 4 in Section II, covering the fatality report analysis, discussed the apparent effects of low job task experience, which occurs in a disproportionately high number of fatal accidents. Without repeating the analysis made in that chapter, this discussion will cover some additional aspects of the problem as observed during the field study. The topics are:

1. High Job Turnover, especially for new workers in smaller mines.
2. Absenteeism
3. Job Posting and Job Mobility
4. Crew Inexperience on Swing and "Graveyard" Shifts

1. High Job Turnover

Considering that the average age of underground bituminous coal miners is close to 50 years of age and that older workers are perhaps less likely to exhibit as high job turnover, the turnover figures for the industry may understate the real turnover of younger, new coal mining workers. The new data base established by the Bureau on the worker pneumoconiosis tests may indicate in the future the job mobility of the industry. In our interviews with coal operators, figures as high as 60% per year were sometimes quoted for the turnover of new employees, especially in medium and small mines.

One description of this problem often heard is that there is a labor shortage of mature, hard-working, ambitious workers who are willing or desire to become skilled miners. This may be true, but another description of the same problem may be more appropriate, as formulated by P. B. Doeringer, a labor economist. He studied the reasons for the large number of unemployed men and the paradoxical shortage of labor and high worker turnover in unskilled jobs in Boston. ("Ghetto Labor Markets", Monthly Labor Review, March 1969.) He found that unskilled workers would take unskilled jobs for a while but would quit if they perceived the job as onerous or as a dead-end job with little hope of advancement.

Doeringer's findings are very similar to a study in Montana by R.E. Gorman, et al, ("A Guidance Project to Investigate Characteristics, Background, and Job Experiences of Successful and Unsuccessful Entry Workers in Three Selected Industries", September 30, 1966, University of Montana, H.E.W. Office of Education, Bureau of Research, Division of Adult and Vocational Education, Office of Education Grant OEG4-6-062147-1932). Reasons for high turnover of entry (new) workers were investigated in three industries -- mining, construction, and logging. This study found that the workers were "poorly oriented to their job assignments by management, ineptly instructed in the performance of their assignments, outraged by the needlessly dangerous working conditions...dumbfounded by cryptic directions from their supervisors... They were all pained by the realization that their hard, hot, sweaty jobs yielded them only slightly more in wages than jobs of those who can qualify for assistance in 'War on Poverty' programs." We believe the Gorman study is very descriptive of many coal mining job situations.

Britain and Germany are experiencing similar problems in attracting and keeping good workers in coal mining. Germany especially has a severe coal mining worker shortage and imports large numbers of foreign workers from Italy, Spain, and Turkey. The National Coal Board in Britain has been conducting a national advertising campaign including television commercials to recruit workers, especially young workers. The commercials we observed stressed thorough training, safety, and opportunities for promotion and education. One commercial stressed that the men could continue and finish their schooling while earning good pay (similar to U.S. military recruiting programs with high school "dropouts").

Both Britain and Germany require training and certification before being assigned underground, and many educational programs are offered to the miners to upgrade their skills. During our brief visit this last summer in Britain, we met several men who had become mining engineers after entering mining at the lowest skill level, who had taken training courses and programs continuously, and who had become engineers or managers while maintaining their employment. The German coal officials were also very proud of their educational programs and stressed them as very important to the future competitiveness of their coal industry.

We have observed that some progressive American companies have safety programs and some training programs designed for shot firer or foreman state certification, but we have not observed any extensive educational opportunity programs of the type described to us in Britain or Germany.

To some extent, the bad image of a job in American underground coal mining may be exaggerated. Many companies have excellent safety records, and the compensation and fringe benefits compare well to many other jobs. Moreover, to the extent that the image of the job is unrealistically exaggerated, a concerted public relations effort by the industry will help attract better labor and may reduce job turnover. However, to the extent that mining worker jobs are and continue to be monotonous, dangerous, and dead-end jobs, the image of coal mining work is not likely to improve.

2. Absenteeism

Accurate industry figures do not exist on absentee rates. However, all operators interviewed cited absenteeism as a major safety and production problem. Based upon the individual experiences and estimates of the consultants performing this study, an annual absentee rate of 7-15% for the coal industry seems reasonable. This compares to a 1-4% average rate often used to represent industrial absenteeism nationwide.

Absenteeism leads to "short-crew" sections, with crew members forced into unfamiliar operations and tasks. In short-crew situations, section foremen often request that one or more crew members from the previous shift "double-back"; i.e., work a second consecutive shift. Fatigue is the natural result of a 16-hour period of hard physical activity, and fatigue and accidents are highly correlated in any industrial activity.

Absenteeism is also a serious problem in many collieries in Britain and Germany. German officials indicated that high absenteeism is associated with a higher incidence of accidents, despite concerted efforts to be sure that no job is performed unless the worker is certified for the job. If this is true in Germany, one would expect absenteeism to have an even greater effect on safety in American mines where little, if any, job certification exists and job substitution is practiced with little concern for worker qualifications.

3. Job Posting and Job Substitution

Roof control is the most crucial operation in most mines in terms of crew safety. The roof bolter is in the best position to "know" roof conditions and make on-the-spot adjustments to handle changing circumstances. "Tailings", drill speed, bit condition, bit penetration, and various sounds are good indicators of actual conditions. Yet, paradoxically, roof bolting frequently ends up as the responsibility of the most inexperienced man on the crew. Experienced men exercise seniority by bidding away from roof bolting because it is dangerous, difficult, uncomfortable (dust and noise), and pays less than other crew positions such as loader and undercutter operator.

The inexperienced roof bolter not only is performing one of the most dangerous jobs in the mine, he may be creating hazardous conditions for the entire section crew: overspacing bolts or bolting too far from face/ribs; overlooking or incorrectly bolting kettlebottoms; leaving loose bolts; over/under-torquing bolts; or creating bottlenecks in section work cycles, leading to out-of-cycle hazards such as the undercutter moving ahead of the bolter. The situation in which one of the least experienced men operates the bolter has been observed during this study as the <u>rule</u> rather than the exception.

A better roof bolting machine could eliminate much of the negative aspects of the roof bolter's job, but without such a machine other measures must be considered. Elimination of posting or modifications to posting regulations, such as minimum experience at one job before bidding to another, might slow down the roof bolter job turnover. But more incentives to make the roof bolting job more attractive is perhaps the best way to lessen roof bolter turnover. Wage scales could be revised to reflect the responsibility and experience requirements of roof bolting. The roof bolter should, in our opinion, receive the top wage rate along with the loader operator, while the <u>undercutter operator</u> pay scale should be comparable to the present roof bolter scale.

Even if the roof bolter job turnover cannot be eliminated, better selection and training of new roof bolter operators would substantially improve many section operations relative to both safety and production. Roof bolting is typically a bottleneck production operation. The roof bolter example cited may suggest that as equipment and mining jobs change over the years, the compensation ratios for jobs no longer reflect their relative importance to productivity, their relative hazardous exposure, or their desirability as perceived by the workers. A detailed study of fatality and injury rates per job classification would be helpful to both union and management in negotiating rates to compensate for relative degrees of hazard. Similarly, a comprehensive human factors study of worker skills ideally required on various jobs would assist in the worker selection process, the design of training programs, the design of jobs themselves, and the assignment of relative wage levels or compensation to jobs to attempt to keep the most experienced and skilled workers on the most critical jobs.

Job posting, the practice of filling jobs on the basis of seniority and notifying workers of job vacancies via "posting" lists of available jobs, greatly increases the effects of job turnover in a mine. Filling a few job vacancies can set off a chain of job vacancies, very much like a game of musical chairs.

Unions in the U.S. have historically fought for seniority rights, with mining unions being no exception. As already discussed, the present lack of training and certification practices in many mines, combined with posting practices, apparently increases the probability of accidents. In interviews with German union safety officials, a preference was expressed for the existing training, certification, and close supervision programs for new workers, and for more worker educational opportunities rather than for seniority provisions. These officials also predicted from their experience that posting practices without adequate guaranteed training for the worker would prove to be a dangerous practice in U. S. mining operations. Since training is expensive, the cost of more training, compounded by existing posting procedures, may in fact delay an easy resolution of the problem.

Besides job posting practices, other forms of mine job mobility and job substitution practices create situations where men with little or no experience attempt to operate equipment or perform unfamiliar job tasks. Some mine crews attempt to work through the lunch hour by rotating and substituting crew members. Many equipment operators will attempt to repair their own machine. Repairmen will attempt to operate a strange piece of equipment. Foremen will often fill in as equipment operators. All these hazardous situations would be mitigated by decreased job turnover, by training for and certification of minimum skill levels, and by restricting workers to performing only those jobs for which they are qualified.

4. Swing and "Graveyard" Crew Inexperience. Experienced miners often exercise their seniority to bid onto the day shift and away from swing and midnight shift positions. This results in a disproportionate number of new and relatively inexperienced miners working these shifts. The absentee and turnover problems discussed above are compounded for these shifts, especially midnight, with a corresponding increase in the fatality rate. For the 50-mine sample utilized in this study, normalized figures show that 19.8% of non-roof fall fatalities occurred between 8 AM and 4 PM; 22.2% occurred between 4 PM and 12 AM; and 58.0% occurred between 12 AM and 8 AM. If these estimates are true for the industry, the term "graveyard shift" has real meaning in the mining industry.

   Posting elimination will reduce the disproportionate number of new men on swing and midnight shifts and decrease absenteeism and turnover rates caused by the non-desirability of swing and midnight shift hours, particularly for younger men.

   If the elimination of posting proves impossible, operators could employ rotating shifts (a few mines use this system now) to avoid the prospect of an indefinite period on an undesirable shift and, thus, avoid the accumulation of experienced, high-seniority miners on one shift.

B. Lack of Training and Certification

Training programs in the industry vary widely, ranging from the comprehensive operations, health and safety training programs at large captive mines to the complete absence of any training other than section on-the-job-training (OJT) at small, independent mines. Section OJT itself can be dangerous. As mentioned earlier, the first 1 to 3 weeks of a job are extremely hazardous when compared to the remainder of the worker's career at a particular task. This danger becomes even greater when the trainee is working in a highly responsible crew-dependent position such as roof bolting or shuttle car operation. For this reason, the initiation of a required, short orientation course covering major safety precautions in at least a rudimentary way in order to get the young miner through the first hazardous weeks could have significant impact upon fatalities.

Two things characterize mine safety training in the industry today: 1) extreme variability, ranging from well-constructed, thorough programs in some larger captive companies to non-existence in other companies; 2) the large number of mines in which training is virtually non-existent, probably as much as half the total mine population.

Many operators view safety training as an expensive luxury, detracting from vital production time. In selling the value of training to these individuals, it is worth noting that good safety practice and good operating practice are indistinguishable -- good safety training is good operations training. If safety training is viewed largely as training in efficient methods, procedures and practices, then the value of such training to production as well as safety becomes clearer.

To sift through the variety of existing programs and determine a group of effective approaches, we recommend that the USBM: 1) thoroughly study and evaluate all forms of training presently being offered to miners -- from preshift five-minute safety talks to Bureau sponsored classes and foreman certifications; 2) compile a library of all training tools now being used and incorporate the best along with new ideas into an effective program; 3) evaluate ways to make training programs workable for both small and large operators.

Some of the possible approaches for accomplishing these objectives are outlined below. We recognize that a number of these may duplicate or closely parallel existing USBM programs, but we feel they should be included here to present a more complete list:

1. Interview all coal operators sponsoring their own training classes and procedures. Compile a composite list of training programs and ideas for other operators to use in developing their own programs. (For example, one mine has trainees wear different colored caps for a given period of time to identify them as trainees so all miners can help them.)

2. Consider certification of miners for all jobs, or at least the most hazardous jobs; evaluate ways to make this economically feasible and decide who should sponsor the certification. Certification would contribute to a reduction in the disastrous fatality rate during the first 1 to 3 weeks of new task experience.

3. Consider a training program offered by the USBM as a service to those operators and miners who cannot afford to sponsor their own. Perhaps operators could form training cooperatives.

4. Explore the possibility of USBM-funded subsidies to share the cost of training plans which are submitted by coal operators for approval by the USBM (as roof plans, ventilation plans, etc. are now submitted for approval).

C. Shortage of Quality Supervision

Almost every operator interviewed during this study cited the insufficient numbers of high quality operating supervisors, and the resultant loss of supervisory effectiveness at the working face, as one of the major problems confronting the industry today in terms of both safety and production. A recent study of the coal industry also documented this problem. The term "quality" supervision raises some important questions, independent of the shortage issue. One aspect of the quality issue is the claim that the best men either refuse to become foremen or leave their foreman jobs for other jobs.

In our interviews with mine foremen and miners, the following factors were listed in order of priority as the most dissatisfying and unattractive parts of the foreman job:

1. The prospect of long, irregular hours -- often a 50-60 hour work week.
2. The lack of a fringe package competitive with the union -- hospitalization, disability, retirement.
3. A general hesitancy to leave the security of the union.
4. Modest pay (considering the number of hours worked), often on a straight salary basis with no overtime.

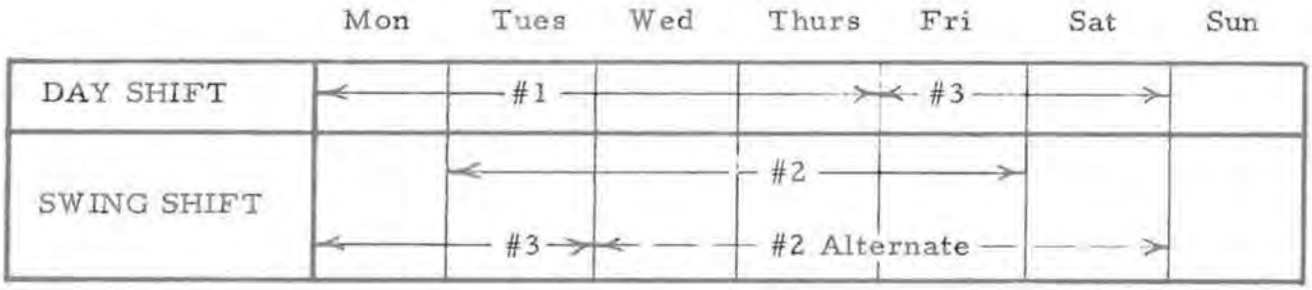
The order of priority of the factors listed above is important. Long and irregular working hours were by far the most frequently cited deterrents to attracting quality foremen in our interviews. Since our interviews were not designed to scientifically explore the foreman shortage problem, the above results need to be verified and thoroughly investigated.

Assuming our observations are correct, there are many alternatives available to improving the attractiveness of the foreman job:

1. Obtain shorter hours by studying the foreman tasks and redesigning the job to transfer much of paperwork and unessential studies to clerical or other support personnel.
2. More fringe benefits -- bigger vacations, insurance, retirement, etc. -- at least to match the union fringe benefits.
3. Higher pay.
4. Obtain shorter hours via 3-Foreman Plan.

All of the above are self-explanatory except the 3-Foreman Plan. In this plan three rotating foremen would be assigned to two shifts as shown:

THREE-FOREMAN PLAN



The basic addition to the present system is the utilization of an extra foreman (Foreman #3); that is, each two-shift working section has three foremen rather than two. Foremen #1 and #2 work conventional four-day schedules, with their work week falling in the 38-48 hour range instead of the 50-60 hour range. Foreman #3 works a split week according to the following schedule: Monday -- supervise swing shift; Tuesday -- assistant foreman/general trouble shooter on swing shift; Friday -- supervise day shift; Saturday -- supervise maintenance/clean-up. An alternate schedule would be for Foreman #2 to work Wednesday through Saturday, resulting in the availability of two foremen for Saturday maintenance and trouble-shooting operations; Foreman #3 would function as section boss on both Monday and Tuesday under this latter schedule.

The advantages of the system are clear: 1) a regular work week; 2) a shorter work week in terms of total manhours; and 3) less fatigue and increased mental alertness while supervising.

The problem with the proposed solution is also apparent: the cost of an extra foreman per section. The overhead cost of the extra foreman in a typical mine is estimated at 5 to 6¢ per ton. This cost, however, does not take into consideration the increase in productivity nor the decrease in fatalities which would most likely result from an increase in the percentage of high-quality foremen.

As the cost factor is likely to deter wide acceptance of the program initially by the industry, an experimental program is needed to determine the impact of the program on both safety and production. The objective of the program would be to determine: 1) the significance of improvements in accident and fatality rates; and 2) the economic feasibility of the innovation. Increased productivity must be sufficient to offset or significantly reduce costs to the point at which the plan is acceptable to a substantial number of medium-to-high production mines in the industry.

Perhaps the investigation of manpower shortage will help in resolving the "quality" issue in supervision. The fatality reports, our field observations, and other studies clearly indicate that too many foremen are not safety conscious supervisors. In many cases they actively encourage unsafe practices or give instructions to perform unsafe practices. For example, as discussed in Chapter 5, the majority of fatal roof fall accidents involved unsafe deviations from roof control plans or other safety regulations; the foreman was usually aware of the deviation and had apparently given tacit approval to the unsafe procedures.

Certainly, high production is a mark of "good" supervision from a manager's point of view. What about safety and "good" supervision? Are safe procedures and high production procedures congruent in the continuous mining and conventional mining technologies? Our simple answer is yes -- safety and high productivity procedures are more complementary than is generally recognized in the industry. A number of companies in the industry have already demonstrated this, especially those companies with good training programs.

A particularly discouraging part of the poor safety attitudes of foremen is the effect on the workers. Since almost all mining job training is on-the-job training, the first line supervision now provides the vital training and informal training certification ("I think you can do this") function. Since no physical constraints prevent miners from going out under unsupported roof unnecessarily, or from using many other unsafe procedures, the first line supervisor is really in the best position to insist on worker compliance with safe procedures.

The foreman is regarded almost unanimously by American mine management as a key link to safety and high production. A common theory in U.S. mining is that the tougher the supervision the better the results. An interesting view on supervision has been developed by Trist and others, (Organization Choice , Tavistock Publications, London 1963) who found that British coal mining jobs could not be effectively supervised by traditional factory standards. The study team actually experimented and demonstrated in several British collieries that miners who were trained to be interchangeable on all face jobs and who worked in crews organized to have a high degree of group cooperation and group autonomy worked more productively with fewer accidents than traditionally organized and supervised sections.

An interdisciplinary study of American mining practices similar to the famous studies conducted by Trist and others in British coal mining might destroy a number of commonly held beliefs about the ideal roles of supervision relative to the unique problems of mining. Technical mining experts worked in teams with industrial engineers and psychologists to study low productivity mines. The theory behind the approach is that jobs should be designed relative to both technical and social (or psychological) aspects. Technical and social factors are considered together rather than as separate issues. The approach achieved some dramatic turnaround results in those collieries studied. The research results cannot be directly transferred to the United States because the technology was very different, but the study approach has great merit.

II. SUMMARY OF RECOMMENDATIONS

Problem Area "A" - Aspects of Low Job Task Experience Problems

- High Job Turnover, especially new workers
- Absenteeism
- Job Posting and Job Mobility
- Swing and "Graveyard" Shift Crew Inexperience

1. The Bureau should conduct more research on the relationship of the above factors and task experience to accident occurence, especially on non-fatal injury accidents (see chapter 4).

2. Management and the unions should either eliminate job posting, or allow the practice only for men trained and certified for minimum performance proficiency on the new job. The fatal accident report data strongly suggests that any policy that encourages job mobility without prior training for the job is a dangerous policy.

3. We recommend that job mobility patterns be studied among various mining jobs, relative to the importance of the job, the skill level required, the relative hazard, the worker preference for the job, and the compensation for the job. We believe that the compensation system and the job design of certain critical jobs, i.e., roof bolter, encourages needless job turnover. The high job turnover results in low task experience and a disproportionately high number of accidents.

4. Management and the unions should carefully consider rotating shift schedules to prevent accumulation of all the experienced miners on permanent day shift.

5. We recommend a comprehensive study be made of the causes of job turnover and absenteeism in the industry with special emphasis on new worker problems. A 10-year comprehensive geographic forecast of needed and available labor in the coal industry would help companies, unions and the Bureau plan for the future. Determining how much of the new worker problems are "image" problems would help the industry decide whether better public relations would help. Identifying with documented evidence the major job "dissatisfiers" will help both management and labor eliminate some of the most critical job dissatisfactions.

Problem Area "B" - Lack of Training and Certification

1. Compile a "library" of current training techniques in the industry.

2. Consider "certification" of minimum proficiency as a requirement for all working positions, or at least key jobs.

3. Develop a USBM subsidy program to assist training, especially for small-to-medium-size mines. Perhaps subsidized cooperative training centers could be set up by the operators.

Problem Area "C" - <u>Shortage of Quality Supervision</u>

1. The Bureau should fund or encourage research into the so-called foreman shortage problem in the industry. Is there a shortage? Why is there a shortage? Are long hours and fringe benefits more than wages the major deterrent to attracting and keeping good foremen? Would the Three-Foreman Plan help?

2. Bureau research on experimental foreman training and certification programs will provide valuable guidelines to the industry and to the various states who have foreman certification programs. The accident data, our observations, plus interviews with mine management, union officials, and the miners themselves indicate serious supervision problems in the industry which seriously and adversely affect safety in the mines.

3. Bureau research, particularly interdisciplinary research that includes industrial behavioral expertise on job design in coal mining, may provide new job designs that are inherently safer, more productive and perhaps less dependent on supervision quality for safety or performance.

CHAPTER 20

AREAS OF NEW RESEARCH

This chapter describes technical, procedural, and management problems associated with underground coal mine production which Theodore Barry and Associates feels could benefit substantially from additional study and research. These suggested areas of new research differ from the recommendations presented in Chapters 7 through 19 in that: 1) we are uncertain as to the ideal or optimal solution to the problem -- hence the call for new research; or 2) we do not feel sufficient data exists to make a useful judgement concerning the impact of the project upon fatality reduction; or 3) we do not know if all aspects of the problem have been identified and defined accurately -- hence, the need to study and weigh the subject in greater depth.

In collecting, reviewing, and evaluating these areas for potential research, we have assigned priorities based upon the collective judgement of the TB & A consultants who have conducted this study. The priority system used here is as follows:

- Top Priority -- A research breakthrough could have a significant impact on fatality reduction; or, a significant contribution could be made for a minimum expenditure of time and research funds.
- Second Priority -- This research is less significant in terms of potential payoff (lives saved) but still can contribute to fatality reduction; or, the research benefits are still some distance (time distance, money distance, etc.) "downstream".
- Low Priority -- These projects should be considered if additional funds are available.

The areas of new research are grouped under three major headings:

I Technical/Engineering Research: Mining Equipment
II Technical/Engineering Research: Personal Clothing and Equipment
III Management/Administrative/Organizational Research

We recognize that some of the following proposals are being investigated or may have been investigated by the U.S. Bureau of Mines or organizations under contract to the Bureau. However, a review of external and internal research programs was not considered to be within the scope of this contract.

I. TECHNICAL/ENGINEERING RESEARCH: MINING EQUIPMENT

A. Roof Measurement, Testing, and Scaling

1. Measurement

The Problem: Miners carry posts for use as supports into presently unsupported areas to see if the posts are the correct size. If, as a consequence of sloppy measurement, the posts do not fit properly, a variety of methods, including excess blocking and other unsafe, procedures, may be employed.

Research Recommendation: Develop a measuring device that would permit both remote measurement as well as accurate and efficient transfer of measurements to post without entering unsupported area or lifting post. Some possible devices might be: a lightweight "yardstick" or measuring jack, or a light-projection device to triangulate roof height.

Research Priority: Second

2. Testing

The Problem: Roof testing is almost a mystic art among miners. New miners quickly learn to tell the obvious sound difference between a "drummy" roof and a solid roof. It is the interpretation of the various gradations of sound in between which seems to require years of experience and about which there is still not unanimous agreement. Roof testing is a "gut feeling" kind of operation, and -- as a result -- is uneven, unpredictable, and chancy in its outcome.

Research Recommendation: A need exists for a seismic, sonic, infrared or other more reliable and consistent roof-testing device to replace the procedure of striking the roof with a hard object. Such a device, however, may still be years away from practical use.

A less exotic solution would be an accelerometer or vibration-measuring device attached to a standardized roof testing hammer. Experienced miners could "scale" the measuring device by making numerous roof tests under varying conditions and explaining their interpretations of roof sounds. These qualitative judgements could be matched with equivalent readings from the measuring device. After hundreds of such tests, a range or scale could be worked out which effectively quantifies the experienced miners' judgement on the device.

Research Priority: Second

3. Scaling

The Problem: Roof scaling is performed using a variety of instruments including short handled hammers and pick axes. Regular scaling bars are both too heavy and too short.

Research Recommendation: Discourage use of hammers or other short handled prying devices. Develop a more efficient bar which combines greater length with a strong tubular handle for weight minimization.

A more complex, but more effective device would be a "power scaler". The tool could be lightweight with a telescoping handle for good reach. The tip of the device would be inserted in the desired roof crack, and hydraulic pressure would expand the tip or probes to force the rock down. The tool could be powered by the conventional miner, loader, or roof bolter.

Research Priority: Top

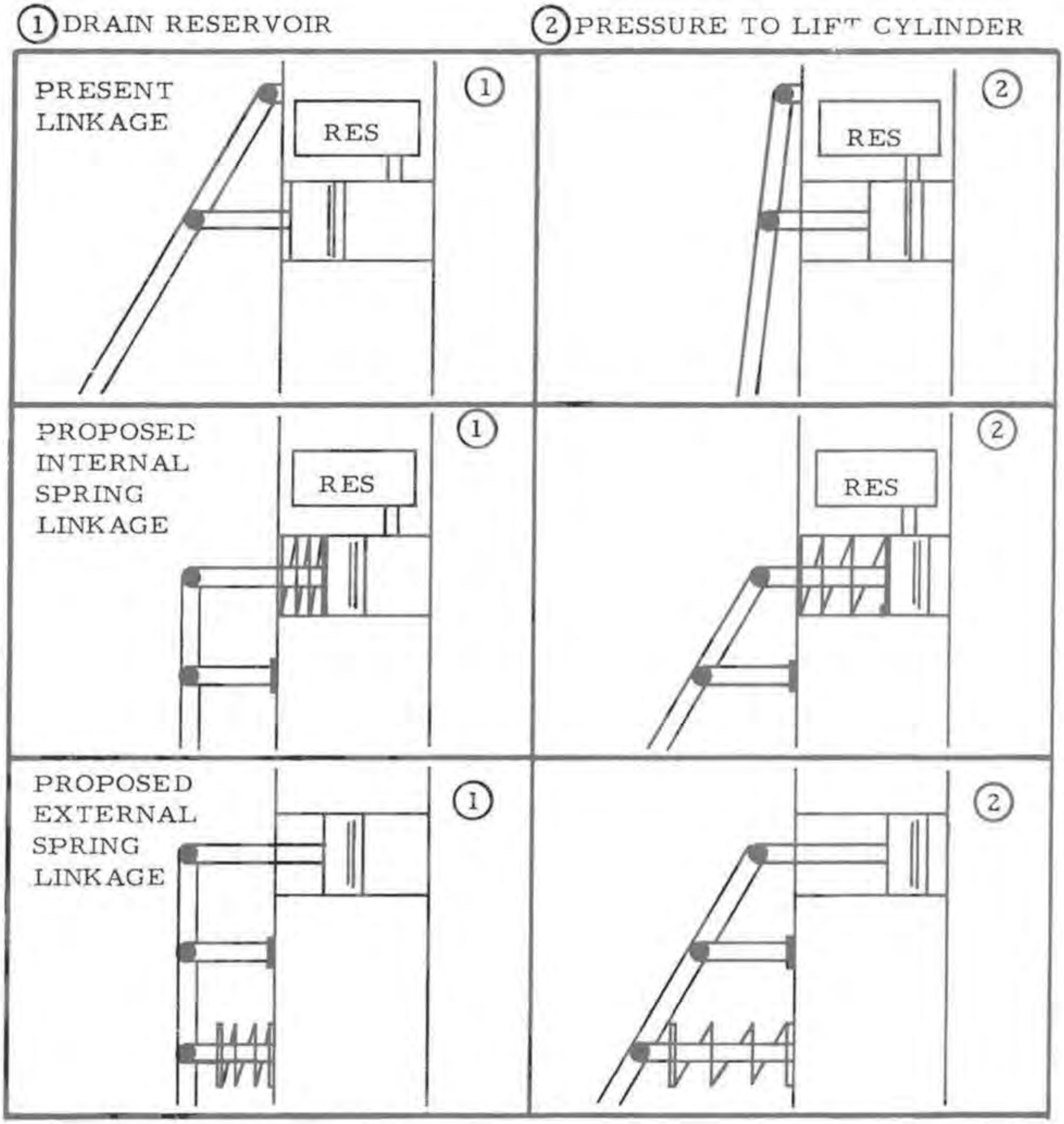
B. Roof Bolting

4. Temporary Support Jacks

The Problem: All hydraulic jacks tend to leak down and release support over a relatively short period. This often results in a large section of roof remaining unsupported for a long period of time (e.g., from the end of swing shift until the beginning of the day shift), allowing roof strata to flex, separate and weaken.

Research Recommendation: Develop a jack assembly with a high compression spring which matches the pressure required to tighten the jack. Pressure could then be maintained by the spring -- probably even overnight.

A residual benefit would be the movement of the jacking arm to a horizontal position if leaking down; lack of support and the need for jack repair then could be determined by visual observation.



The disadvantages of a similar mechanism to prevent or indicate jack leakage would be greater weight, additional cost, more maintenance, and possible physical handling problems if something like the external spring system is used. Still, unless the jack is serving its purpose -- providing support -- there is no reason to use it in the first place.

Research Priority: Top

5. Extendible Drill

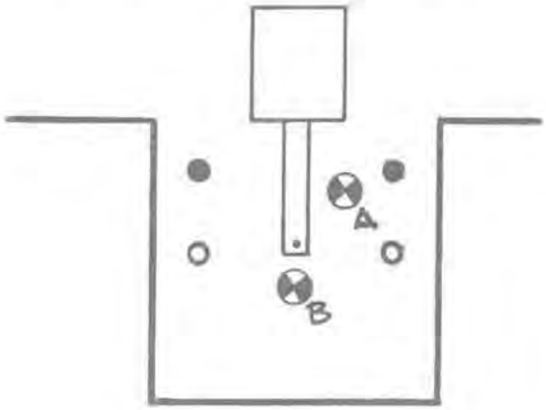
The Problem: Current roof bolting equipment usually exposes the operator to unsecured roof during the following elements of the roof drilling cycle.

Exposure - Minutes	Description
.15	Insert drill and bit into chuck on boom.
.25	Remove drill, add extensions, and re-insert drill into roof hole.
.25	Remove drill, remove extensions and bit.
.50 to 3.00	Drilling time.

For roof with adequate height, only one operation is required to insert and tighten the roof bolt after the hole is drilled, and this can be accomplished by a simple turret bolt storage. The real problem comes with long bolts and low roof. As many as 3 to 5 bit extensions may be required to drill under these conditions. It is relatively easy for the human hand to accomplish these changes but duplication via remote control is very expensive. Again, breakthrough technology is needed. In the absence of such technology, a hydraulically retractable and extendible drill boom and seat would allow both hand changes of bit extensions and seating of the roof bolter under supported roof.

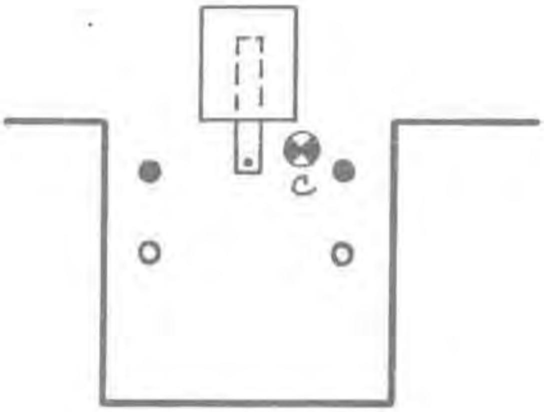
Research Recommendation: There is a need to develop an extendible drill boom and seat to eliminate the hazardous exposure of the roof bolting operator. One possible configuration is shown in the diagram on the next page.

● — Last Line of Roof Bolts
○ — Temporary Supports



Present Method

Operator must be at either A or B to perform the drill insertion and removal tasks. He has been observed at B more often than A because he has more space to work.



Recommendation

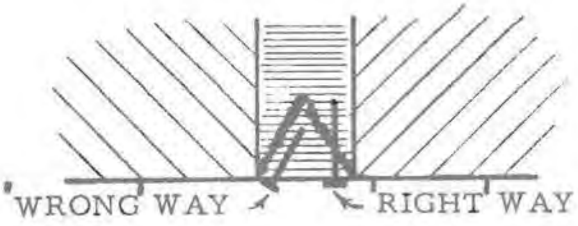
Operator C is able to work safely under supported roof. The hydraulic extendible drill permits operator to change bits and seat bolt in drill under supported roof.

Research Priority: Top

6. Kettlebottom Bolting

Lack of widespread understanding among foremen and workmen regarding the mechanics of kettlebottom bolting creates a significant hazard. At least three different philosophies of kettlebottom bolting exist and are in use:

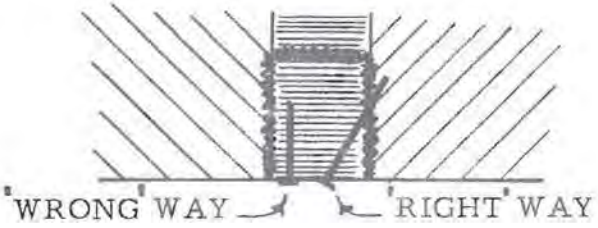
THEORY A



SIDE VIEW
OF
ROOF

Theory A - Although old petrified trees, called kettlebottoms, extend up into the roof in a perpendicular direction, they tend to shear loose in a cone-shaped form, as illustrated. Running a slant bolt creates the risk of bolting parallel to the shear (see "wrong way"). The bolt should be set vertically, off-center, as shown, to pin the cone-shear to the stable kettlebottom.

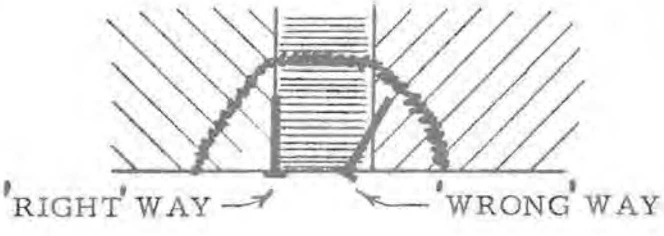
THEORY B



SIDE VIEW
OF
ROOF

Theory B - Kettlebottoms shear loose perpendicularly, so vertical bolts are useless. Bolts must be slanted.

THEORY C



SIDE VIEW
OF
ROOF

Theory C - You can't tell how a kettlebottom will shear; any bolt runs the risk of failing to hit solid roof; bolt must be used as wedge between kettlebottom and roof to compress and tighten entire kettlebottom area.

The variety of explanations from experienced section foremen regarding kettlebottom bolting suggests widespread ignorance about this hazard. One, two, or all of the above explanations may be dangerously wrong. In some seams in West Virginia it is not uncommon to find and bolt one or two kettlebottoms per working face per cycle -- making faulty-bolted kettlebottoms as potentially hazardous as working under unsupported roof.

Research Recommendation: The problem calls for research into the geological characteristics of kettlebottoms and the mechanics of kettlebottom bolting. The results of such research may show that kettlebottoms require particular kinds of expansion bolts.

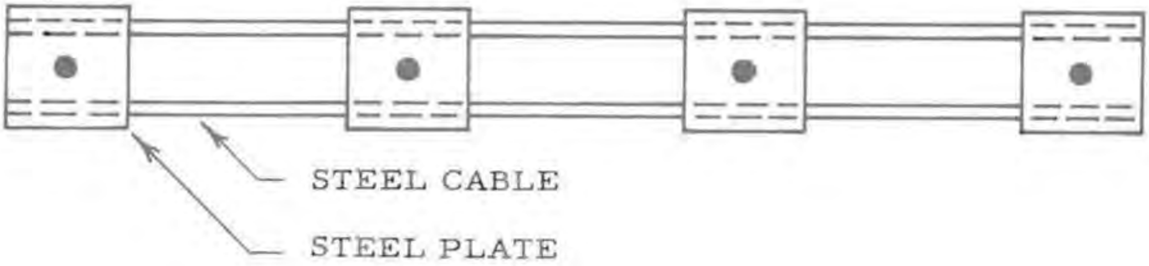
Research Priority: Second

7. Flexible Headers

The Problem: Present wood headers greater than seven feet long require two men to lift and hold during the roof bolting operation. Steel headers, used in some deep shaft mines, require 5 or more men or must be machine lifted. This manpower requirement in lifting and holding headers generates a significant amount of total exposure time to unsupported roof (2.50 minutes) x (2 or more men).

Rigid headers are often necessitated by roof conditions; however, where the purpose of the header is merely to anchor unpredictable roof (draw rock, etc.) flexible headers may serve just as well.

Research Recommendation: Design and fabricate a flexible header consisting of steel bearing plates attached to steel cables.



The advantages of a flexible header would be:

a. One man can handle the flexible header. Sections of the header can hang to the floor while the operator is securing one end; hazardous exposure is therefore reduced by 50%.

b Lightweight. One man can carry several headers at one time.

c. Can absorb roof deformation with small loss in effectiveness.

Research Priority: Low

C. Dust Control

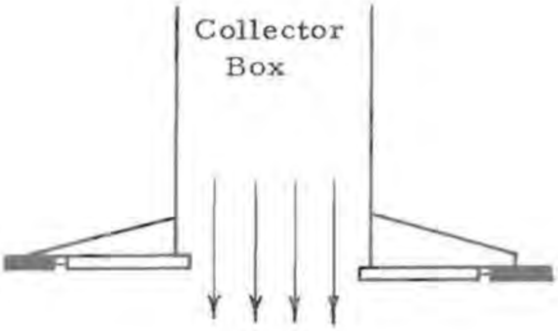
8. Self-Dumping Dust-Collector

The Problem: The present method of dust box maintenance is to open the side door of the dust collector box and manually scrape the rock dust out onto the floor. The cleaning is done between the roof drilling and bolting cycles and requires from one to two minutes. The operator is under exposed roof at least 50% of this time.

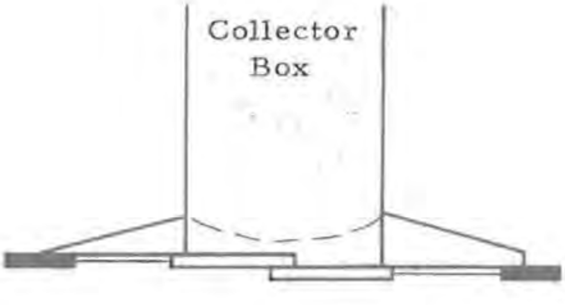
Cleaning once a cycle is not always sufficient and often results in a plugged or full dust collector system during the roof drilling and bolting cycle at a face. Two alternatives then face the operator -- stop and clean out the dust collector box, drill and bit, or continue at a reduced drill feed speed and generate dust.

Research Recommendation: Develop a dust collector box which will automatically dump its contents of rock dust when the vacuum is removed from the system.

A sliding tray attached to the bottom of a fixed dust collector box can be piston-actuated by the vacuum system. The tray would normally be closed to create a closed vacuum system. When the roof bolter boom is lowered, it trips a vacuum switch, which activates the piston, opening the sliding tray and dumping the rock dust.



OPEN



CLOSED

Research Priority: Top

D. Miscellaneous

9. Battery Shuttle Recharging

The Problem: Shuttle car cables are inherently unsafe due to the necessity of frequent and sometimes dangerous repairs, particularly in wet mines. Damaged cables preclude movement of the car, which can be both a work obstacle and an equipment collision danger. Energized cars also present a hazard to repair men. In addition, cables impose routing limitations on both the shuttle cars and other section equipment.

Battery cars are presently limited in endurance and present charging problems. Many battery powered cars are "duplicated" so that one car is available while the alternate car is charging.

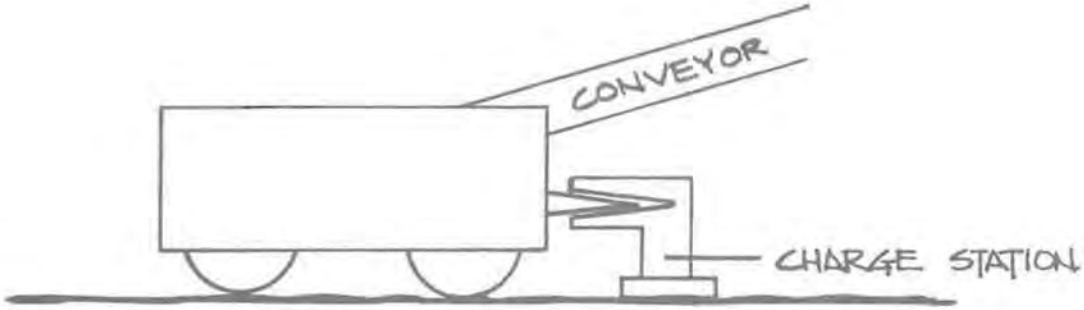
Research Recommendation: Investigate the feasibility of a permissible quick charge station at the tailpiece which would supply the conveyor power while recharging the batteries used for the tramming and loading movements of the conveyor. This would allow use of present shuttle car designs and remove the endurance obstacle for battery-powered cars (or tractors).

A permissible "probe" with appropriate sheathing would be necessary to provide a permissible quick charge station. The car would have approximately 30 seconds to receive its "boost" while dumping to the belt, tailpiece or mainline haul. Since the power for the conveyor could be directly supplied at that point, only the propulsion motor requirements would be charging. The minor exception to this requirement is the power needed to advance the conveyor to adjust the distribution of coal while loading.

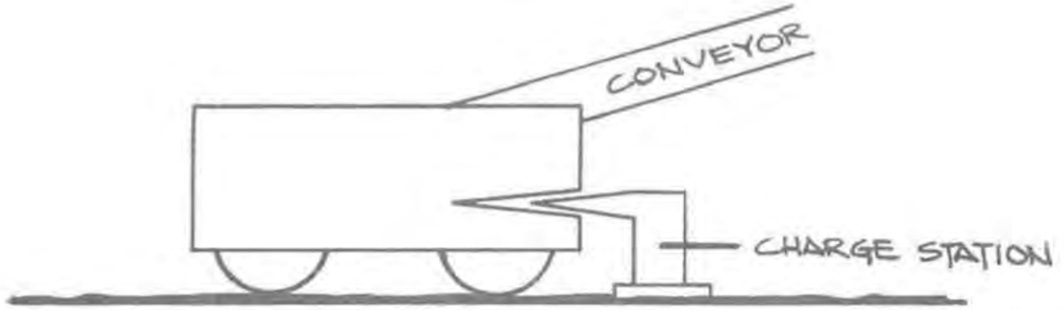
The probe would have to be a flexible snorkel with well shielded contacts on the male connection. If placed on the car, the probe should be retractable automatically to avoid a dangerous protuberance. It should also be automatically de-energized when retracted. If placed at the dump point, the probe must be sheathed except during actual penetration of the car.

This idea is apparently beyond the state-of-the-art and will require an advance in battery design technology.

A. CAR MOUNT



B. CHARGE STATION MOUNT



Research Priority: Second

II. TECHNICAL/ENGINEERING RESEARCH: PERSONAL CLOTHING & EQUIPMENT

A. Personal Lighting

The Problem: The light cord presently used by miners creates dangers and inconveniences for the wearer. The attachment to the miner's belt is strong enough to drag the miner into machinery -- and has in several fatal instances. The cord can also become entangled in machines, supports and roof.

Research Recommendation: Develop a permissible, quick-disconnect at both the cap and battery ends of the light cord. With this arrangement the light could be made an integral part of the helmet. The quick disconnect on the battery pack would provide protection against the danger of being pulled into machinery by the cord since the cap would normally by pulled off first. The battery pack would incorporate a small safety light to be actuated by forceful removal of the cord. The cord would also be reduced in size and weight allowing it to be worn under clothing and connected through a small hole at the beltline. It would only be exposed between collar and cap and would not be likely to catch on nearby projections.

Some major advantages of this new system would be:

1. Lighter cap; more maneuverability.
2. Room for permissible dry cell long-life battery/emergency light on cap for emergency use (1 to 2 hours).
3. Greater working flexibility.
4. More convenient battery maintenance.
5. Greater safety.

The disadvantages are:

1. Greater exposure to wear factors and connectors -- could become non-permissible.
2. Possible inconvenience on routing of cord. Workers may still leave cord outside of clothing -- danger here.
3. Greater initial expense since companies must now buy caps.
4. Education required to induce acceptance.
5. Company must assume inspection duty and prevent tampering; must maintain caps and provide clothing grommets.

Other temporary improvements on existing helmet lights should be considered.

1. Cord strength should be decreased, especially where fastened to battery pack. An occasional failure at this point would probably be less dangerous than the present arrangement.

2. Lighter batteries would be helpful to productivity and safety -- particularly if they could be worn at a location closer to the helmet (shoulder holster?).

3. Optimal solution is a cordless cap but this may take a breakthrough in battery technology.

Research Priority: Top

B. Respirators

The Problem: The present respirator is effective if used. It is seldom used, however, because:

1. The weight of the unit requires that the elastic strap be snug. This tight strap cuts into the face and also pulls on the respirator which cuts into the face.

2. The strap must be worn around the back of the head just above the ears. The strap position tends to pull the mask up rather than back and releases the tight seal around the lower lip.

3. The mask must be removed from the face to talk or chew tobacco.

4. The mask makes breathing difficult during strenuous activity such as crawling or rapid walking.

Research Recommendation: Design a lightweight respirator which covers the nose only, permitting talking and chewing. The nose respirator might be combined with safety glasses as a single unit, insuring the use of both.

The advantages of a nose respirator would be that it:

1. Can be worn while talking and chewing tobacco.

2. Is lightweight and therefore more comfortable to wear.

3. Allows breathing to be accomplished through the mouth without respirator restriction during periods of heavy physical exertion.

Research Priority: Top

C. Equipment Interrelationship and Integration

The Problem: When considered individually, personal equipment aids such as the self-rescuer, dust sampler, anemometer, methane detector safety lamp, and noise sound instrument are adequate in solving the various safety problems they address. Little thought, however, seems to have been given to how this equipment fits together, how it can be transported, how it affects the personal movement and comfort of men, or how it interacts with other equipment. As a consequence, miners often go without certain pieces of required equipment in order to improve comfort and mobility (and therefore safety). Self-rescuers, for example, are often left in their original shipping box somewhere near the intersection of section and mainline haulage, which might be a half mile from the working face.

Research Recommendation: We recommend that a study of the miner and his personal equipment and clothing be made at the work place in various mining conditions to determine essential equipment and how individual equipment items should interrelate. We further recommend a USBM/equipment manufacturers' joint developmental effort to test the feasibility and practicality of new types of clothing and equipment.

Research Priority: Top

III. MANAGEMENT/ADMINISTRATIVE/ORGANIZATIONAL RESEARCH

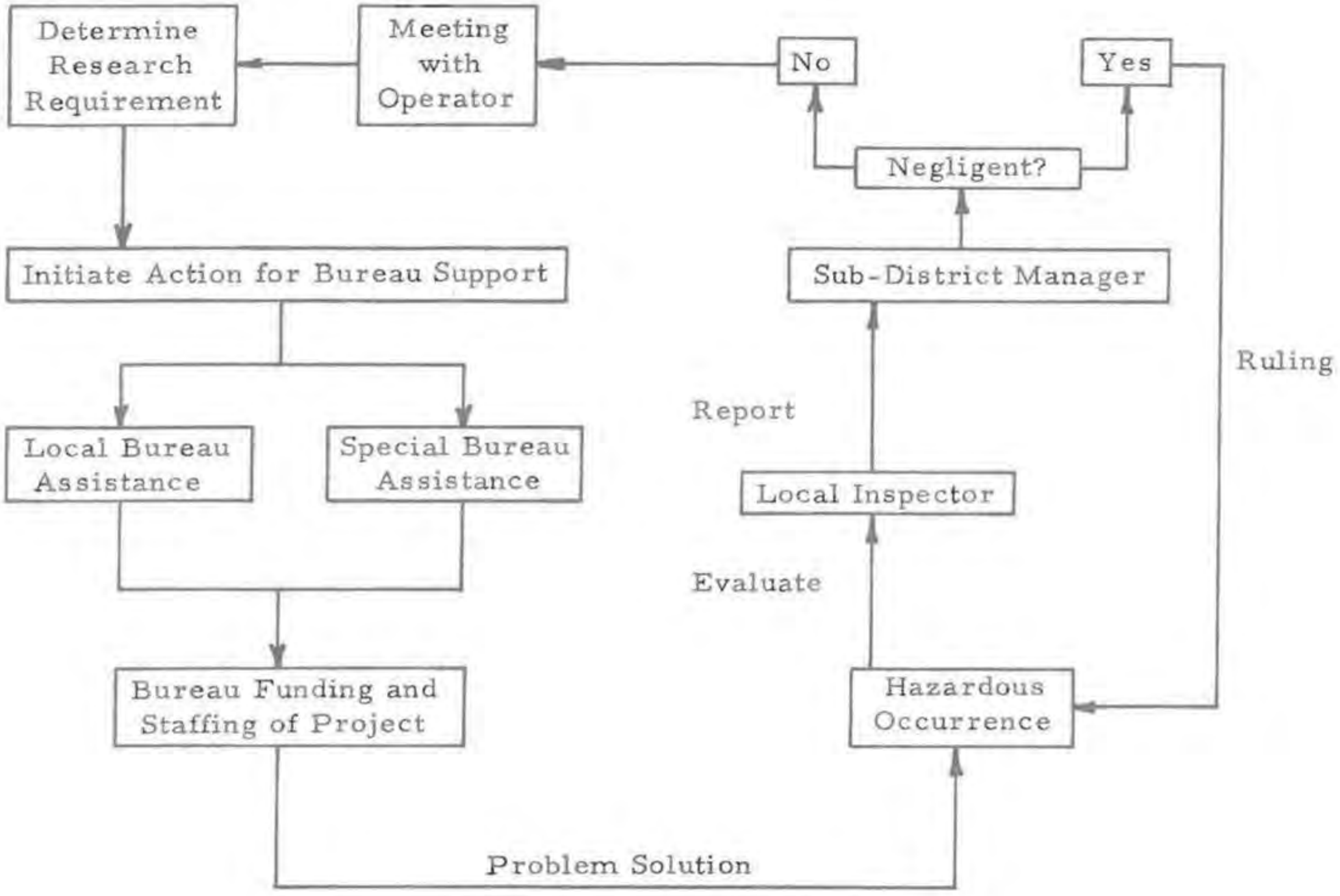
A. USBM Internal Technical Consulting Group

The Problem: The majority of small and medium sized mines do not have the resources to employ a staff of experts in the various specialty areas of coal mining (ventilation, roof control, electricity, etc.). Therefore, these mines often find it difficult to cope with unusual technical problems, even though the problems may contribute to hazardous conditions. Although USBM research centers are often prepared to help the small operator solve these problems, many of these small operators say they are hesitant to contact the local USBM for fear of receiving a violation notice from local USBM officials. Thus, many hazardous situations go uncorrected when they might be easily remedied.

At least at the local sub-district level, the Bureau lacks a systematic means of coping with non-negligent mine hazards stemming from unknown or unclear causes. At the present time non-negligent hazards are often dealt with in the same manner as negligent and willful hazards; i.e., they are viewed as an "offense" rather than as a research problem.

Research Recommendation: An organizational/administrative system which recognizes the essential difference between negligent and non-negligent hazards needs to be developed. This system would have the capacity to help the small operator solve problems arising from non-negligent hazards.

AN ALTERNATIVE TO PRESENT SYSTEM



Some comments on the proposed system shown above: 1) A process similar to this often takes place on an ad hoc basis but often only after the problem has become desperate or critical. In such cases, the operator "jumps" the Bureau chain-of-command and calls Washington or Pittsburgh. 2) As a result, local Bureau managers tend to see requests for help as a reflection on their competence; this encourages "police" rather than "problem solving" behavior on their part. 3) A regular administrative system for handling non-negligent hazards would operate through the local Bureau apparatus, giving the sub-district manager viable procedures for handling hazard problems. 4) Such a system implies changes in organizational relationships, changes in role perception, changes in planning, programming and research expenditures, etc. which would require in-depth study before implementation.

We believe the Bureau should conduct a study of organizational, administrative, and informational requirements involved in developing closer Bureau/operator cooperation. The study would: 1) determine the feasibility of the above system; 2) determine the attitudes and opinions of principal parties involved in such a change; 3) estimate the increased cost of the system; and, 4) develop a detailed operating plan for implementing the system.

One outcome of such a study could conceivably be an internal USBM consulting group which would be available to the operator upon request. Numerous operators have commented that they could use such a group. The service of the consulting teams could be confidential in order to encourage operators to discuss their problems without fear of punitive action. These consulting groups could also provide the additional service of reviewing operators' administrative (and other) records and offering constructive criticism. They could also make tours of the mine (on the operator's request) and point out various problem areas the operator may have overlooked; the results of these tours would be strictly confidential.

Research Priority: Top

B. Mine Classification System

The Problem: At the present time, all coal mines throughout the country are considered to be identical under the coal mine Health and Safety Act of 1969. Each mine, though, is unique unto itself by the very nature of the coal mining process. Different conditions within a given mine combine to create hazards of varying natures and precedence. For example, mine "A" has zero methane liberation and coal which cuts quite easily, therefore giving off relatively little dust. Mine "A" also has extremely bad top. On the other hand, mine "B" is a hot mine with very hard coal which results in a great deal of coal dust. Both of these mines have to put the same effort into ventilation and ignition control although they clearly have different primary hazards: Mine "A" -- roof control, mine "B" -- ignition control.

Research Recommendation: Study the requirement for and feasibility of a mine classification system. Part of the objective of such a study would be to determine the important classifying variables, such as methane liberation, coal grindability, top conditions, overburden, rib conditions, etc.

The study would also determine whether more stringent regulation in a given area (ventilation, roof control, etc.) is needed for certain classifications of mines while perhaps less rigid control would be appropriate in other areas. The ultimate implication of such a study would be the re-evaluation of the present Health and Safety Act with a view toward structuring flexibility into the law in recognition of the variability in mine conditions.

Research Priority: Top

C. Economics of Roof Control

The Problem: Mine management lacks information (or communication) on the actual cost of roof falls. Operators need to be sold on the economics of prudent roof control. An honest evaluation of roof fall probability and costs versus roof control costs should show that, while not always true, good roof control often costs less than the pro rata cost of probable roof falls.

Research Recommendation:

1. Develop costs for typical operations by production size and equipment.
2. Provide forms listing all developed costs so mine operators can learn typical costs.
3. Develop worksheets so mine operators can figure their personnel costs with help from #2 above.
4. Sell the industry on the economics of roof control through printed matter, articles, personal contact by inspectors.

This project would require careful costing of all roof control materials, e.g., mechanical, hydraulic, and wooden supports, on a comparative basis (purchase and use). The cost of roof falls could then be illustrated.

1. Medical and legal obligations (injuries). $__________
2. Adjustment of compensation rate, number of years applicable payroll. __________
3. Lost revenue (number of hrs. spent for clean-up) x (normal tons/hr.) x (gross profit/ton). __________
4. Cost of processing rock instead of coal (including special handling expenses). __________
5. Cost of schedule adjustments and lack of flexibility due to committed crew. __________
6. Lost future production due to slow-up of affected crew and others in mine who learn of the fall. __________
7. Cost of repairs and lost time on equipment. __________

TOTAL OBVIOUS COST $__________

Then, consider hidden costs:

1. Cost in terms of worker morale and willingness to cooperate on controversial assignments.
2. Possible UMW problems if negligence is suspected.
3. Possible state and federal restrictions if roof fall is the result of poor production techniques.
4. Higher labor costs in turnover of good men who can secure employment in safer mines.
5. Higher labor costs due to acquisition and training of new men.

6. Possible labor shortages if mine develops a reputation for lack of concern over welfare.

7. Lost time due to discussion and bickering about any unusual or dangerous event.

8. Additional exposure to workmen who have to remove fall and support roof, the most dangerous job in any mine.

9. Potential for greater disaster if fall occurs in conjunction with or even close to another dangerous event -- could cut off an escape route or hinder efforts to deal with an emergency situation.

10. Could cause or increase the likelihood of other dangerous conditions such as explosion, fire, equipment injuries.

11. Could develop into a running roof fall that would be disastrous.

Research Priority: Top

D. Equipment Economics

The Problem: A significant number of permissible items under the new law are -- or have the effect of being -- sole source accessories and equipment. Having captured the market, the unit prices of these items often rise significantly.

This problem has several parts: 1) price behavior in a monopolistic market creates significant financial hardship for the small or independent operator, who cannot counter such market tendencies by refusing to buy; 2) the situation creates hard feelings and mistrust on the part of the operators; 3) such hard feelings are enhanced by promotional mail and magazine advertisements which capitalize on the enforcement powers of the Bureau, e.g., "use Brand X -- it's the law now!" This situation leads to antagonism and cynicism toward the new safety law.

Research Recommendation: An econometric analysis should be conducted of the price/supply/demand behavior of equipment/accessories/supplies which exist in an effective monopolistic market. The objective would be to determine what actually happens to price, supply and demand before and after the particular item becomes required by law -- e.g., the over 300% increase in the price of the methane monitor for the continuous miner.

Research Priority: Second

E. Mine Reports

The Problem: The multiplicity and great variety of forms which federal law requires operators to complete creates two problems: 1) a significant portion of the superintendent's and mine foreman's time (foremen estimates range from 15-30%) is spent filling out forms instead of in line supervision; 2) the number and complexity of forms generate cynicism toward the law. Forms are completed for the sake of completing them, not for the purpose of conveying information

A general management principle is that the individual completing any form must: 1) understand the reason for completing it, and 2) be convinced of the value of the information contained therein. Neither of these could be said to apply to most of the mine foremen, superintendents, etc. observed during this study. Four specific examples are outlined below:

1. Injury Reports

Form 6-1420	Individual Injury Report
Form 6-1423	Monthly Injury Report
Form 6-1498	Daily Injury Report (ledger)
Form 6-1459	Quarterly Injury Report

Comment: In this case, it is the multiplicity of reports that generates hard feelings. The question asked time and time again is: "Why a Quarterly report to summarize a Monthly report to summarize Daily reports to summarize Individual reports?"

2. Unexplained Reports

a. Form 6-1419-Q, distribution of bituminous coal and lignite shipments.
b. Requirement to submit names and dates of birth of all employees (USBM letter).

Comment: In these examples, the main gripe is simply "Why?". Management (superintendents, foremen, etc.) would like a more comprehensive explanation of the need for the information. (This comment applies to the injury report example above as well. Perhaps management would be more amenable to four injury reports if they understood the necessity for them.)

3. Odd Sized Reports

Form 6-1423-AM

Comment: The form is just large enough to be inconvenient -- can't be duplicated on a Xerox/Thermofax machine without a reduction lens; won't fit a standard business envelope.

4. American Printing Co. Forms

Includes all report forms manufactured and sold by American Printing Co., Madisonville, Kentucky -- for example, the separate pre-shift and on-shift daily report log used for each shift in each section. In a 7-section mine working 3 shifts, 21 separate logs are in use at one time, all of which must be reviewed and signed by the superintendent. This "sole supplier" problem is significant in other areas besides forms.

Comment: All superintendents, mine foremen, and operators interviewed complained about the unnecessary bulk, length and variety of these reports. They are suspicious of the fact that only American Printing Co. supplies these items. They feel that American Printing Co. must have a "friend" in the Bureau. Actually, the operators are mistaken; there is at least one other firm supplying these forms -- Durham Offset Co., Harlan, Kentucky; however, even in Harlan/Bell/Knox Counties, the American Printing Co. forms were used in almost all mines visited. Anyway, the result is the same -- an effective, if not actual monopoly.

General Comment: The problem with these forms is not directly related to safety, but it is one area which has contributed directly to the morale problem among operators in coping with the new law. It leads to a general cynicism in responding to the letter rather than the spirit and intent of the law. One quote is worth recording here: "If they want 10,000 reports, I'll give 'em 10,000 reports, and I'll sign every one of them in my best handwriting; screw safety."

Research Recommendation: USBM should conduct a comprehensive source document evaluation. Such an analysis would involve: 1) interviewing every agency within the Bureau that requires raw data from operators to determine precise objectives in gathering information, alternative sources of information, and required frequency in updating information; 2) examining possibilities for elimination of forms or consolidating forms; 3) redesigning/simplifying forms where warranted; 4) developing a forms manual for operators which describes each form, its purpose and significance and how the forms should be completed in order to be most effective.

Research Priority: Low

CHAPTER 21

INSIGHTS, OBSERVATIONS, AND COMMENTS

This chapter discusses a variety of hazards which we observed in the mines and recommends possible solutions. These observations have been assembled in this section for any of three possible reasons:

- They are insights that we feel are valuable, but for which supporting data does not exist.
- They are valid observations, but their impact on safety may not be as great as other recommendations within this report.
- Our observations may well have been identified by others and our recommendations may duplicate those made by others.

Some of our interpretations of the hazardous problems listed in this section may be subject to subsequent revision or expansion; some may be proven invalid. But, in keeping with the ultimate objective of this study -- to save lives -- we feel that it is important to include any idea which might furnish a new insight or creative idea regarding fatality reduction.

This chapter is divided into two subsections: Procedural Hazards and Equipment Hazards.

I. PROCEDURAL HAZARDS

The implementation of the recommendations within this subsection requires minimum capital expenditures, and in most cases only entails simple procedural changes. Many of the recommendations are accompanied by greater worker productivity and/or improved efficiency, resulting in greater output per manhour. The following is a listing of our observations and recommendations concerning procedural hazards.

A. Hazard: In mines with a great deal of rib sloughage (50-100 lb. chunks), workers often set timber lines with their backs to the rib, standing between the post and the rib.

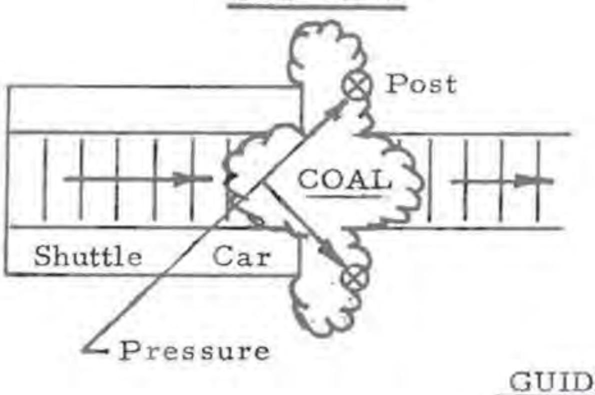
Recommendation: Worker should always stand on the entry side of the timber, or at least at right angles to it, in order to minimize the potential rib sloughage hazard.

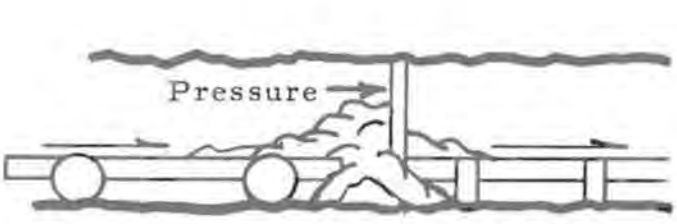
B. Hazard: New roof is sometimes left unsupported for 15-20 minutes due to the absence of a loader helper who normally erects temporary supports at the completion of the loading cycle. Such support delays contribute to roof flexing and hence a weakened roof.

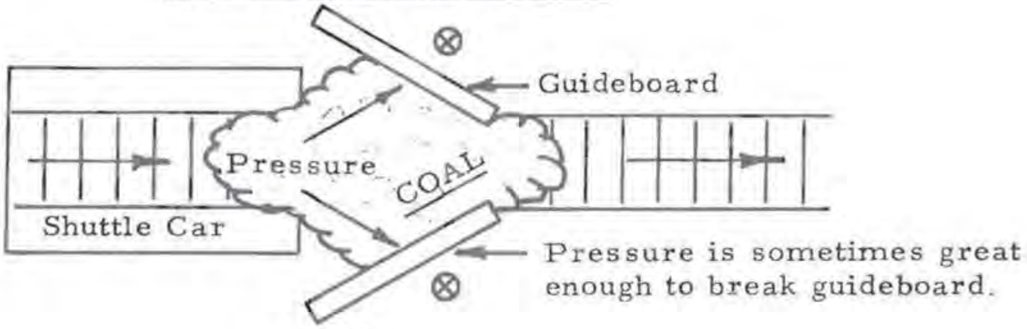
Recommendation: In such a situation, the loader operator should be responsible for erection of temporary support. He is normally well ahead of the bolter on the cycle, and by setting the temporary supports himself, he would be:

1. Significantly reducing the roof hazard by supporting the roof before it has time to separate.
2. Reducing the bolter's cycle time.

C. Hazard: Pressure is applied against roof supports at shuttle car dumps by the weight and force of the coal being unloaded. Pressure may be applied directly by coal against the posts or by coal pressing the guide boards against the posts.


TOP VIEW


SIDE VIEW


GUIDEBOARD PRESSURE

Recommendation: Roof support posts at the belt dump offer too tempting a base against which guide boards can be placed. Extra bolts should be placed in the dump area in addition to posts. That is, posts should be recognized as primarily a dumping aid rather than a roof support mechanism in the dumping area. The roof should be bolted as if the posts in that area did not exist.

D. Hazard: The outgoing shift foreman must communicate the details of the shift's work in a few hurried moments above ground to the oncoming shift foreman. This exchange is expected to include progress diagrams, dangers, supplies required, etc.; however, the briefing is often incomplete and the omissions are usually those related to safety.

Recommendation: Continue present briefing system but use a blackboard at the section entrance to jot equipment positions and safety problems; the board could be prepainted for most sections and show both development and retreat operations. Foremen are in a hurry above ground but have excess time underground to make notes. Workers can also note "working" roof needing support and other individual items that the foreman omits or about which he is not informed.

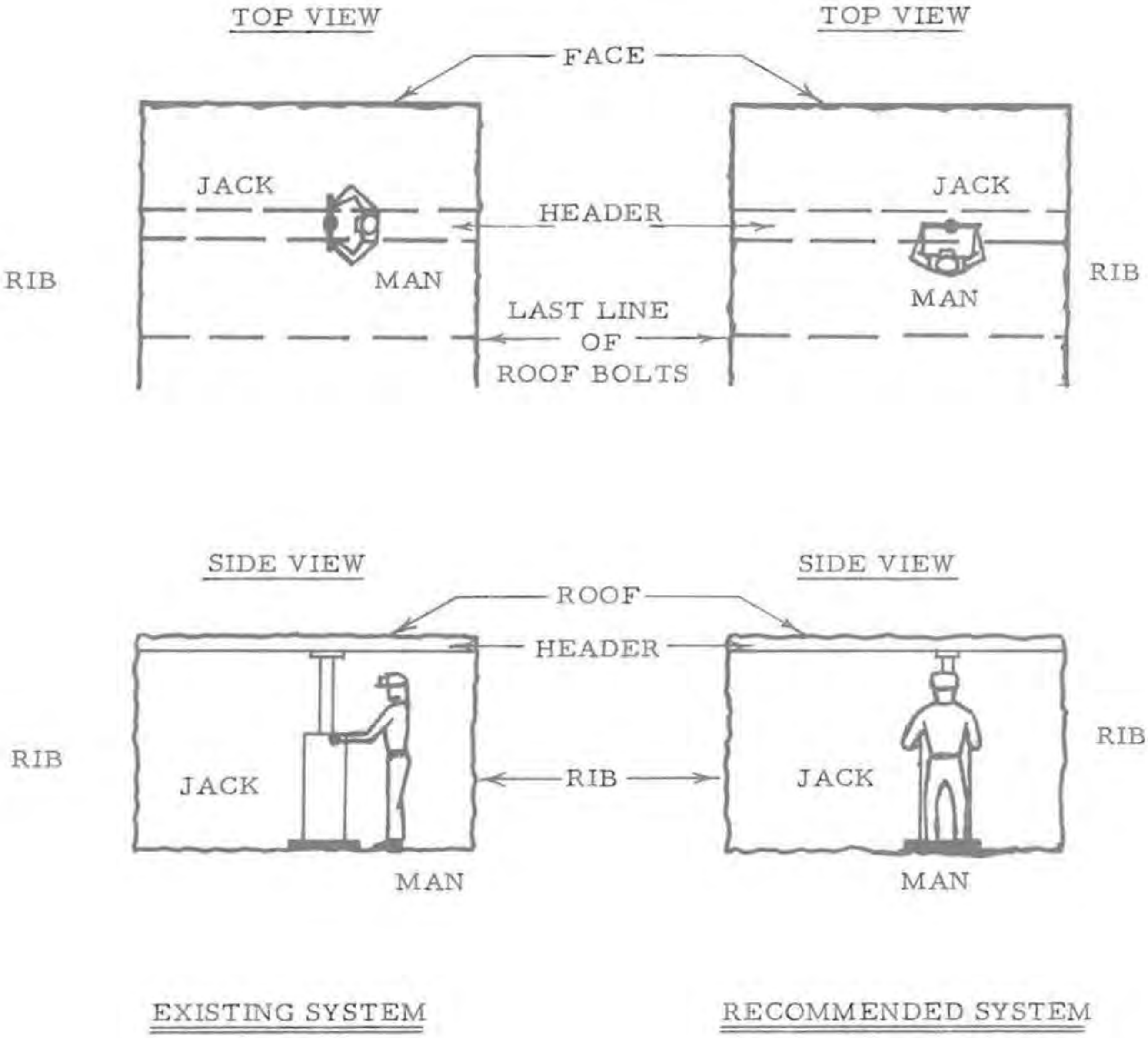
E. Hazard: Wires that are often used to hang cables, water pipes, etc. are placed on the roof bolts. Normally these are left hanging with the wire ends pointing downward. This creates a serious injury hazard (especially to the eyes).

Recommendation: Turn up the ends of the wires as shown in the following diagram.

FIGURE A FIGURE B

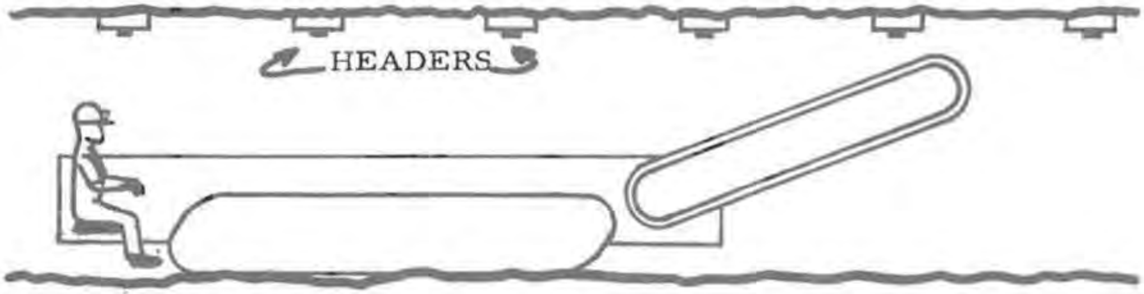
F. <u>Hazard:</u> The roof bolter often sets screw jacks in the position shown in the diagram. He is unable to watch the roof and is in a rather immobile position should a portion of the roof begin to fall.

<u>Recommendation:</u> Instruct the roof bolter to stand in such a position that when the jack is grasped he is looking toward the face and is standing nearer to the last row of bolts.



G. Hazard: While tramming the continuous miner in low coal, the operator keeps the bits high off the floor, and in the process, strikes a number of roof bolts. This ruins their torque and makes them ineffective.

Recommendation: The miner operator should carry a torque wrench. After striking a roof bolt, the torque should be checked and adjusted, if necessary. To prevent striking bolts, carry bits in a lower position whenever possible.



H. Hazard: Because coal shooting is usually a bottleneck in the work cycle (the loader is usually idle, waiting for shooter to finish), firemen often begin preparing and inserting shots while the cutting machine is still at the face, creating the opportunity for a man-machine accident.

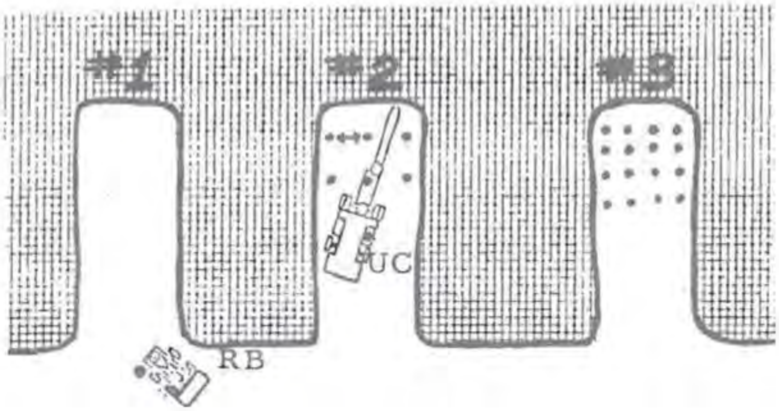
Recommendation: Management should make sure that only one operation is conducted at the face at any one time.

I. Hazard: The roof bolter sometimes drills holes and inserts the bolts but does not tighten them, leaving this job for another crew member. The roof bolter will then often stand beneath an untightened bolt while drilling the next hole, resulting in unnecessary exposure to unsupported roof and increasing the danger of being struck by a falling roof bolt.

Recommendation: Tighten all bolts as soon as they are inserted.

J. Hazard: Roof bolts are often over-spaced when the roof bolter is under work cycle pressure. TB & A consultants have seen bolts as much as 10' apart in 4' and 5' center plan mines. In one case, the cutter operator noticed over-spaced bolts above another man in the face area; he pushed the man aside and scaled down several hundred pounds of roof on top of the cutter.

THE SITUATION



RB plan calls for 5' centers, as in face 3, but roof bolter has over-spaced in #2 to stay ahead of cutter. This hazard may take on different forms -- the bolter may "overlook" bolting kettlebottoms or re-bolting loose bolts in order to stay ahead.

Recommendation: Reduce work cycle pressure on the roof bolter, using any of the following methods: 1) assure him that safety is first and that he will not be singled out as a production bottleneck for taking the time to bolt carefully; 2) use two roof bolting machines to eliminate the bottleneck (some mines do); 3) employ only high-skilled operators on the roof bolter in order to achieve faster work pace (the inherent conflict between union required "posting" and job placement is discussed in Chapter 19).

K. Hazard: The roof bolter operator and helper stand under unsecured roof as they stack headers on the floor for the temporary roof jacks which are not long enough to reach the ceiling without blocking.

Recommendation: Obtain temporary jacks of the correct length.

L. Hazard: Irregularly spaced intersections and the resultant irregular pillars significantly contribute to rib and roof falls. This irregular pattern is primarily due to the lack of communication between engineers and line management (foremen) following corporate changes in the general mine plan.

Recommendation: Communicate mine plan changes immediately to all foremen via a pre-shift foreman meeting; man-trips could be delayed to allow for such important meetings.

M. Hazard: In an area of suspected bad top, the foreman and both roof bolters stand in unsupported area while the foreman sounds the top. Hazardous exposure is tripled by having 3 men present to do the work of one.

Recommendation: Only one man should be necessary to sound top in an unsupported area.

N. Hazard: A man cleaning a rib in preparation for timbering an entry is shown in Figure A. If rock and coal came down suddenly, he would have no place to jump. (See figure on next page.)

Recommendation: Stand on opposite side of ladder to obtain some protection, and have a clean jump away from rib.

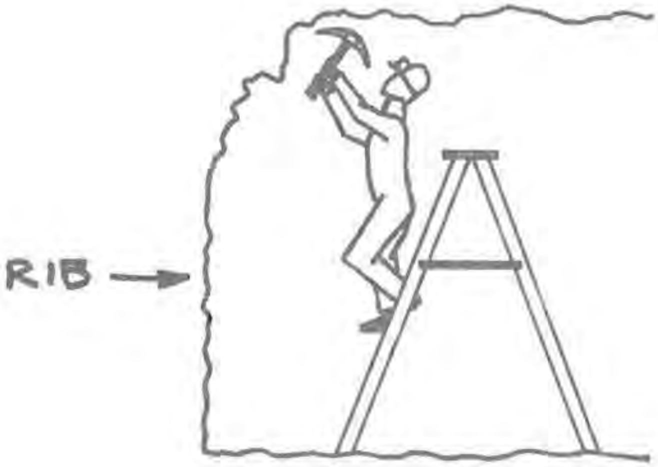


FIGURE A

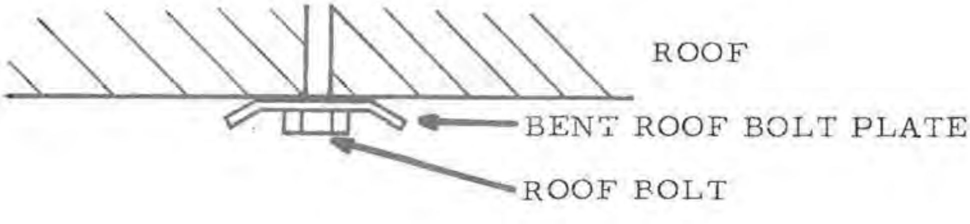
O. Hazard: Temporary cable splices left overnight in sections with considerable floor water (3" to 1') tend to become soaked. If they "blow", they create serious electrical hazards for nearby men working in the water. Foremen feel that a "blow" will come at the electrical "switch-on" at the beginning of the shift or not at all.

Recommendation: At the beginning of the shift, before the electrical "switch-on", raise and hang all splices above water; if splice survives "switch-on", then cable can be returned to normal use.

P. Hazard: Roof bolts are over-torqued with multiple activations of the head rotation control, causing possible weakening of the roof bolts and bolt plates, and improperly secured roof.

Recommendation:

1. Check torque setting on roof bolt machine frequently.
2. Adjust torque setting on roof bolt machine as required.
3. Activate tightening clutch just one time per roof bolt.
4. Insure spot check of roof bolt torques per Federal law.



Q. Hazard: New cuts made at the end of swing shift are usually left overnight without support. Cuts made at the end of day shift may go 60-90 minutes without support during man-trip out, man-trip in, crew preparation, etc. This contributes to roof flexing and increases the possibility of a fall of supported roof at some time in the future.

Recommendation: Federal regulation should require all temporary support plans to provide for temporary support of any new cut before changing shifts.

R. Hazard: Haulage accidents occur frequently when machinery from a previous shift has been left parked behind a check-curtain and is run into by another machine.

Recommendation: Off-going foremen should be required to communicate equipment positions to in-coming foremen at the shift change. (Note: See Recommendation D concerning section blackboard.)

II. EQUIPMENT HAZARDS

Recommendations within this sub-section generally do require some capital investment. In all cases, either equipment modifications or purchase of new equipment is required. The following is a listing of our observations of equipment hazards and recommendations.

A. Hazard: Temporary cable splices afford little protection against water contacting electrical conductors and create serious electrical hazards for nearby men working in the water.

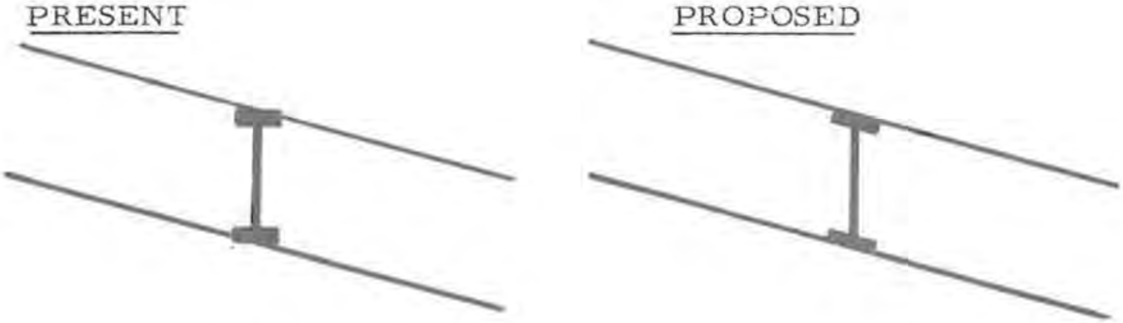
Recommendation: Develop a rugged, waterproof splice "jacket" for use over temporary splices in wet sections until cables are pulled for vulcanization. This self-adhesive, external canvas jacket would be the equivalent of a large, latex bandaid. (Note: Many mines with permissible underground permanent splice equipment have found it to be unreliable and difficult to use.)

B. Hazard: Occupants of open-top mantrip cars are exposed to roof ready to collapse along the entire length of the main entry. Untorqued bolts often drop down, reducing the height of the roof. As the cars travel through the mine, miners can be speared by these loosened bolts or struck by falling fragments of roof. Open-tops also afford no protection in mainline collisions, as evidenced by 4 men in an uncovered car killed in one accident (those in the covered car were only injured).

Recommendation: Covered mantrip cars should be used whenever roof height permits.

C. **Hazard:** Present temporary roof jacks cannot be used other than perpendicularly to the floor because the jack base is fixed. The jacks do not provide good roof support when either or both the roof and floor slope.

Recommendation: A swivel top and swivel base on each temporary jack will allow good roof support from a jack perpendicular to the floor, whether the floor and roof slope or not.

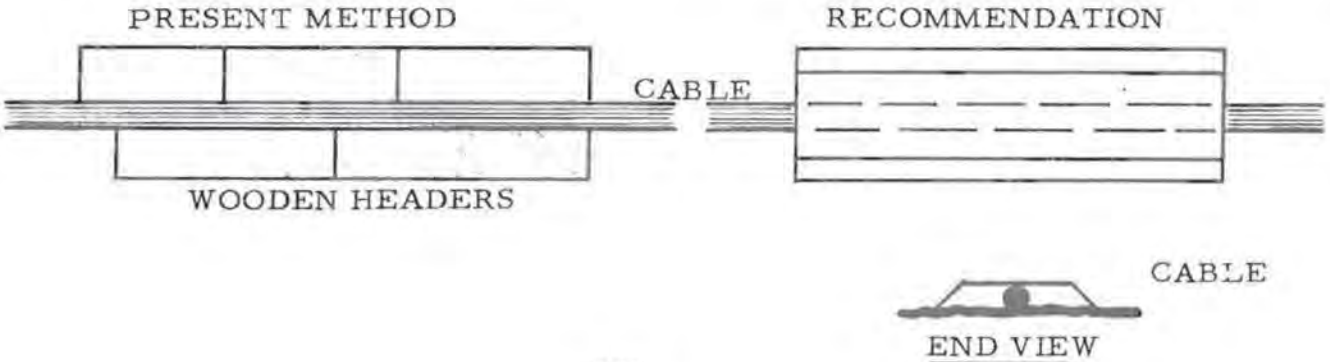


D. **Hazard:** The present method of measuring the face is for the foreman and a crew member to hold a tape measure under the exposed roof at the face to check the cut width.

Recommendation: A simple battery-operated projector should be used to measure distances. When the projector is set a prescribed distance from the face, the width of face is established using a set focal length.

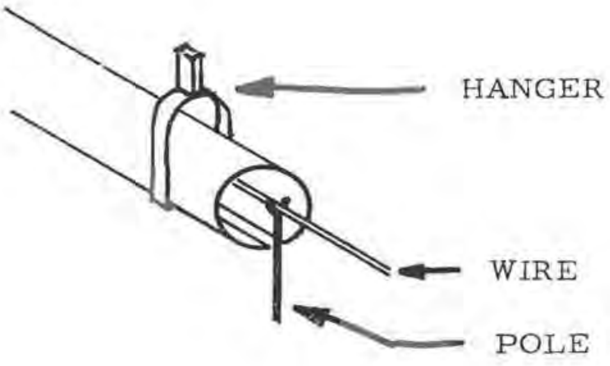
E. **Hazard:** The equipment operator lays header blocks on either side of the cables, trams over the protected cables, and recovers the headers. This procedure is dangerous, time consuming, and affords only poor blocking quality when it is done at all.

Recommendation: Design and fabricate a metal riser. The riser will provide consistently excellent protection and will be much easier to locate and recover.



F. Hazard: Mainline haulage accidents often involve either electrocution caused by contacting bare trolley wires, or falls occurring during the replacement of trolley poles.

Recommendation: Trolley wire protection should be extended throughout the system instead of being placed only at active loading/traffic points. Protection should be provided not only against accidental contact, but also against the trolley pole becoming dislodged. Research on an economical material, preferably more rigid than the present rubber flaps, must be conducted.



HIGH VOLTAGE TROLLEY WIRE

G. Hazard: Present hand-held face drills have a tendency to move away from the operator unless a second man places his foot against the base to prevent this.

Recommendation: Devise a non-slip foot for the drill so that the movement will be arrested. The second miner can then be eliminated, reducing total exposure to unsupported roof by 50% as only one man is involved instead of two.

H. Hazard: The routes from operating sections to the escapeways are not well identified in most mines, and the miners are generally unfamiliar with the route or routes to follow during an emergency requiring escape to the mine surface.

The Federal Register specifies that each mine shall provide escape facilities and escapeways, but the Register does not state how the miners shall find their way to the escapeways during an emergency evacuation.

Recommendation: The recommendations for identifying escapeways are listed below in descending order of effectiveness.

1. Tack phosphorescent pointed directional arrows at 6-10 foot intervals onto all roof center lines. It is especially important to identify the route on roofs in operating sections. The arrows would glow and show the escape paths to follow in the event of total darkness.

2. Same as #1 above, except that the directional arrows would be coated with glass beads instead of phosphorescent paint. The directional arrows would be recognizable in a dim light situation, but could not be seen and followed in total darkness.

3. Paint a colored stripe down the center line of all roofs. The advantages are:
   a. Inexpensive.
   b. Fast and easy to apply with an extended handle on a paint roller.

   The disadvantages are:
   a. Cannot see the stripe in total darkness.
   b. A man may become confused without directional arrows, and may return to another section of the mine instead of reaching the mine surface.

4. Post maps with escape routes shown. The advantages are nominal. The disadvantages are:
   a. Cannot see the map in total darkness.
   b. Man may become disoriented during an emergency and misread a map.
   c. Need to constantly update all maps located in working sections. The maps would seldom be current because they would always lag the actual section configuration by one or more shifts.
   d. Maps would have to be located on walls approximately 5' from the floor, and would be subject to accidental removal by men and equipment.

The tentative cost from a Los Angeles supplier would be \$.40-.50 per phosphorescent sign in quantities of 10,000. Wider spacing of signs and larger order quantities would cost a large mine about \$5,000 for the material.

The 3M Company can furnish reflective tape signs for approximately the same cost as above.

I. Hazard: The repositioning of the continuous miner for better loading position, or to do clean-up work on roof, ribs or floor requires the constant attendance of the miner helper. Because of his constant responsibility for keeping the power cable from beneath the miner, the helper is exposed to both equipment hazards and roof hazards by his position between the machine and rib. (One helper was recently killed by a rib burst when blown against the miner by the coal -- others survived by rolling with the burst.)

Recommendation: One solution is to develop a device to hold the cable at right angles to the continuous miner. One large mine company currently uses a device composed of 5 wire cables (approximately 12-18" long) to help hold the power cable away from the machine.

These cables are flexible and not likely to cause injury. Unfortunately because of this flexibility the device sagged too much and reduced the "reach". As a result, the device was not effective. In fact, the continuous miner ran over the cable and cut it while being observed by TB & A consultants.

A more satisfactory solution would be to develop a spring loaded rigid arm which would not sag but which would provide lateral movement at 30-40 pounds resistance. This would allow the arm to fold flat if a rib or person required clearance. The arm would be extended only during short movements conditional upon the slack in the cable. The weight of the cable during tramming operations would pull the arm against the side of the miner.

J. Hazard: Electrical cables hung from the roof at intersections often droop sufficiently to be caught and jerked down by a shuttle car carrying a high load of coal. On occasion, the cable has blown.

Recommendation: Metal risers (see Recommendation E) would allow cables to cross intersections on the ground, would eliminate time lost due to raising and hanging cables, and would eliminate the cable "droop" hazard.