USBM S0122023 MOD 1A

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ACCIDENT PREDICTION INVESTIGATION STUDY

THEODORE BARRY AND ASSOCIATES

USBM CONTRACT FINAL REPORT S0122023 MOD 1A

SEPTEMBER 30, 1972

THEODORE BARRY AND ASSOCIATES

MANAGEMENT CONSULTANTS

DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

WASHINGTON, D. C.

United States Department of the Interior

BUREAU OF MINES
WASHINGTON, D.C. 20240

In Reply Refer To:
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April 30, 1973

Memorandum

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From: Acting Assistant Director--Mining

Subject: Disposition of Report, "Accident Prediction Investigation Study," (S0122023), Theodore Barry and Associates

Placing of the subject report on open file has been approved as indicated by the enclosed memorandum. Two copies of the report are enclosed for your library.

Please acknowledge receipt of these reports by calling (202) 343-8060 or by writing to Donald E. Ralston of my staff.

J. J. Yancik
Joseph J. Yancik

Enclosures

United States Department of the Interior

BUREAU OF MINES
WASHINGTON, D.C. 20240

April 19, 1973

Memorandum

To: Director

Through: Deputy Director--Mineral Resources and Environmental Development
Chief, Office of Mineral Information

From: Acting Assistant Director--Mining

Subject: Disposition of Report, "Accident Prediction Investigation Study"

The subject report was prepared under Contract No. S0122023 Mod. 1A, "Accident Prediction Investigation Study," to Theodore Barry and Associates. It provides the results of a study to identify factors contributing to underground bituminous coal mining accidents and the investigation of the relationships between these factors. Recent and current data was gathered on non-fatal inquiries from mines in the Pittsburgh seam. This report complements other Bureau research reports on industrial hazards.

To make the report available to interested parties it is recommended that two copies each of the report be placed on open file for public review in the Department of the Interior Library and at the Bureau facilities in Pittsburgh, Denver, Spokane and Twin Cities.

In addition, two copies will be placed with the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22151, for reproduction and distribution.

A copy of the report is enclosed.

Joseph J. Yancik

Enclosure

Recommended:

Chief, Office of Mineral Information

(OK with deletion of [illegible] press release [illegible])

Approved: APR 26 1973

Acting Director, Bureau of Mines
Paul Zinner

USBM S0122023 Mod. 1A

ACCIDENT PREDICTION INVESTIGATION STUDY

THEODORE BARRY AND ASSOCIATES

USBM CONTRACT REPORT S0122023 Mod. 1A

September 30, 1972

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. S0122023, Mod 1A. 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. Al Young was the contract administrator for the Bureau of Mines.

This report is a summary of the work completed as part of this contract during the period August 1971, to September 30, 1972.

TABLE OF CONTENTS

		Page
FOREWORD		i
ACKNOWLEDGEMENTS		ii
CHAPTER 1	INVESTIGATION OBJECTIVES AND ACCIDENT PREDICTION TECHNIQUES	1
	Overview	1
	Accident Prediction from Accident Occurrence	9
	Limitations of Accident Analysis	22
	Critical Incident Technique	27
CHAPTER 2	RECOMMENDATIONS FOR BUREAU ACTION AND FURTHER RESEARCH	30
	Job Inexperience Monitor	30
	Individual Mine Accident Analysis Program	31
	Inspection District Accident Analysis Reports	34
	Special High Accident Occurence Problems	36
	Controlled Job Training Experiments	36
	A Revised Pittsburgh Seam Accident Analysis	37
	Effects of 1970 Roof Control Plan Changes	40
	Job Enrichment and Social - Technical Job Experiments	41
	Experiments with Job Certification	43
	Critical Incident Demonstration Program	44
	Other Predictive Factor Investigation Studies	44
CHAPTER 3	ACCIDENT ANALYSIS FOR THE PITTSBURGH SEAM	46
	Development of the Injury Data	46
	Normalizing the Data	48
	National Accident Data	50
	Methodology for Data Analysis	54
	Summary of Accident Analysis Findings	55
	Appendices	63

CHAPTER 4	RESULTS OF THE ANALYSIS OF PITTSBURGH SEAM VERSUS ALL UNDERGROUND ACCIDENTS	72
	Type of Accident	72
	Job Categories	75
	Victim Doing	86
	Job Experience	90
	Underground Experience	103
	Age	111
	Time of Accident	123
	Absenteeism	127
	Turnover	130
	Other Factors	132
	Appendices	136
CHAPTER 5	THE SAFETY PROFILE ANALYZER	150
	The Original Study Concept	150
	Methodology of the SPA Interviews	156
	Findings of SPA Interviews	161

TABLE OF EXHIBITS

		Page
EXHIBIT 1-1	Potential Accident Situation Event Ratios	24
EXHIBIT 3-1	Flow Chart	53
EXHIBIT 4-1	Accident-Type Pittsburgh Seam Sample of Non-Fatal Accidents	76
EXHIBIT 4-2	Accident-Type for the Pittsburgh Seam Showing the Four Major Types of Accident	77
EXHIBIT 4-3	Underground Bituminous Coal Mines in the U.S.A.--The Four Major Accident Types	78
EXHIBIT 4-4	Underground Bituminous Coal Mines in the U.S.A.--Accident Type	79
EXHIBIT 4-5	Underground Bituminous Coal Mines in the U.S.A.--Type of Accident Comparison Between Injury Data, 1966 & 1971	80
EXHIBIT 4-6	Non-Fatal Accidents by Job Type in Pittsburgh Seam	83
EXHIBIT 4-7	Average Accident Rate Per Year by Job Category per 1,000 Workers	84
EXHIBIT 4-8	Underground Bituminous Mines in the U.S.A. Average Accident Rate for 1971 by Job Category per 1,000 Workers	85
EXHIBIT 4-9	Pittsburgh Seam Victim Activities	88
EXHIBIT 4-10	Victim Doing Activities and Apparent Cases of Job Substitution in Pittsburgh Seam	89
EXHIBIT 4-11	Job Experience of All Injured Miners at Accident Time for Pittsburgh Seam	96
EXHIBIT 4-12	Job Experience of Injured Miners at Accident Time for Pittsburgh Seam	97
EXHIBIT 4-13	Job Experience of Loading Machine Operators at Accident Time for Pittsburgh Seam	98

		Page
EXHIBIT 4-14	Combined Job Experience Distribution for Five Job Categories in Pittsburgh Seam	99
EXHIBIT 4-15	Job Experience Distribution for Four Job Categories in Pittsburgh Seam	100
EXHIBIT 4-16	Job Experience Distribution of Loading Machine Operators in Pittsburgh Seam	101
EXHIBIT 4-17	Job Experience and Job Mobility by Occupation	102
EXHIBIT 4-18	Total Underground Experience of All Injured Miners in Pittsburgh Seam	106
EXHIBIT 4-19	Combined Total Underground Experience of Five Job Categories in Pittsburgh Seam	107
EXHIBIT 4-20	Distribution of Total Underground Experience for Four Job Categories in Pittsburgh Seam	108
EXHIBIT 4-21	Distribution of Underground Experience for Loading M/C Oper. in Pittsburgh Seam	109
EXHIBIT 4-22	Comparison of Total Underground Experience for Injured and All Miners in the U.S.A.	110
EXHIBIT 4-23	Age Distribution of All Injured Miners in Pittsburgh Seam	114
EXHIBIT 4-24	Age Distribution for Five Job Categories	114
EXHIBIT 4-25	Comparison of Ages Between Injured Miners and All Miners	115
EXHIBIT 4-26	Age Distribution of Four Job Categories in Pittsburgh Seam Mines	116
EXHIBIT 4-27	Age Distribution of Loading Machine Operators in Pittsburgh Seam-41 Responses	117
EXHIBIT 4-28	Age of Injured Roof Bolters Compared to Ages of All Roof Bolters	118

		Page
EXHIBIT 4-29	Age of Injured Loading M/C Operators Compared to Ages of All Loading M/C Operators	118
EXHIBIT 4-30	Age of Injured Shuttle Car Operators Compared to Ages of All Shuttle Car Operators	119
EXHIBIT 4-31	Age of Injured Motormen Compared to Ages of All Motormen	120
EXHIBIT 4-32	Age of Injured Continuous Miner Operators Compared to Ages of All Cont. Miner Op.	120
EXHIBIT 4-33	Percent Miners in Each Age Group for Different Mining Methods	121
EXHIBIT 4-34	Percent Miners in Each Age Group for Different Mining Methods	122
EXHIBIT 4-35	Percentage Distribution of Non-Fatal Accident in Pittsburgh Seam by Time of Occurrence--Months	125
EXHIBIT 4-36	Percentage Distribution of Non-Fatal Accident in Pittsburgh Seam by Time of Occurrence--Days	125
EXHIBIT 4-37	Percentage Distribution of Non-Fatal Accident in Pittsburgh Seam by Time of Occurrence--Hours	125
EXHIBIT 4-38	Percent of Roof Fall Accidents by Hours Worked-Pittsburgh Seam	126
EXHIBIT 4-39	Absenteeism versus Accident Rate Pittsburgh Seam- 8 Mines	129
EXHIBIT 4-40	Turnover versus Accident Rate - Pittsburgh Seam - 8 Mines	131
EXHIBIT 4-41	Productivity versus Accident Rate - Pittsburgh Seam - 8 Mines	133

CHAPTER I

INVESTIGATION OBJECTIVES AND ACCIDENT PREDICTION TECHNIQUES

OVERVIEW

The original work statement of this contract was entitled: "A Predictive Accident Analysis Model for Use in Underground Coal Mines." The contract was scheduled for a duration of 26 months and was to be in three phases: Phase I - Model Development, Phase II - Application of the Model, and Phase III - Installation, Monitoring and Evaluation of the Model. After three months in Phase I, it became apparent that much of the needed data for the model was not available and could not be made available within the original study schedule. Proceeding as planned would have resulted in a model of limited utility.

Personnel from Theodore Barry and Associates and the Bureau discussed the problem in detail and mutually decided to utilize the majority of remaining funds to assist the Bureau in solving these data problems and develop a stronger ongoing capability for safety analysis within the Bureau. Both the contractor and the Bureau officials involved believed that this decision greatly enhanced the Bureau's ability to develop future accident prediction models, whose rigor would greatly exceed what was currently possible.

The revision of contract objectives divided the contract work statement into two parallel studies: this study, the "Accident Prediction Investigation" study (Contract No. S0122023 Mod 1A), which continued selected aspects of the original work at a reduced level of effort, and a second study entitled the "Safety Analysis System Study" (Contract No. S0122023 Mod 1B). The systems study assessed the then current Bureau accident analysis system, in the former Office of Accident Analysis, and investigated what accident analysis system should replace it in the planned Health and Safety Analysis Center in Denver. In the systems study, the Contractor examined the questions of what accident data should be gathered on a routine versus special study basis, what kind of reports should be issued, and what internal processing and analysis operations were required. The recommended improvements of the systems study would have a much greater and longer lasting impact on developing more useful data on mining safety problems - hence greater accident prediction ability - than if the original study had proceeded without alteration.

This report primarily concerns the continuing study called an "Accident Prediction Investigation," but also includes a short summary of the results and problems of the original study. The revised accident prediction investigation study concentrated on analyzing the effect of accident factors that could be investigated from existing mine data. The Bureau and Theodore Barry and Associates had already made a commitment to several large steel companies and a number of mine operations in the Pittsburgh seam, which had been selected as the location for the original investigation. Since a considerable investment in time and money had been made to gather data from these mines, the contractor and the Bureau felt obligated to make the best possible use of the data.

Study Objectives

The major investigation topics of the Pittsburgh seam accident analysis were as follows:

- Uniqueness and variability of accident factors such as accident type, occupation, equipment type, etc., associated with accidents in the cooperating Pittsburgh seam mines. The greater the uniqueness of accident factors found in a given mine, the greater the predictive potential to be found from the accident analysis. Conversely, the greater the variability in the accident the smaller the predictive potential derived from accident data, at least in the short run.

- Job inexperience factor in non-fatal accidents. This was the single most important factor identified in the fatal accident data base previously developed by the contractor for the Bureau. Since this variable had not been recorded in non-fatal injury reports reported to the Bureau, this was believed to be an important objective.

- Accident factors not previously investigated that were closely related to the job inexperience factor, such as gross absenteeism, mine employment turnover, job posting or job turnover, etc. This objective was somewhat restricted to using available data, because of budget limitations and completion deadlines. There was not sufficient time in the revised study to set up new accident data collection efforts because the contract revision shortened the project by one year.

- Accident variable "normalization" data for the Pittsburgh seam accident sample. In other words, the investigators were to convert as many raw accident frequencies into accident frequency rates as possible.

The latter normalization objective is necessary to estimate the risk or degree of hazard associated with an accident, and thus to separate degree of risk from degree of exposure in the accident data. For example, obtaining the worker job classification distribution from the participating mines permitted an accident rate calculation for each job in terms of accidents per 1000 workers. The normalization permitted the analysts to observe that, although roof bolters exceeded all other occupations in number of injuries, machine loader operators and helpers were far more likely to be injured than roof bolters in terms of accidents per 1000 workers. Accident data can be normalized in a number of ways, but the normalization process is essential to developing a greater accident prediction capability.

The accident data normalization project with the highest priority was to obtain normalizing data for the job inexperience factor, not only for the Pittsburgh seam non-fatal accident sample, but also for the fatal accident data base previously developed by the contractor. In response to the need for normalizing data, the contractor extracted data from the following U.S. Bureau of Mines files:

- Employee history file containing data on over 80,000 underground coal miners primarily about their respirable dust samples which must now be submitted to the Bureau under the 1969 Coal Mine Health & Safety Act. Variables in the file include job title, age, underground experience, mining style, etc.

- 1971 Injury File which is the coded computer tape file of reported injury accidents.

- 1970 Employment Data File. This file contains employment and production data about each mine and included the interesting seam height variable.

The purpose of extracting this data was to 1) compare national injury data vs. the Pittsburgh Seam sample, and 2) to attempt to further resolve the validity controversy surrounding the job inexperience factor for the fatal accident data base. The question was whether job inexperience associated with high accident rates was valid or was an illusion created by high job mobility patterns.

Major Findings

Some of the major findings of the accident analysis from 15 mines in the Pittsburgh Seam and from comparisons with selected nationwide data, are as follows:

- The job inexperience factor is not explained by job turnover. The job inexperience factor was an even stronger factor in the non-fatal Pittsburgh Seam accident sample than in the fatal accident data base. For example, 16% of the roof bolter accidents in the Pittsburgh Seam mines occurred during the first month on the job versus about 2% per month average roof bolter job turnover. Job turnover data, derived from USBM respirable dust reports on over 80,000 underground workers, indicates that job mobility is relatively high (20 - 40% per year) but not nearly high enough to explain the job inexperience factor found in the fatal accident data which would require a turnover percentage over 100%.

- The accidents in the mines studied varied considerably, as expected, from national data, both in type and characteristics. The implications for better utilizing more detailed regional accident data is discussed in this report.

- Factors that were thought to be related to the job inexperience factor, such as gross annual absenteeism, job turnover, and productivity, were not consistently correlated with accident rates in the various mines.

Chapter Three provides a more detailed summary of the accident analysis findings and methodology. Chapter Four presents the detailed analysis and the comparisons with 1971 national non-fatal injury accident data.

Some of the comparisons in Chapter Four have never been published before to the best of our knowledge. Calculation of accident rates per job category, for example, was not really possible until the recent creation of Bureau data gathering activities such as the respirable dust sampling program. Similarly, certain age comparisons were not possible before. The job inexperience comparisons are most significant in our opinion because they offer the most definite proof of the job inexperience factor in accidents and indicate that the problem may be much worse in non-fatal injury accidents.

Besides the accident analysis, this report discusses other aspects of the original accident prediction study, including the proposed SPA concept and a summary of the interview results obtained by the attempted Delphi technique interviews in Chapter Five. A promising accident prevention interviewing technique, called the Critical Incident Technique, is discussed in this chapter in addition to the discussions of accident prediction techniques.

ACCIDENT PREDICTION FROM ACCIDENT OCCURRENCE

The term "accident prediction model" has been a very confusing term for those concerned with this study. The term "prediction" and the term "model" both tend to convey widely differing meanings to different people. Thus, it may be useful to discuss various concepts of accident prediction before discussing the recommendations and findings of this study.

Some of the accident prediction concepts to be discussed include

- Statistical forecasting and quality control calculations to answer the "who? what? where? when?" questions.
- Analysis of causal and correlative accident factors to answer the "why" or "if-factor-X-then-result-Y?" questions.

The most common errors made about accident occurrence include an underestimation of the statistical variation associated with accident occurrence and the accompanying oversimplified assumptions of accident causality. Hopefully, the following paragraphs will review some of the most relevant accident prediction techniques and help clarify some of these misconceptions.

Accident Prediction From Statistical Forecasting

The term accident prediction tends to be commonly understood as the process of identifying and measuring the importance of accident "causal" factors. However, in some cases, one can "predict" accident occurrence in the immediate future by simply statistically projecting past accident frequency occurrence data into the future without reference to any so-called causal factors. Obviously, there are certain risks in projecting the past into the future, but the techniques, if refined, can be very valuable for certain prediction purposes.

A large mine or group of mines which have been having a large number of roof fall accidents will tend to continue having a large number of roof fall accidents, unless fundamental changes occur, and it is important to know whether or not changes have occurred prior to inspection. Unique accident factors in a mine which have been statistically consistent over time are of great value to anyone attempting to identify and cope with current and future safety problems in that mine or mine group. The desire of mine inspectors to be able to review the accident history of a given mine prior to a mine inspection is recognition of the value of projecting from the past to the present and to the future.

Forecasting from previous accident frequency data can be made considerably more precise by calculating rolling averages and standard deviations of the data points included in the rolling average. The amount of the frequency variation of the points within a rolling average is a direct measure of the stability of accident occurrence over time and hence a measure of future accident occurrence predictability. Exponential smoothing calculations for means and variances offer an enormous shortcut in the calculation effort and offer nearly equivalent precision for calculating rolling average means, variance, and trend corrections.

The same statistical calculations described above for accident frequency projections into the future can also be used for detection of true changes and trends in the latest frequency occurrence data. The mean and variance calculations can be used to determine statistically whether the most recent data point represents a significant change up or down in frequency or whether the last data point is within an expected frequency range. The technique just described is similar to "control charting" and is a common quality control technique in production industries. Control charting avoids either over-reaction or under-reaction to either apparent or real changes in a production process and/or in the occurrence of defects (accidents). Most importantly, the technique provides reliable detection of real changes in the production process which require corrective action.

At the present time, the Bureau has been developing selective enforcement inspection programs that provide for increased inspection emphasis in mines that are considered especially hazardous and/or which have had especially poor safety records. Selective inspection is a commendable and sound program. It makes no sense to spend equal amounts of inspection time in mines of equal size which have accident frequency rates that differ significantly.

Applying statistical and quality control techniques to the raw summary accident data can considerably enhance the effectiveness of selective enforcement and inspection programs.

Statistical control charts can provide valuable feedback on the effectiveness of certain inspection or enforcement programs. If accident frequencies decrease in a group of mines that were selected for special programs, the critical evaluation question is whether the decrease was statistically significant.

Experiences encountered by organizations who make decisions on frequency data over time reveal that without statistical control evaluation, people tend to over-react to apparent changes in frequency either up or down and thus misuse and waste valuable resources that could have been used to work on more critical control problems. Conversely, subtle shifts or creeping trends in data are often missed until the shifts are substantially large.

Statistical forecasting techniques with rolling averages (or with equivalent means calculated by exponential smoothing) work best when restricted to means whose value exceeds five per time period. A mine with 100 mine workers with an accident frequency rate of 50 accidents per million man-hours would expect 10 accidents per year. Thus an appropriate time period for this size mine and accident rate would probably be six months. Obviously, statistical monitoring of accidents in individual small mines poses a difficult problem regardless of the monitoring technique. One valid monitoring technique for overcoming the problems of smallness is to group mines similar in size and problems. Other variables, such as seasonal variation, pose problems, but judicious grouping of categories, time periods, and formulae, can compensate for many of the problems.

Undoubtedly, statistical forecasting and quality control calculations in themselves will not reduce mine accidents. These calculations do not significantly contribute to an understanding of how or why accidents are occurring or what the remedies should be to reduce accident occurrence. Moreover, we risk the criticism that advocating the use of these techniques in mine inspection is an inappropriate attempt to make "statisticians out of mine inspectors." We are not advocating that the mine inspector perform the statistical analysis, but rather that his inspection efforts be directed to the most critical problems by the proper statistical evaluation of accident statistics. We believe the Health and Safety Analysis Center in Denver is the logical organization to set up a statistical monitoring and forecasting program for the inspection districts and subdistricts. Most of the monitoring calculations can be set up for timely and routine computer feedback reports to inspection districts. Also, making statistical information available will not be helpful if inspection managers are not involved in its development and are not trained in the fundamental concepts behind these techniques.

Our discussion of recommendations on statistical forecasting are based on the observation that at the time of this study the majority of expenditures by the Bureau have been to collect accident and inspection violation information rather than to systematically analyze and utilize the data in responsive programs. We know many plans are under way to correct this problem, but we advocate the acceleration of efforts to better utilize the data now collected.

In visiting over seventy mines and in interviewing numerous mine inspectors our consultants have been impressed by the great detailed knowledge that mine managers and inspectors have about many safety problems. At the same time, our consultants have been surprised over the misconceptions and lack of perspective many of these men have over major accident problems. This lack of perspective results, we believe, from the lack of timely and helpful feedback data available to these men on significant accident factors.

Many of the above suggestions of feedback reports are covered in the recommendations the contractor has already made in the sister report, Safety Analysis Systems Study. The spirit of the recommendations and the reasoning in both studies is much the same, although the emphasis of the recommendations in this study is to place more emphasis on statistical forecasting and control concepts.

A good reference on statistical forecasting with short-cut exponential smoothing techniques can be found in "Statistical Techniques and Forecasting in Inventory Control" (4th edition) by R. V. Brown, published by Prentice Hall Inc., Englewood Cliffs, New Jersey.

Accident Prediction from Analysis of Causal Factors

The term "accident causal factor" tends to suggest a deterministic relationship between the occurrence of accidents and a factor, but accidents do not result from a single act or single condition. At the present stage of information gathering in a mine, we do not have advance knowledge of the state of a sufficient number of physical variables to reliably predict a roof fall, nor can we reliably predict the behavior of human beings whose actions may coincide with certain of these physical conditions to result in an injury roof fall accident.

Investigating accidents and assigning a single cause or a ranked list of causes may psychologically satisfy an investigative committee, but provides almost no useful information to an analyst attempting to analyze the accident occurrence likelihood associated with a given set of conditions or the benefit of a proposed remedy to a known safety hazard.

The problem of roof fall accident control provides a good example of problems of so-called "causal" analysis. Previous Bureau research attempts to develop an analytical approach to predicting roof fall occurrence has achieved only limited success. The combined theoretical effect of several variables associated with roof stress in room and pillar operations, i.e. seam height, roof deformation, entry width or intersection dimensions, type of roof support and overburden depth, depth of overlying strata, etc. are insufficient for accurate prediction of roof fall occurrence. The randomness and variance of natural non-uniformities in overlying rock strata is too great to be approximated by engineering calculations of stress which assume uniform material characteristics. The calculations are, however, helpful for establishing a point of departure for minimum roof support criteria. Most roof support plans are empirically tested in the mine and adjustments are based on the resulting roof deformation and number of falls. "Rules-of-thumb" definitions of "adequate" roof support emerge from experience in various mines which is applied to new mine sections with similar conditions.

Following the guidelines of a roof control plan is no guarantee of avoiding roof fall accidents and the great difficulty in roof control is to recognize dangerous roof conditions and increase the roof support where needed to avoid roof falls and roof fall accidents. This required judgment to maintain safe roof support introduces the human element in a major way into the safety problem.

A fatal roof fall accident report will typically indicate some degree of variation had occurred in the roof control plan, will indicate the victim was taking unnecessary chances, and will have an observation that the roof fall outline followed some sort of slip or fault line.

To relate these accident factors in an empirical way to the future likelihood of accident occurrence requires numerous pieces of information. Basically one must have some knowledge of the number of other similar situations that both did and did not result in accidents.

Suppose one wished to compare empirically the general effectiveness, as measured by accident frequency rates, of roof support plans that utilized posts only versus those that utilized bolts only. To do this comparison properly one would need to know 1) the post vs. bolt associated roof fall accident frequencies that occurred in matched conditions of equipment, seam height, overburden depth, entry width, circle-of-largest-diameter between-ribs, etc.; and to know 2) the number of roof control plans and the number of men exposed to each roof support plan. If the accident frequencies were dramatically different, for the two support plans, one would want to investigate the subject further by testing for intervening variables and by field observation. Important intervening variable questions to examine would be: 1) how close are roof control plans being followed in practice and 2) are there important differences in work practices or equipment which would affect the type of worker exposure to potential roof falls.

Using roof fall accidents as an example, the difficulties of performing empirical roof fall accident analysis described above are as follows:

1. Only fatal accidents are investigated and reported with detailed narratives.

2. Reported non-fatal injury accidents contain almost no data about the roof fall circumstances.

3. Many roof control plans are only recently established. (since 1969)

4. No systemmatic compilation of roof support plans has been made for purposes of analyzing the relationship between roof fall accidents and roof control plans.

The fatal roof fall accidents from 1966-1971 have been coded into a data base with approximately 250 variables and about 125 variables relate only to roof falls. However, without the data base of roof control plans one cannot determine the empirical relationship of most of these roof fall variables to fatal accidents. In the case of non-fatal accidents, an analytical roof fall non-fatal injury accident base is precluded because no roof fall data is recorded on the current injury accident reporting collection forms.

Despite the lack of data problems in establishing empirical relationships between accident occurrence and many accident factors, much information has already been derived from an analysis of the accidents. As the Bureau builds its data bases it will be possible to investigate many factors more systemmatically. The essential secret to exploring these empirical relationships, is to build a data base on a case by case basis in such a way that one can tabulate the relative occurrence frequencies of any combination of factor values. This methodology is described in more detail in our report, Fatality Analysis Data Base Development. (Contract No. S0110601, Mod. 2)

Ideally, a systemmatic researcher would analyze the relationship of as many variables to accident occurrence as possible until he can prove certain factors are unimportant or unrelated. This is an idealistic inductive approach to investigating accident occurrence, in contrast to investigating preconceived ideas or theories about accident occurrence. Unfortunately, preconceived ideas about accident occurrence too often dominate the data collection and analysis of accident data.

Sometimes, certain variables which seem of little value in a single accident, may become important when examining a collection of accidents. This was the case in analyzing the job experience variable in the original fatal accident analysis. Many Bureau investigators never bothered to indicate job experience in the earlier fatal accident reports because they didn't realize this variable might be important.

We believe that assigning a high priority to the strategic gathering of additional detailed accident data and related mine data offers the greatest hope of meaningful gains in understanding the nature of accidents and evaluating the most promising accident reduction measures.

LIMITATIONS OF ACCIDENT ANALYSIS

The difficulties of this study and the problems of achieving safety have prompted us to look for new ideas. We have discovered some new ideas, critiqued some of our old ideas, and will present some of these thoughts in this section.

Every underground coal mine has associated with it a set of potentially important safety hazards such as a mine floor with a high degree of incline, coal that liberates substantial amounts of methane, a roof with a "brittle top," equipment with an inherently high accident history, etc. In a similar fashion, there exists a set of behavioral acts which describe the movements and actions of the miners on the job. Included in this set would be activities such as walking out under unsupported roof, setting timbers, or operating a machine. Some of these acts and conditions are considered by definition to be safe, while others are distinctly unsafe. Still others can take as a range of values from safe to unsafe depending upon the circumstances. Whenever unsafe acts, unsafe conditions or some combination of unsafe acts and conditions occur, the possibility of an accident arises and a Potential Accident Situation is created.

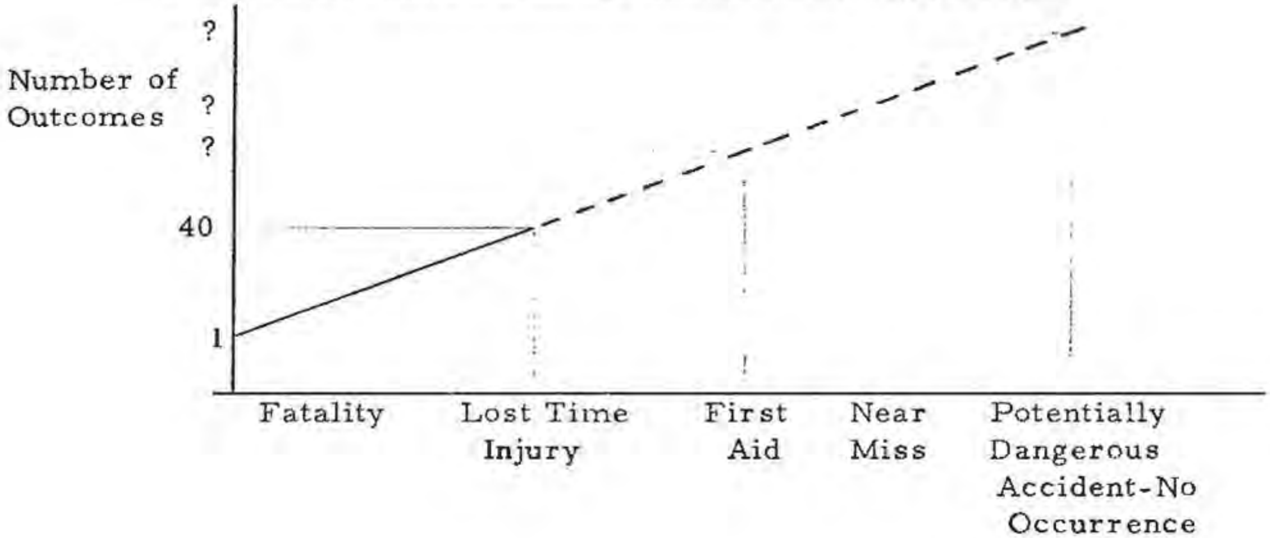
Every Potential Accident Situation has associated with it a set of possible outcomes. Listed in descending order of severity, they are:

- Fatality: results in the subsequent death of the accident victim
- Lost Time Injury: prohibits the injured person from performing effeciently the work of a regularly established job, which is open and available to him, throughout a full shift.
- First Aid Injury: permits the injured worker to perform effectively throughout a full shift in a regularly established job.
- Near Miss: involves a potential injury producing occurrence which does not result in bodily injury. (For example, a roof fall that occurs near the work place or in the work place while miner was eating lunch.)
- Potentially Dangerous Incident--No Occurrence: exists when unsafe acts or unsafe conditions have combined in a manner that typically results in an accidental event, but the event fails to occur. (For example, a miner roof bolts without using temporary support, or he stands underneath unsupported roof unnecessarily and no roof falls occur.)

Exhibit 1-1 illustrates this theoretical concept of accident occurrence. The number of outcomes of any particular Potential Accident Situation are distributed among the five categories according to a probability distribution similar to that diagrammed on the following page:

EXHIBIT 1-1

POTENTIAL ACCIDENT SITUATION EVENT RATIOS



The figure shows that a lost time injury accident is more likely to occur than a fatal accident. In underground coal mining the ratio of reported lost time to fatal injuries historically exceeds 40, and injuries requiring simple first aid have been more numerous than reported injuries. Furthermore, whether a fatal accident or a near miss is the consequence of the particular combination of unsafe acts and unsafe conditions which produced the Potential Accident Situation (PAS) is simply a matter of chance. In most cases the severity of injury depends on minute variations of circumstance. For example, a roof fall hitting a foot instead of the head or shoulders or an object hitting an eye instead of the forehead are almost indistinguishable events in terms of causes and preceding events.

It is important to note that every PAS has associated with it a unique probability curve of outcomes. Some accident situations may have outcomes more heavily skewed towards the fatality end such as massive roof fall or mine fire situations. Others, such as a miner walking in the dark and approaching a timber lying in a passageway would be more heavily skewed towards the No Occurrence end since the chances are the miner will only receive a cut or a bruise if he is injured.

The fact that the number of fatalities or even lost time injuries is such a small percentage of the total number of possible outcomes associated with any PAS suggests why fatality accident analysis and/or non-fatal accident analysis fail to provide definitive descriptions of all the factors contributing to underground coal mine accidents, especially in a single mine. The total number of accident cases is too small for meaningful analysis except in those cases for which a given cause is a critical factor in all the accidents.

A mine with 200 men employed will work approximately 400,000 hours per year. At a typical level of 40 reported lost time injury accidents per million man-hours, the mine would report 16 lost time accidents a year. Similarly a mine with 50 employees would expect about 4 lost time accidents per year. Each mine will have a small sample of accident cases, and analyzing accident data from several years to obtain a bigger sample risks including obsolete data. Moreover, if the information collected contains no more details than those reported on Bureau injury or State compensation forms, the value of causal accident analysis is almost precluded. Hence, only a few of the large companies operating a number of mines are able to take advantage of accident analysis.

Obviously enlarging the data base of cases that identify causal accident factors will help the process of measuring hazards. A more systemmatic collection and analysis of data surrounding all accidents including first aid injury cases would significantly improve the measurement of potential mine hazards. To the extent that the U. S. Bureau of Mines enlarges the amount of detail to be collected in accidents reported to the Bureau, a far more precise analysis of hazards will be possible.

Most Bureau officials who agree with the above observation theoretically object to enlarging the accident reporting forms for several of the following reasons: 1) mine personnel will refuse to fill out longer forms, 2) more details will tend to be incriminating, 3) unless the Bureau investigates the accident, the information will often be disguised, 4) analyzing more data is too expensive, and 5) the causes of accidents are already known; the problem is to get companies to comply with regulations. There is merit in some of the above reasons, but we believe that some of these objections are worth review.

Using more paper and more questions does not necessarily imply requiring longer amounts of time to fill out, code, and keypunch an accident report form. Structured questionnaires are faster to fill out and certainly faster to prepare for computer processing than narrative replies to open ended questions. Moreover, more accuracy, reliability, and volume of data can be obtained with well designed forms. Many states have removed the threat of incrimination in their accident report collection and analysis process. The cost of analyzing more accident data versus other alternatives has proved cost effective to those companies who have tried it as part of their program to achieve excellent safety records. The argument that the causes of accidents are already known is too simplistic. Safety problems are continually changing and safety efforts need to emphasize those areas creating the greatest hazards.

Even with excellent detailed accident data and analysis, identification of problems through accident analysis is after-the-fact. The best time to identify problems is before accidents occur. After considerable research on various approaches to safety achievement, we are impressed with the potential of Critical Incident Technique (CIT) for defining in advance the causal factors relating to potential underground bituminous coal mine accidents.

CRITICAL INCIDENT TECHNIQUE

The Critical Incident Technique (CIT) is a mechanism for identifying factors which have contributed to actual or potential accident situations. It allows the researcher to catalogue the circumstances surrounding not only actual lost time injury and fatal accident situations, but first aid, near miss, and no occurrence incidents as well. Because it considers all Potential Accident Situations, a very large data base can be collected in a very short period of time.

The CIT is an outgrowth of the Aviation Psychology Program of the US Army Air Forces in World War II. Originally used as a method of collecting data to study psychological problems, its value as a method for determining the causes of industrial accidents was not established until 1963.

A study by William E. Tarrants at a Western Electric Company plant in New Jersey concluded that the method dependably reveals causal factors in terms of behavioral errors and/or unsafe conditions which lead to both injurious and non-injurious accidents. Furthermore, the total amount of information about accident causes obtained with the CIT is greater than that obtained by any other available method including accident analysis.

The procedures involved are fairly simple and are outlined below:

1. Select a stratified random sample of workers.
2. Designate an observer/interviewer.
3. Interview members of the worker groups who have performed particular tasks under certain environmental conditions within a given time period, asking them to recall and describe all the unsafe acts which they have performed or which they have observed others perform while in that situation, as well as any other unsafe acts or conditions which have come to their attention in conjunction with their jobs.

4. Classify each of the above incidents into hazard categories from which the behavioral and environmental causal factors relating to each category can be derived.

The use of the CIT may induce some important perceptual and behavioral changes in the workers. First, it may demonstrate to the workers that the company cares about safety, assuming the company reacts and does something constructive about the hazards identified. Second, it may encourage the workers to look for hazards that they can report in the next interview. It may make the workers more conscious of performing unsafe acts because these unsafe acts get reported in the interviews. It is interesting to note that one company with an enviable mining safety record has incorporated many of the elements of CIT with their formal safety program.

The CIT is not a panacea, however; it does not provide a reliable assessment of the expected accident frequency associated with hazards nor a solution to the hazards. The value of CIT is that it identifies hazards quickly and directly from the group most closely associated with the hazards. Where it has been tried, the technique has identified more hazards than the regular safety engineers could identify!

CHAPTER 2

RECOMMENDATIONS FOR BUREAU ACTION AND FURTHER RESEARCH

Some of the following recommendations concern features of U. S Bureau of Mines programs already under development. This study was not directly concerned with these programs but we hope these recommendations will influence those programs in a constructive way.

We recommend that the U. S. Bureau of Mines utilize existing accident data that has been proven to be "predictive" in a more effective manner. Specifically, we recommend the following: -

- Job Inexperience Monitor. We recommend the Bureau Health and Safety Organization monitor all reported mine accidents on a mine-by-mine basis for evidence of the job inexperience factor. The magnitude of the "job inexperience" factor in accidents has been verified in this report as the number one correlative accident factor in underground coal mine accidents. Evidence of a strong job inexperience factor in accidents indicates defective job training and job assignment practices in the mine. The inexperience effect may be difficult to completely eliminate, but British and German coal mining industry experience suggests that job training, job certification, and special supervisory programs have significantly controlled this problem and thus dramatically decreased accident rates in underground coal mining.

- <u>Individual Mine Accident Analysis Program</u>. That the Bureau Health and Safety Analysis Center develop a computerized feedback analysis program for mine accidents from individual mines and from clusters of similar mines for the benefit of both district and sub-district Bureau mine inspectors and mine management. This computerized analysis program would incorporate statistical forecasting techniques (such as exponential smoothing) to calculate meaningful accident averages and variances to track progress and trends in accident occurrence in individual mines and carefully selected clusters of similar mines. The computerized analysis programs would also apply statistical decision rules to accident frequency rates to detect genuine versus only apparent changes in accident occurrence rates.

  Most individual mines have too few accidents to be analyzed on a meaningful basis more often than once a year. However, by careful grouping of the accidents from mines with similar characteristics in terms of equipment, size, seam height, roof control plans, etc., more frequent statistical analyses are possible.

After interviewing large numbers of mine managers, company safety personnel, mine foremen, and Bureau safety personnel, we are convinced that these men strongly desire and really need much more feedback about the relative importance of current accident problems and hazards in individual mines. Having both the accident profile of the mine to be inspected and the typical accident profile in similar mines would greatly assist mine personnel and Bureau mine inspectors in adjusting their efforts to solve the most serious problems. Also, having an accompanying elaboration of the most serious accident problems with suggestions for accident prevention would make the data more meaningful. If, for example, a mine had haulage accident problems, the inspector might not find any Bureau regulations in violation on his inspection tour. However, he could spend some time emphasizing tips for safer operations of the mine haulage system to the foreman in charge. Also, from the mine management side, if the mine management can be shown the evidence why certain haulage procedures or equipment should be changed to prevent accidents, the mine management is more likely to respond to suggestions for safer operation.

Fortunately, the operational cost of implementing this recommendation should be small after the initial computer programming was performed. Most of the data is available in Bureau computer files now and we understand plans are under way to provide summary reports of accidents on a mine-by-mine basis. Most large digital computers can perform all the calculations that we are recommending in the same amount of time required to print such reports, thus the additional cost of providing more meaningful data should not be significant.

As inspectors learn what data is available, they will most likely increase the number of special inquiries for data. Inspectors tend to have specific questions regarding accident occurrence that concern particular safety problems they are trying to resolve. For example, an inspector may be concerned about typical types of accidents concerning a particular type of locomotive or certain types of roof support plans. The advantages of a central data base can only be fully realized when large numbers of these types of potential users can gain access to the information in the data base.

- Inspection District Accident Analysis Reports. We recommend the Bureau Health and Safety Organization periodically perform special District and Subdistrict accident analyses similar to the one in this study to better identify the unique problems in each area. This recommendation is a slight variation of the previous recommendation which emphasized the domain of an individual mine with unique characteristics. This recommendation emphasizes the district inspection management problem for allocating inspection time and shifting inspection emphasis on districtwide safety problems. Because certain types of mines are too dissimilar, it may seem more logical to develop a regional clustering of accident data, however, we have observed some dramatic differences in accident occurrence and problems in similar mines which are separated by only a state boundary line. Also, some accident variables are more universal and should be tracked on a district-by-district basis. Examples of these factors are job inexperience in accidents, belt versus locomotive haulage accident rates, roof bolting accidents rates, etc.

Unfortunately, the accident analyses shown in this report is slightly biased because some of the smaller mines and a few large mines are not included in this accident sample from the Pittsburgh Seam and a Bureau sub-district area. Moreover, the data is somewhat biased by the accident reporting practices, prior to April, 1972, which understated minor injury accidents. Nevertheless, the data revealed important unique accident characteristics of individual mines and in clusters of mines belonging to the same company. The accident characteristics of the sample mines, as a whole, differ significantly from the national accident data compilation as shown in Chapter 4. To truly appreciate the significance of the uniqueness of accident problems of one region, one must perform a similar analysis of each region. Then, certain unique regional work practices (such as rotating shifts, job training and job assignment policies for new men, and roof support practices) can be better understood in terms of their relationship to accidents. The investigators formed a number of hypothesis on the relative merits of some of these practices, but can offer only weak emperical evidence to support these hypotheses until the contrasting practices in other regions are thoroughly investigated.

We recommend the U. S. Bureau of Mines conduct special studies as soon as possible to extend empirical predictive knowledge about factors associated with accident occurrence and control. We believe that several topics are worthy of special consideration:

- Special high accident occurrence problems in each region. We recommend special studies be performed in conjunction with regional accident analysis or analysis of accident problems associated with certain clusters of similar mines, or mines with similar problems. Special studies involving limited data collection could be performed at reasonable costs on major accident problems. For example, a selected sample of mines with excessive numbers of roof fall accidents or equipment accidents could be asked to fill out expanded accident questionnaires and provide certain helpful mine data for the purposes of developing a special data base on the mines and their accidents. Special analysis of this data base may reveal valuable new insights into problems. Comparison of these problem mines, with mines which have similar equipment or conditions and low accident rates, may also provide some new answers to old problems.

- Controlled job training experiments. A variety of training approaches are being tried, and opinions differ sharply in the industry about their effectiveness. Training experiments where workers are tested before and after training, and are carefully evaluated on their accident performance before and after, will help clarify which techniques are truly the most effective in terms of safety and productivity. It goes without saying that considerable time and money will be saved if training ideas are thoroughly tested before widespread dissemination, rather than to let a series of training fads sweep the industry and create widespread disillusionment.

- A Revised Pittsburgh Seam Accident Analysis. The new non-fatal injury accident reporting system implemented by the Bureau as of April 1972 provides a new opportunity to extend and refine the accident analysis from the 15 mines performed in this study. The accident analysis in this study has revealed some promising topics for future research.

In 1971, the mines that we studied in the Pittsburgh Seam had an average accident rate of 5.9 per million man-hours. This is nearly 9 times lower than the national average of 50.75 per million man-hours. Possible reasons for the relatively good to excellent safety record of mines in the Pittsburgh Seam are as follows:

- The Pittsburgh Seam has many large mines owned by large companies with sufficient resources to provide adequate equipment, support services and staff for safety programs, inspection, job training, mining engineering, equipment maintenance programs, etc. However, merely having the resources does not guarantee results in better safety records. In our opinion, the key factors seem to be the attitude of management and the willingness to stress worker training programs and to invest in the development and training of quality supervision.

- The Pittsburgh area has a labor practice of rotating shifts. This means that every worker and his crew will alternate working between the day and night shifts. This reduces the perpetual problem of workers with seniority (from the second or third shift) bidding for and obtaining jobs on the more popular first shift.

- The labor force in the Pittsburgh Seam seems to be more experienced and more stable than in many areas we have visited. The Pittsburgh Seam mines have provided more steady employment and possibly are able to select and retain more desirable workers than are mines in many areas.

Does the apparently better safety record of the selected 15 mines in the Pittsburgh Seam mines mean that these mines are safer than most coal mines in other underground seams in the United States? The investigators believe the mines in this study have superior - safety records, but cannot determine, with certainty, the degree of superiority. Reported rates are substantially lower than the national average, but one safety director has stated that he thinks the true accident frequency rate for the Pittsburgh Seam mines is closer to 30 vs 6 per million man-hours. Even to reduce all mines to the national accident frequency rate average of 30 accidents per million man-hours would be a significant improvement.

The problem of determining the true accident frequency rate for the Pittsburgh Seam lies with the policy of some large companies to try to keep an employee on the payroll. This is certainly a very desirable thing to do from the employee's point of view; it keeps him productive, he receives income, and it aids in his psychological recovery from the injury. However, it has not helped the study of past accident statistics. Only lost time injuries were reported to the Bureau up until April 1, 1972, and if the employee could be kept busy in another less demanding occupation, no lost time was recorded. Some companies keep their own internal records on serious or disabling injuries as distinct from lost time injuries, but in the past these have not been available for public record. The new accident reporting requirements, instituted April 1, 1972, should record all the disabling injuries, whether or not lost time was involved. A repeated analysis of 1972-1973 accidents from the same mines covered in this study should yield more accurate analysis of job inexperience and substitution effects, the two most universal safety problems in underground coal mining.

We would also recommend extending this research to accident factors in the Pittsburgh seam versus other regions. We would study differences and similarities in accident factors between the Pittsburgh Seam and one or more seams or areas in other regions of comparable size. West Virginia has a reported accident rate considerably higher than that of the mines studied in the Pittsburgh Seam. We believe, based on limited observations, that some of the general differences found in West Virginia would be:

- Non-rotating versus rotating shifts
- Higher absenteeism and job turnover rates
- Fewer hours of job training
- Smaller mines which are less capital intensive
- Less qualified foremen
- Equipment less well maintained.
- Stronger production pressure on supervision

Do these factors in fact correlate with accident occurence? The mines in our study did not provide a broad enough range of values to be representative of the extremes present in the industry or to test completely the correlation of these factors with accident rates.

- <u>Effects of 1970 Roof Control Plan Changes on Roof Falls</u>. This would be a systematic follow-up of sample mines that significantly changed their roof control plans in 1970 to see what results have been achieved. For example, we understand many mines in the old District No. 2 were required to adopt "positive support" plans, i.e., either bolts or cross-bars. A careful comparison of roof fall accidents for two years prior to and after the change might provide valuable insight into the effectiveness of the changes. Obviously, a number of adjustments or classifications must be made for whether roof falls occurred during advance versus retreat cycles, or occurred under unsupported versus temporarily supported versus fully supported roof(s). Other factor adjustments might be roof area supported, average in overburden, production rates, equipment changes, age of roof, etc.

- Job Enrichment and Social-Technical Job Experiments. In the Pittsburgh Seam mines studies, the absenteeism rate was typically 10% ranging from 5% to 16%. We understand these rates are considerably below the national average and that certain regions have typical rates about 20%. High absenteeism, high job mobility (20-30% of the underground miners shifted job classifications in 1971), and relatively high job turnover (workers entering and leaving the industry) are all costly to the productivity of the industry, and strongly suggest great worker dissatisfation with mining jobs.

  Job enrichment experiments in other United States industries have proved that jobs can be made more interesting and more satisfying to workers and more productive at the same time. Social-technical system experiments in underground coal mining in Britain, conducted by The Tavistock Institute, have shown that revised organization of work groups which better fit the interdependent work cycles of coal mining have yielded dramatic decreases in absenteeism, accident rates and turnover. (Trist, Higgin, Murray, and Pollock, Organizational Choice, Tavistock Publications, 1963, London). In contrast to the common sense assumption that less job mobility or job posting will yield greater safety and productivity in United States coal mining, the Tavistock experiments encouraged significantly higher job task variety and reduced accidents by 50%. Clearly, the answers are not simple, but the point is that enough is now known about worker motivation and job satisfaction to begin applying some of these principles to U. S. underground coal mining.

We believe that the Bureau could make a significant contribution to both safety and productivity by joining with union and industry groups to sponsor a series of experiments applying job enrichment and social-technical system principles.

- Experiments with Job Certification. A large number of mining accidents, especially equipment related accidents, occur with inexperienced or substitute workers in the job classification. The evidence strongly suggests that limiting certain jobs to certified workers who have passed an examination, proving their qualifications to operate equipment or perform the job tasks, will significantly reduce accidents. Mining workers must have drivers licenses to drive to work and most of their teen-age children undergo extensive drivers education courses to prepare them to drive an automobile. Mining workers, on the other hand, typically learn to operate equipment on their lunch hour and are often allowed to become operators of this equipment with their foreman's permission. Mining equipment costs many times the value of an automobile; it is far more complicated, with numerous hydraulic controls, and it is operated in a hazardous environment. Job certification is not a panacea, but it would seem to be a very cost effective way of reducing accidents. We recommend that the Bureau begin developing and testing certification programs for jobs that require use of mining machinery. We do not recommend that job certification be adopted without careful study of its cost versus the results achieved in actual field experiments.

- A Critical Incident Demonstration Program. The Critical Incident Technique, applied in worker interviews, has been shown in experiments to be superior to accident analysis or safety inspections in identifying hazards in a work environment. As was explained in the description of the Critical Incident Technique's applicability to industrial settings, it is the workers themselves, the potential accident victims, who are in the best position to observe deficiencies in worker behavior or in the environment. They are the only ones who can describe specific Potential Accident Situations whose outcomes were a near miss or no occurrence, since this information is seldom, if ever, reported to anyone. Furthermore, it is the workers themselves who ultimately have a major shared responsibility with mine management for making their working environments and own actions safer. Hence, we believe that the technique is worthy of examination and trial in underground coal mining.

- Other Prediction Factor Investigation Studies. The contractor's earlier studies, the Industrial Engineering Study of Hazards Associated with Underground Coal Mine Production, Volume I and Fatality Analysis Data Base Development analyzed the job inexperience factor in fatal accidents, but this study was the first to survey actual job experience and job mobility in the appropriate working population in the industry. Thus, this study contrasted the job experience of accident victims versus the worker population, and obtained a truer measure of the impact of the factor on accidents. We hope that future research will investigate other promising factors identified in the fatal accident data base by gathering appropriate data to properly contrast the accident data with the population data. Since these promising factors are discussed in these earlier reports, it would be inappropriate to duplicate a discussion of these factors in this report.

CHAPTER 3

ACCIDENT ANALYSIS FOR THE PITTSBURGH SEAM

DEVELOPMENT OF THE INJURY DATA

The initial aim in collecting the non-fatal injury data on accidents that had occurred in the Pittsburgh Seam was to obtain more detailed information than had previously been reported to the Bureau of Mines, particularly data relating to job task experience and training. To accomplish this objective, the majority of companies operating mines in the Pittsburgh Seam in Pennsylvania were contacted. The objectives of the study were explained and their cooperation was requested in releasing information on non-fatal injuries. Complete anonymity of data sources was assured.

Those companies that indicated a willingness to cooperate were visited by one of our consultants who again explained the purpose of the study. In those cases where permission was granted to examine the individual accident records, it was generally necessary to visit the mine site to obtain the accident records. Whenever possible the consultant also visited underground to see the actual mine conditions and working practices. Details of each injury were recorded onto the Accident Report Form (Appendix 3-1) except in the cases where copies of the state workers compensation form (Appendix 3-2) were obtained. Both these forms listed details on the victim, his experience, the type of accident and the circumstances surrounding the occurrence. Efforts were also made to collect data on the job task experience of the victim (the experience the victim had in performing the task in which he was involved at the time of the accident) and on job substitution, especially instances incurred because of absenteeism. As we mainly had to rely on historical records, however, very little information could be obtained on either of these variables. The information that could be obtained from the injury forms was coded onto punched cards for subsequent computer analysis. The layout of the punched card is shown in Appendix 3-3.

A significant problem associated with the developent of the accident data was that it represented only accidents which caused lost time disabilities as defined by the rules prior to April 1, 1972 for reporting non-fatal injury accidents to the Bureau of Mines. It was the policy of some companies, especially large companies with captive coal mines, to maintain an injured employee on the payroll if he could report for work and could be reassigned a temporary job. This policy has been shown to minimize the absenteeism time taken by injured employees and has certain economic benefits to both the worker and the employer company. However, the non-uniform application of this policy from mine to mine and from company to company makes valid comparison of accident statistics almost impossible. It also tends to understate the accident occurrence typically reported by the large mines in the industry.

NORMALIZING THE DATA

An analysis of accidents that is confined solely to the accident statistics alone does not give any information about the relative frequency of accidents, or about the people who do not have accidents. For example, we know that the roof bolter in the Pittsburgh Seam is involved in more non-fatal accidents than any other job classification. Does this mean that the roof bolter is the most accident prone occupation, or are the number of roof bolters greater than other occupations and hence their share of accidents greater? The only way to answer these questions is to view the data on accident victims against the background data for the mine. This means determining the total number of miners in each occupation and calculating the accident rates for each occupational group. Additional factors that require substantial background data to permit meaningful analysis are the ages, job experience and total underground experience of the mine population. The process of comparing data on injured miners to the background data of all miners is called normalization. It permits an evaluation of the statistics on injured miners that highlights factors peculiar to the injured miners as distinct from the total mine population.

The normalizing data for the Pittsburgh Seam was obtained by contacting each of the mines that had agreed to make their accident data available to us and asking for their help in obtaining the normalizing data. As an aid in compiling the information we distributed to each company five working sheets to summarize the needed information (Appendix 3-4). We had hoped that much of this information might be available from company records. However, some of this information soon proved difficult to obtain. For example, it is often the case that a company has absenteeism records but they are not in such a form that one can ascertain or summarize how many men were absent in each job classification throughout the year. Similarly, job posting records are kept but they are not kept in a form that is easy to condense and summarize. While most mines could readily list the number of men employed during the past year under each occupation, it became more difficult to obtain the ages of these men. Many mines had difficulty in listing the number of men leaving the mine or hired during the year and no record was kept of the number of manhours worked for each occupation. Data on miner job experience was initially unobtainable.

The preliminary findings in this study indicated the importance of job experience as a factor in accidents. It was thus imperative to obtain information on job experience of the general mine population to provide a background with which to view the job experience of injured miners. This information could only be obtained by taking a direct survey of the miners involved. To help facilitate this task, we designed a questionnaire (Appendix 3-5) to be distributed to all the mine foremen, and asked that the foremen directly poll the miners under their control. To facilitate the cooperation of the mines, we restricted the survey to the four or five occupations showing the highest probability of accidents, namely roof bolter, shuttle car operator, motorman, loading machine operator, and continuous miner operator. This method proved successful, and we were thus able to complete the normalizing data.

We are extremely pleased with the cooperation and help shown by the mines in gathering data and would like to record here our sincere appreciation and thanks. We believe this to be the first really comprehensive normalization effort on job experience in any major coal seam or coal mine production area in the United States.

NATIONAL ACCIDENT DATA

The Pittsburgh Seam tends to be unique in that it is relatively uniform in geological structure and is mined by several large well-run companies. Only comparisons to national accident data put the Pittsburgh Seam in perspective with the whole U.S.A. and highlight those areas for which are representative of the national scene.

National accident data is compiled by the U.S. Bureau of Mines. All mines in the United States are required by statute to report injuries to the Bureau. Prior to April 1, 1972, few details were collected about non-fatal lost time accidents. On April 1, a new accident reporting form was introduced that required more information on each disabling injury, whether or not lost time was involved. All fatal accidents have been fully investigated by the Bureau and reported in a narrative report for a number of years.

Each accident reported to the Bureau is coded for computer processing. The 1971 computerized injury data file contains information on the cause of accident, part of body injured and the victim's occupation. Although space was provided on the computer tape for details about the victim's age, experience and place of accident, this information was not initially available. It was later partially obtained by merging the accident file with the employee history file as explained below.

Since the latter part of 1970 the U.S. Bureau of Mines has also been compiling a data bank on employees in connection with the respirable dust sampling program. This is as a result of the 1969 Occupational Safety and Health Act regulations concerning control of black lung diseases. This employee history file includes information on the age, experience (20% response), occupation at the time of each dust sample, and type of mine. In May, 1972, this file contained data on over 75,000 miners from 1,600 mines. The file is being continuously updated as more miners submit dust samples. This employee history file has proved very useful in providing normalizing data for the national accident data and in providing age and underground experience information for the injury file.

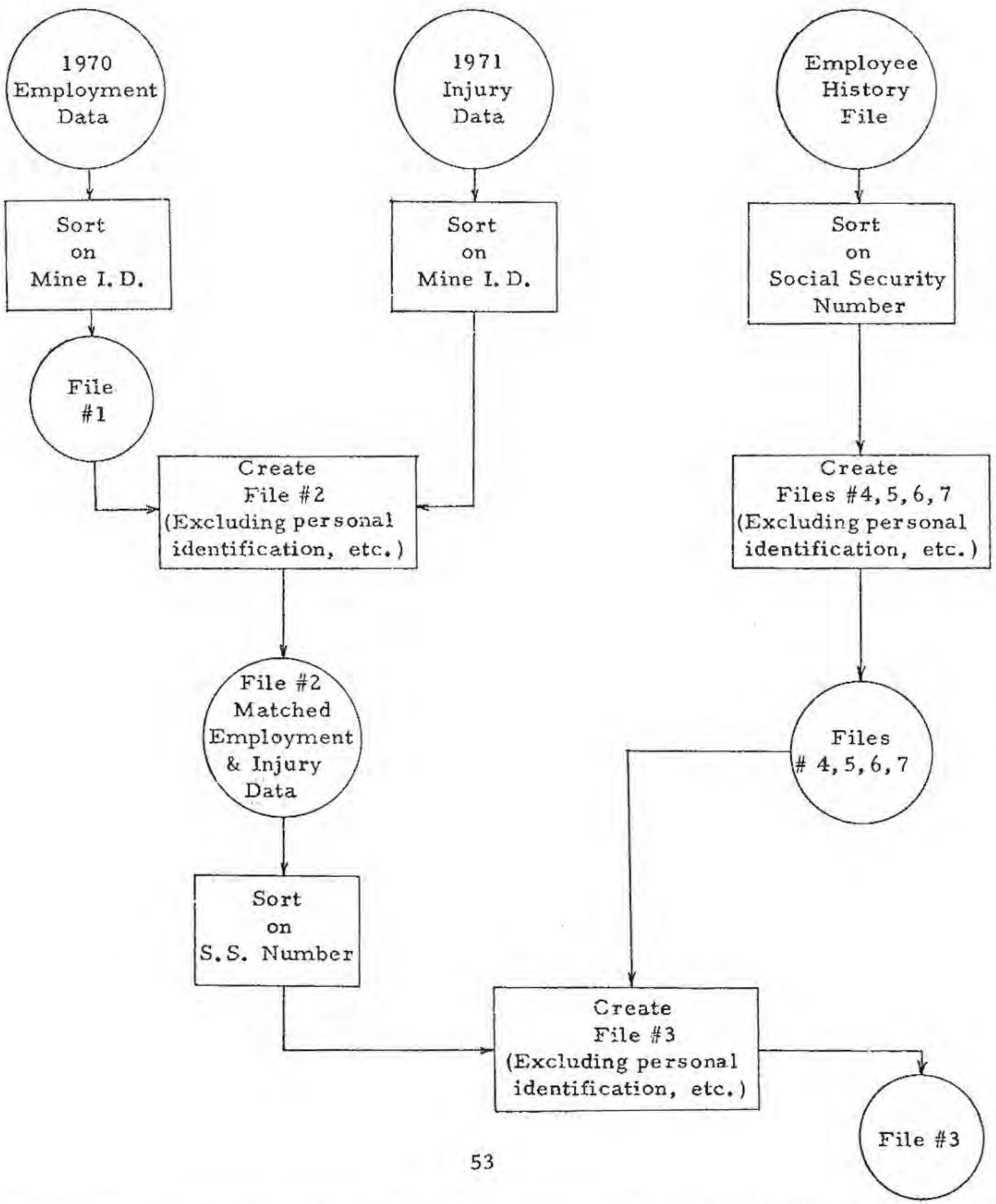
The Bureau also has computerized information on each mine. This includes the number of men employed, annual man-hours worked, tons of coal produced and the seam thickness. This is the employment data file.

At our request, the U.S. Bureau of Mines Automatic Data Processing division in Denver gave Theodore Barry and Associates edited copies of the injury file, employee history file and the employment data file. These were edited to exclude all personal identification. In addition we were given a copy of the 1971 accident file matched by social security number and merged with the employee history file and employment file. The flow chart depicting the creation of the data base from the three files used for the study is shown in Figure 3-1.

From this new data base, we were able to obtain information on the age and experience of the accident victim together with data on the mine where he was working. Unfortunately, only half the 1971 injuries had social security numbers that matched with the employee history file, and the merged file contains only 3,921 of the 7,979 accidents recorded in the injury file. Consequently total underground experience statistics were available in only 10% of the cases and the age of the injured miner and the type of mine in only 50%. It was felt, however, that this was sufficient to give a reasonable indication of the ages of the injured miners and the type of mine where they worked.

FLOW CHART

(Depicting the creation of special tapes used in this study)



METHODOLOGY FOR DATA ANALYSIS

A total of 443 non-fatal accidents in the Pittsburgh Seam covering the years 1966 through 1971[1] were analyzed using TB&A's INFORM program and the National Opinion Research Center's Statistical Package for the Social Sciences (SPSS). The first step in the analysis was the preparation of frequency tabulations. The 443 accidents were categorized along each of several general dimensions including:

Type of Accident	Age
Job Category	Time of Accident
Victim Doing	Absenteeism
Job Experience	Turnover
Underground Experience	Productivity

Then followed cross-tabulations between many of the factors, for example, occupation and job experience.

Whenever possible the frequency distributions and cross-tabulations derived for the Pittsburgh Seam accidents were compared and contrasted with the available information on 1971 national accidents which included 7,979 injuries (106 fatal and remaining 7,873 non-fatal).

1. The years 1966 through 1971 were chosen to provide a sufficiently large sample for statistical analysis.

SUMMARY OF ACCIDENT ANALYSIS FINDINGS

The detailed study of the Pittsburgh Seam has shown that the presence of some factors can have a noticable impact on the accident rate. One notable example is the institution of extensive job training for new employees by one company. Accidents occurring in the first month on the job have been reduced. This would tend to indicate that the existence of extensive job training in a mine is one factor that will help reduce accidents. The detailed analysis of each of the factors for the Pittsburgh Seam along with national comparisons is given in Chapter 4. A brief summary of the empirical findings about the accident factors analyzed in the non-fatal accidents from 1966-1971 for 15 mines in the Pittsburgh Seam follow.

Type of Accident: Roof rib and face falls are the most frequent cause of non-fatal accidents in the Pittsburgh Seam (30.7%), followed by haulage (30.0%), machinery (14.2%) and materials handling (8.8%) accidents. This is in considerable contrast to the mix of accident types for all the United States, where in 1971 material handling accidents (27.0%) ranked first, followed by haulage (17.6%), machinery (16.7%), and then roof rib and face falls (16.5%). As explained in this report, part of this deviation represents distortions in accident reporting practices; however, significant control over equipment accidents have been achieved in the Pittsburgh Seam.

Most Frequent Job Category in Accidents: Roof bolters are the job category most frequently involved in accidents in the Pittsburgh Seam (23.0%), followed by shuttle car operators (10.4%) and motormen (9.5%). For all the United States in 1971, roof bolters (15.5%) and shuttle car operators (11.3%) occupied first and second place for accidents, followed by laborers (11.0%).

Most Accident Prone Job Category: A study of the average accident rate per year by job category per 1000 workers for all types of accidents in the Pittsburgh Seam reveals the following statistics: loading machine operators (28 per 1000) ranked first, followed by roof bolters (24 per 1000), shuttle car operators (15 per 1000) and then laborers (14.9 per 1000). For all the United States in 1971, roof bolters (100 per 1000) ranked first, followed by loading machine operator (83 per 1000), shotfires (65 per 1000) and timberman (64 per 1000).

Victim Doing and Job Substitution: In the Pittsburgh Seam, most accidents occurred while the victim was drilling the roof (7.7%). This was followed by coupling and uncoupling mine cars (6.1%), operating machine haulage equipment and setting props (4.3%). These activities are in line with those expected from roof bolters and motormen. However, 33% of the shuttle car operators were injured in activities other than operating a shuttle car. This implies that a high degree of job substitution occurs in the mines and is likely a factor in accident occurrence. For example, 26% of the victims injured while drilling roofs were not classified as roof bolters and 33% of the miners injured while setting props were not timbermen (Exhibit 4-10). Considerable job substitution in a work crew occurs in mining to expedite production bottlenecks and to compensate for absenteeism. The amount of substitution practiced, however, does not seem sufficient to account for the high number of accidents involving substitution. Therefore, we believe that job substitution correlates with accident occurrence. Special studies measuring job substitution would resolve this question.

Job Experience: Job experience is definitely a predictive factor in accidents. For the Pittsburgh Seam, the data on injured men indicates that 1 in 14 (7.4%) of the injuries occurred during the first month on the job and 1 in 4 occurred in the first year on the job. The criticality of job inexperience in accidents is suggested by comparing the percentage of miners injured during their first year on the job (1966-71) with the percentage of miners who had less than a year of experience in a given job classification in 1972. 36.4% of injured roof bolters were injured in their first year on the job, but only 19.8% of roof bolters were in their first year on the job in 1972. Looking at the injuries occurring in the first month on the job offers even more dramatic evidence of the importance of job experience as a factor in accidents. 15.9% of the injured roof bolters were injured in their first month on the job, that is, nearly half of all the injuries that occurred to roof bolters with less than a year on the job (36.4%). And this compares to an expected average of 1.65% roof bolters with one month or less job experience in 1972. The table below summarizes our findings for the five most accident prone occupations.

PITTSBURGH SEAM JOB EXPERIENCE

	Less than 1 Year Experience		Less than 1 Month Experience	
Occupation	Injured Miners 1966-71	Pittsburgh Miners 1972	Injured Miners 1966-71	Pittsburgh Miners 1972
Roof Bolter	36.4%	19.8%	15.9%	1.65%
Shuttle Car Operator	28.5	19.6	11.4%	1.78
Loading Machine Operator	21.0	12.19	10.5	1.02
Motorman	20.0	12.35	2.5	1.03
Continuous Miner Operator	7.6	12.9	0	1.29

Data on coal miner job experience for all the United States is not available. However, we have established that about 30% of the miners in the United States changed their job classification at least once in 1970-71, and that 40-50% of all fatal accidents from 1966-1971 represent victims with less than 1 year of experience in that job classification. Our data strongly indicates the probability of having a fatal accident is greatest the first month on the job. For example, excluding mine fires and explosions, 9.4% of the fatal accident victims (1966-71) who were roof bolters had less than 1 month experience, but only about 3% of the roof bolters had less than 1 month experience in the 1970-71 period. Similar figures for timberman would be 14.3% versus 4%.

It is true that our job experience data in the Pittsburgh Seam and our national job mobility data do not correspond to the 1966-71 time period of the accidents. However, the job posting rules increasing job mobility became effective in 1968, and thus average job mobility for 1966-71 would likely be less than the figures we used. Hence, we believe our figures are conservative because a lower mobility implies a strong task inexperience effect.

Underground Experience: The average underground miner in the Pittsburgh Seam has 25 years of underground experience, but his current job experience is only 3 years. For all the miners in the United States, the average underground experience is 16 years. The percentage of injured miners having three years job experience or less is higher than the percentage of all miners having three years or less experience.

Age of Victims: The average age of injured miners in the Pittsburgh Seam is 50 years with the majority of miners in the 41-65 age bracket. For all the United States the age distribution of injured miners is more uniform, but contains a higher proportion of younger workers. A comparison of the age distribution of injured and non-injured miners in the United States shows that there is a greater tendency for younger workers to be injured than older workers. However, the severity of accidents for older workers is greater. This age difference may partially account for a lower accident rate for the Pittsburgh Seam, based on total industry data.

Time Factors: The occurrence of accidents is relatively independent of the month or day of the week. There is a slightly greater tendency for accidents to occur between the second to third and the sixth to seventh hour of work. Fewer accidents occur in the first or last hour of work, probably because the mantrips to the work place typically consume 20 to 30 minutes.

The time interval between accidents has no significant relationship to occurrence. There appears to be little evidence of miners' behavior being altered at the news of a serious accident or fatality and thereafter being more cautious or safe.

Absenteeism: No definite relationship was established between the level of absenteeism and accident rates. It was believed that absenteeism would affect the degree of job substitutions and the likelihood of inexperienced miners working at unfamiliar tasks. Only one out of eight mines for which absentee data was available exhibited a high degree of correlation between the level of absenteeism and the accident rate. We suggest that future research measure individual crew absenteeism on days-accidents-occurred versus non-accident-occurrence-days rather than the gross annual mine absenteeism figure used in this study.

Productivity: There was no definite relationship established between productivity and the accident rate within a mine, although for two of the eight mines, this relationship exhibited a fair degree of positive correlation.

Turnover and Job Posting: Turnover, based on the number of men hired and leaving a mine, also did not show any definite relationship to the accident rate. Nor did job posting (as we were able to measure it) show any definite relationship to the accident rate, based on the limited data available for the last two years. New job posting rules were introduced in late 1968 and did not show full momentum until 1971, and then rules changed again in the fall of 1971. Nevertheless, the non-fatal accident data in the Pittsburgh Seam (1966-71) and the fatal accident data in the United States (1966-71) indicate a higher rate of accidents occurring for men in new jobs during the first three or four months on the job. (See Job Experience above) This implies that either a reduction in job mobility or more job training, certification, and better supervision will be required to eliminate this problem.

This chapter has presented a summary of the findings of an analysis of accidents in the Pittsburgh Seam. Each of the factors examined will be discussed in more detail in Chapter 4, which also presents a graphical depiction of the findings.

ACCIDENT REPORT FORM

General Data

Mine ______________________ Company ______________________

County ______________________ State ______________________

USBM District ______________________ Subdistrict ______________________

Coal Seam ______________________ # Employees Underground ______________________

Shifts ____________ # Working Faces ____________ Overburden ____________

Production Days/Week ________ Daily Tons ________ Normal Face Crew Size ________

Specific Accident Data

Date __/__/____ Day of Week ________ Time ________ Shift ________

Shift Start Time ________ # of Fatals ________ # Injured ________

Type Accident ________ Days Lost ________ Part of Body Injured ________

Accident Location ______________________

Entry Width ________ Roof Height ________ Wet or Dry ________

Type of Roof ______________________ Type of Support ______________________

Victim Job Classification ______________________ Victim Age ______________________

Job Level ______________________ Total Experience Underground ______________________

Job Experience ______________________ Experience in This Mine ______________________

Victim Doing ______________________ Experience At This Task ______________________

Training For This Job? ______________________ Foreman Present? ______________________

Foreman Experience: Total Underground ________
This Mine Total ________
Foreman Total ________
Foreman This Mine ________

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF LABOR AND INDUSTRY
BUREAU OF WORKMEN'S COMPENSATION
HARRISBURG

EMPLOYER'S REPORT OF INDUSTRIAL INJURY COAL MINING

POLICY NUMBER

CASE NUMBER

APPENDIX 3-2

INSTRUCTIONS

Reports of industrial injuries must be filed with the Department of Labor and Industry within 48 hours for every injury resulting in death, and within 15 days after the date of injury for all other injuries covered by the Workmen's Compensation Act, except those resulting in disability continuing less than the day, shift or turn in which the injury was received. Every question must be answered fully. Copy of this report must be sent to the Mine Inspector of the district in which this mine is located and also to your insurance carrier.

EMPLOYER

1. Name of operating company (Employer) ....
2. Office address .... City .... State ....

MINE

3. Name of mine or plant ....
4. Location: State .... County .... Nearest town ....
5. Principal product or kind of coal produced ....
6. If mine, type of mine (underground or open cut) ....

TIME

7. Date of accident .... Hour .... m. 8. Hour employee began work ....m
9. Date disability began .... Hour of day .... m

INJURED EMPLOYEE

10 Name .... Address .... Soc. Sec. No. ....
11. Age .... Sex .... Check: Single .... Married ....
12. Number of dependents: Wife .... Children .... Others ....
13. Occupation when injured .... Was this his regular occupation? ....
14. If not, what was his regular occupation? .... Wages per week $............
 (a) How long employed by you at this occupation? .... (b) Total experience at this occupation? .... (c) Total experience in coal mines? ....

PLACE

15. Did accident occur on company property? ....
16. If at mine, did accident occur underground? .... Open-cut .... Surface............
17. If underground, state whether in shaft, slope, entry, room, breast, etc. ....
18. If surface, state whether at tipple, breaker, tramline, power plant, shops, etc. ....
19. If underground, state whether working in pillar or solid .... Pitch or flat ....
20. If injured by cars state whether on slope, entry, room, etc. ....

CAUSE

21. What was injured person doing when accident occurred? ....
22. Describe fully how accident occurred ....
23. Name of machine, tool, object, or substance involved ....
24. Kind of power used by above machine .... 25. Part of machine on which injury occurred .... 26. Was machine or any part of it defective? ....

NATURE AND LOCATION OF INJURY

27. State whether fracture, amputation, laceration, bruise, strain, sprain, crushing injury, etc. ....
28. Part of body injured (head, right arm, left eye, great toe on left foot, index finger on right hand, etc.).... .... 29. If amputation, state part of body lost ....

RETURN TO DUTY Length of Disability

30. Date physically able to return to work .... Date actually returned ....
31. If injured employee returned to work, did he return to the duties of his regular job, the job on which he was injured, or some other job (state which)............
32. Number of calendar days employee was disabled (not including day of accident) from all work .... from his regular work ....
33. Did injury result in death? .... If so, give date ....

PREVENTION

34. Was safety appliance or regulation provided? ....
35. Was accident caused by injured employee's failure to use or observe same? ....
36. Could accident have been prevented? .... If so, how? ....

37 Did the employe have the loss or loss of use of any member before accident? ....
(If so, describe the part of the body affected)

(Signed) ....
(Company official to whom correspondence should be addressed) (Official position) Date of this report)

DO NOT WRITE IN THIS COLUMN

EMPLOYER NO.
COUNTY
INDUSTRY
DATE
HOURS WORKED
AGE
CONJ. CONDITION AND SEX
DEPENDENCY
OCCUPATION
TIME EMPLOYED
WAGE
AGENCY
PART
ACCIDENT TYPE
UNSAFE ACT
MECH. DEFECT
PERSON DEFECT
NATURE
LOCATION
REPORT LAG
INSURANCE
DISABILITY
PAYMENT LAG
TIME LOST
WEEKS DAYS
COMP.
MEDICAL
OTHER
TOTAL
OCC. DIS. TYPE

INJURY DATA BASE CARD LAYOUT

Report Code
Company Code
Mine Code
Number of Underground Employees
Number of Shifts
Number of Work Faces
Average Overburden
Number of Production Days per Week
Average Tons Produced Per Day
Face Crew Size
Month of Accident
Day of Month
Year
Day of Week
Time of Accident
Start Time
Hours Worked Until Accident
Number of Fatalities
Number of Injured
Type of Accident
Days Lost
Part of Body Injured
Location of Accident
Entry Width
Roof Height
Wet or Dry
Roof Type
Type of Support
Victim Job Classification
Victim Age
Job Level
Total Underground Experience
Job Experience
This Mine Experience
Victim Doing At Time of Accident
Task Experience
Injury Type
Foreman Present
Job Substitution

CONFIDENTIAL

COMPANY__________________

MINE NAME__________________

BACKGROUND DATA FOR THE YEAR:_____
Accident Cause and Prevention Study for the Bureau of Mines by Theodore Barry and Associates.

	Number of men employed during year	Number of men leaving mine during year	Number of men hired during year	Absenteeism in days lost, including vacations, etc.	Number of jobs posted	Man hours worked during year	Number of lost time injuries	Number of fatalities
Shuttle Car Operator								
Roof Bolter								
Continuous Miner Operator								
Continuous Miner Helper								
Loading M/C Operator								
Loading M/C Helper								
Cutting M/C Operator								
Cutting M/C Helper								
Repairman								
Motorman								
Brakeman								
Trackman								
Timberman								
Hand Loader								
General Laborer								
Foreman/Mine Foreman								
Other Underground								
TOTAL								

CONFIDENTIAL

COMPANY ____________________

MINE NAME ____________________

NUMBER OF MEN IN EACH AGE CATEGORY FOR YEAR: ________
Accident Cause and Prevention Study for the Bureau of Mines by Theodore Barry and Associates.

	Under 25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	Over 65
Shuttle Car Operator										
Roof Bolter										
Continuous Miner Operator										
Continuous Miner Helper										
Loading M/C Operator										
Loading M/C Helper										
Cutting M/C Operator										
Cutting M/C Helper										
Repairman										
Motorman										
Brakeman										
Trackman										
Timberman										
Hand Loader										
General Laborer										
Foreman/Mine Foreman										
Other Underground										
TOTAL										

CONFIDENTIAL

COMPANY ____________________

MINE NAME ____________________

TASK EXPERIENCE FOR THE YEAR: _____
Accident Cause and Prevention Study for the Bureau of Mines by Theodore Barry and Associates.

	0-1 Month	2-3 Months	4-6 Months	7-11 Months	12-18 Months	19-23 Months	2 Years	3-4 Years	5-15 Years	15+ Years
Shuttle Car Operator										
Roof Bolter										
Continuous Miner Operator										
Continuous Miner Helper										
Loading M/C Operator										
Loading M/C Helper										
Cutting M/C Operator										
Cutting M/C Helper										
Repairman										
Motorman										
Brakeman										
Trackman										
Timberman										
Hand Loader										
General Laborer										
Foreman/Mine Foreman										
Other Underground										
TOTAL										

COMPANY ____________________

MINE NAME ____________________

COAL PRODUCTION

Accident Cause and Prevention Study for the Bureau of Mines by Theodore Barry and Associates.

Year	Tons Produced	Shifts Worked Per Day	Days Worked Per Week	Weeks Worked Per Year
1971				
1970				
1969				
1968				
1967				
1966				

COMPANY ________________

MINE NAME ________________

EQUIPMENT SURVEY
Accident Cause and Prevention Study for the
Bureau of Mines by Theodore Barry and Associates.

Type	Manufacturer	Total # in use	Average Age or Dates Purchased
Shuttle car			
Continuous miner			
Undercutting m/c			
Roof bolting m/c			
Loading m/c			
Face drill			
Tractor			
Locomotive			
Other			

CONFIDENTIAL

JOB EXPERIENCE SURVEY

Roog Bolters, Shuttle Car Operators, Loading Machine Operators, and Continuous Miner Operators

ine:__________ Foreman:__________ Section:__________ Shift:__________ Date:______

ame of Miner or D. Number	Job Classification	Age	Experience in present job in months*	Total underground mine experience in years	Number of job changes as an underground miner

lote: If experience is under one month, please indicate number of days experience.

CHAPTER 4

RESULTS OF THE ANALYSIS OF PITTSBURGH SEAM VERSUS ALL UNDERGROUND ACCIDENTS

Chapter 3 presented a brief review of our Accident Analysis in the Pittsburgh Seam. This chapter presents the detailed findings of the analysis. A total of 443 accidents occurring from 1966 through 1971 have been examined along with over 10 major factors. Appendix 4-1 gives a partial frequency tabulation of the factors involved in each accidents. Each of the factors, including type of accident, job category, victim doing at time of accident, and job experience, is discussed in the sections which follow. Whenever possible comparisons are made with the available national accident data. Note that this chapter gives special emphasis to normalizing accident miners' occupations, ages, job experience, and job mobility--data that has never heretofore been published.

TYPE OF ACCIDENT

The type of accident category was divided into 24 classifications. These are an extension of the 19 main groups of descriptive causes covering the hazards of daily work that was developed by the Bureau of Mines through many years of analyzing descriptions of accidents resulting in injuries. Five additional classifications that are subgroups of the original 19 were developed by Theodore Barry and Associates to meet the special needs of this study. Three of the additional classifications distinguish between different types of haulage accidents, and the remaining two are additional subgroups of the material handling and explosion categories. They were developed to facilitate immediate identification of these accident categories.

Exhibit 4-1 shows that roof falls constitute the major type of non-fatal injury, followed by main-line haulage, machinery and materials handling. Other minor categories then follow. For the complete classification, the reader is referred to the frequency distribution in Appendix 4-1.

Combining the roof, rib and face falls, and all the haulage-type accidents gives the distribution as shown in Exhibit 4-2. This is directly comparable to the national classification of types of accident shown in Exhibit 4-3. Note that for the Pittsburgh Seam, the roof, rib and face falls are the number one type of accident, 30.7%, very closely followed by haulage-type accidents at 30.0%. Then follows machinery accidents, 14.2%, and material handling accidents at 8.8%. This is very nearly in the reverse order from national accidents, where materials handling accidents form the major cause of accidents and roof, rib and face falls are ranked fourth. There are two possible reasons for the reversal in accident types between the Pittsburgh Seam and the overall national picture. The first is that mines in the Pittsburgh Seam are generally large, well managed and highly mechanized. This could contribute to reducing material handling type accidents. The second reason is that many mines in the Pittsburgh Seam have difficult roof problems, and combined with the reduction in other types of accident, roof falls become the most prevalent type. Note that the reported accident frequency rate for the mines studied in the Pittsburgh Seam is 5.9 per million manhours in 1971. The national accident frequency rate for 1971 was 50.75 per million man-hours, nearly 9 times higher. The complete classification of national accident types is shown in Exhibit 4-4.

Exhibit 4-5 shows the changes in the top four national accident categories between 1966 and 1971. These are some significant changes. In 1971 material handling ranked as the major cause; 27% of the national accidents fell into the category. In 1966 material handling ranked second. This indicates a 31.7% increase in the proportion of material handling accidents over the six-year period.

Haulage accidents ranked second in 1971, causing 17.6% of all accidents. In 1966 it ranked third, although the proportion of haulage accidents to all accidents was greater in 1966 than in 1971.

Machinery accidents ranked third in 1971. In 1966 they ranked fourth. This category has remained practically constant over the six years at 16.7% of all national accidents.

Falls of roof, face and rib ranked fourth at 16.5% of all accidents in 1971 in contrast to first position in 1966. This represents a 20.2% decrease in the proportion of roof, face and rib fall accidents.

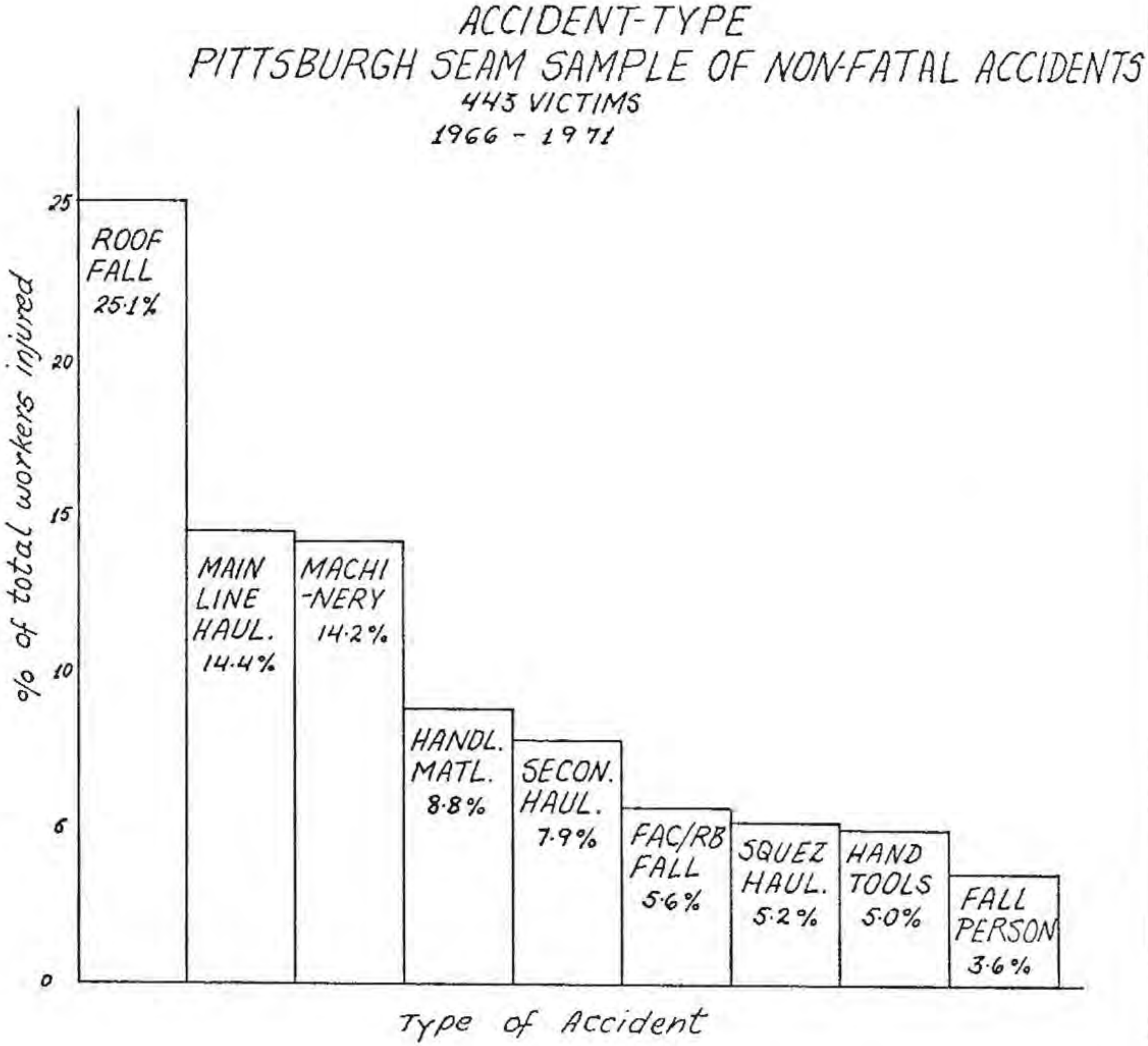
A similar study of the change in rankings of accidents in the Pittsburgh Seam would not be valid because of the small sample size involved. If responses could be obtained from all mines in the Pittsburgh Seam, such an analysis could be undertaken.

Cross-tabulating the type of accident by the victim's job classification gives an indication of the likely type of accident associated with each occupation. For example, 54.9% of the injured roof bolters, 56.0% of the injured loading machine operators and 57.1% of the injured continuous miner operators were injured by roof, rib and face falls.

On the other hand, only 43.5% of the shuttle car operators were injured in haulage accidents. However, 47.8% of the foremen and 30.7% of the general laborers were injured in haulage accidents. These percentages could indicate job substitution situations. Further indications of job substitution are discussed in the following section which shows what the victim was doing at the time of the accident.

JOB CATEGORIES

The eleven job classifications most frequently involved in accidents are shown in Exhibit 4-6. The normalized data on job category is shown in Exhibit 4-7. This shows the number of accidents occurring for each 1000 miners in the job category and can be interpreted as probability rates for each occupation.

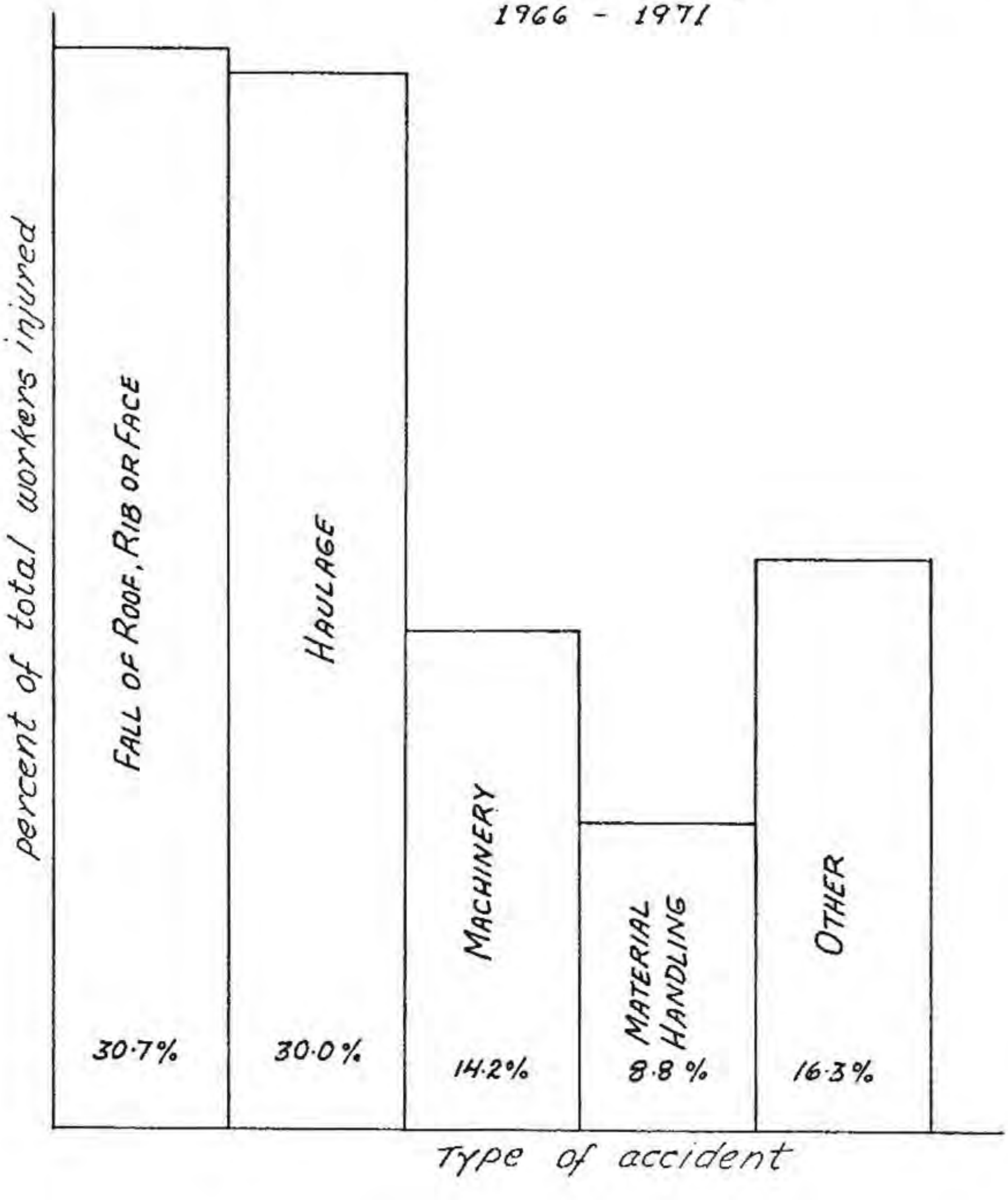


PREPARED BY THEODORE BARRY AND ASSOCIATES

ACCIDENT TYPE FOR THE PITTSBURGH SEAM SHOWING THE FOUR MAJOR TYPES OF ACCIDENT

443 ACCIDENTS

1966 - 1971

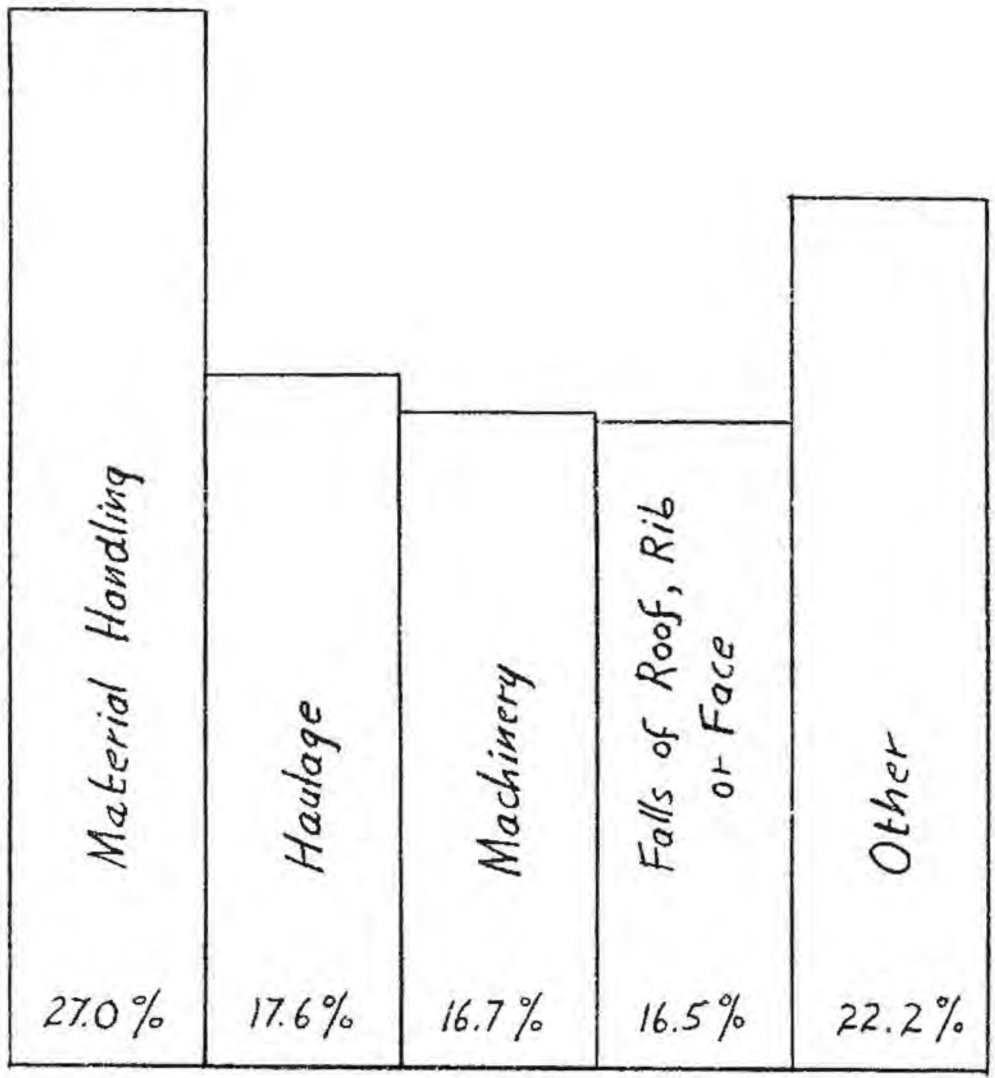


PREPARED BY THEODORE BARRY AND ASSOCIATES

Underground Bituminous Coal Mines in the U.S.A.

THE FOUR MAJOR ACCIDENT TYPES

IN 1971

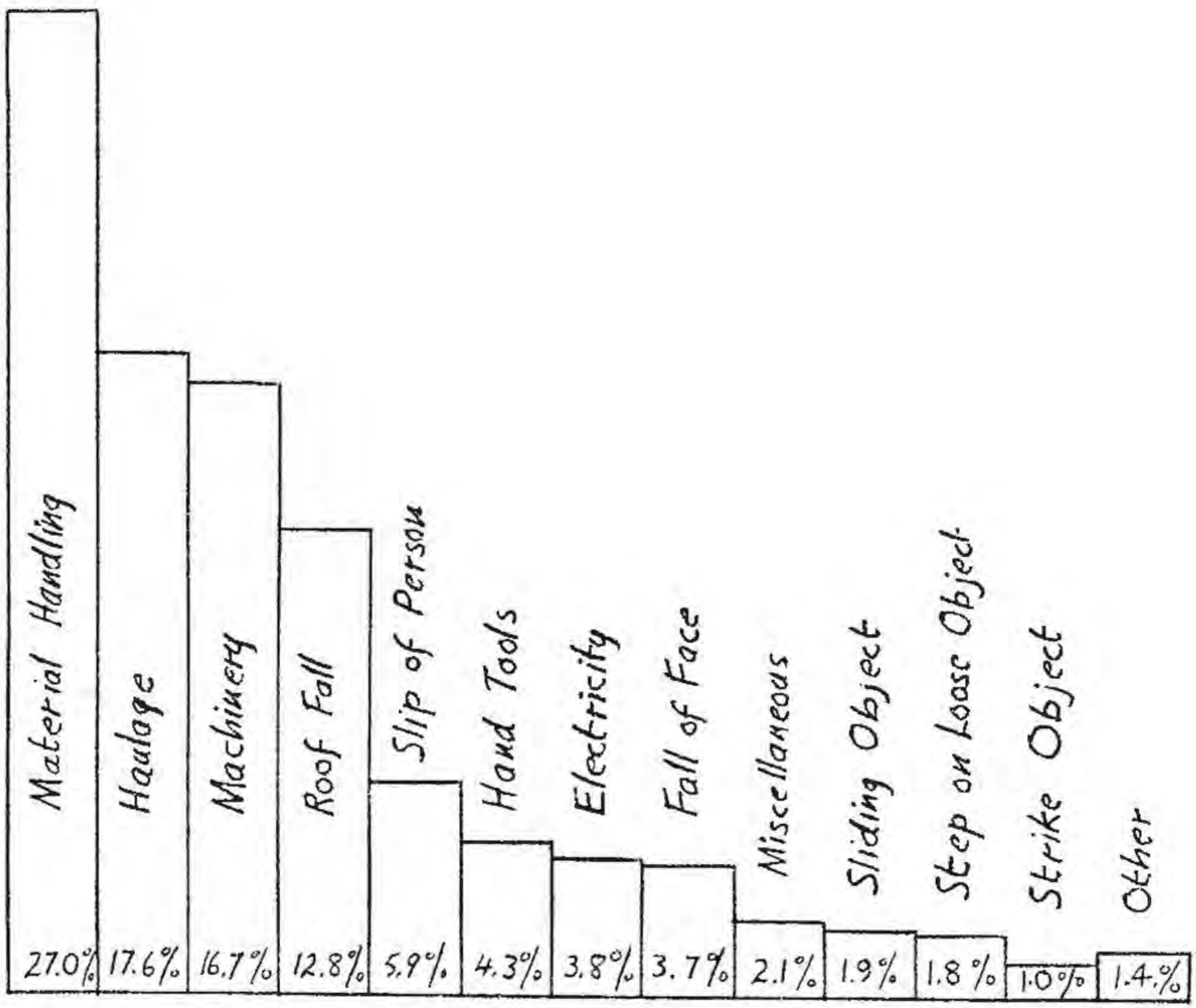


PREPARED BY THEODORE BARRY AND ASSOCIATES

Underground Bituminous Coal Mines in the U.S.A.

ACCIDENT TYPE

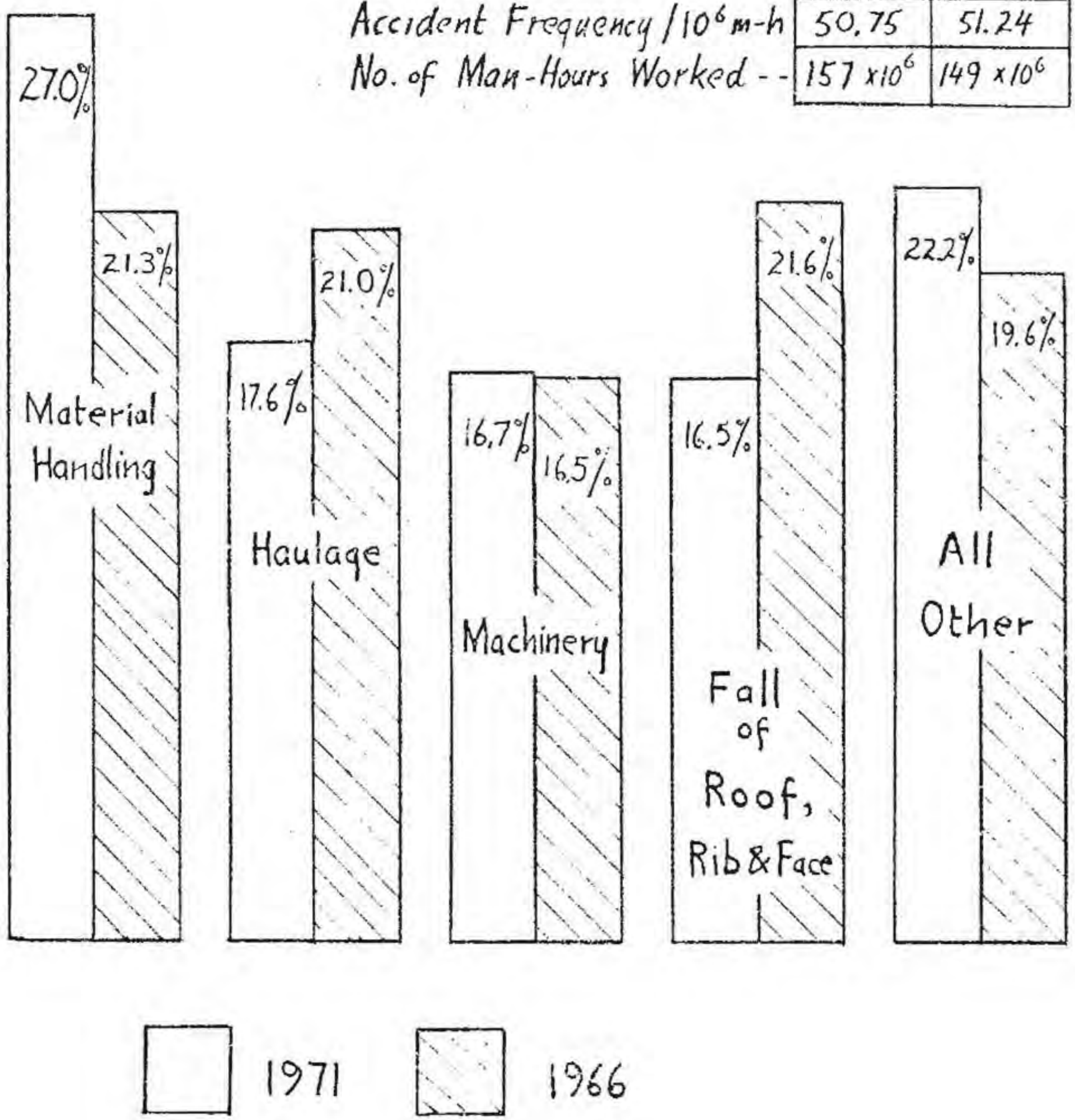
1971



PREPARED BY THEODORE BARRY AND ASSOCIATES

Underground Bituminous Coal Mines in the U.S.A.
TYPE OF ACCIDENT
COMPARISON BETWEEN INJURY DATA, 1966 & 1971

	1971	1966
No. of Injuries	7,979	7,659
No. of Fatals	106	189
No. of Non-Fatals	7,873	7,470
Accident Frequency / 10^6 m-h	50.75	51.24
No. of Man-Hours Worked	157×10^6	149×10^6



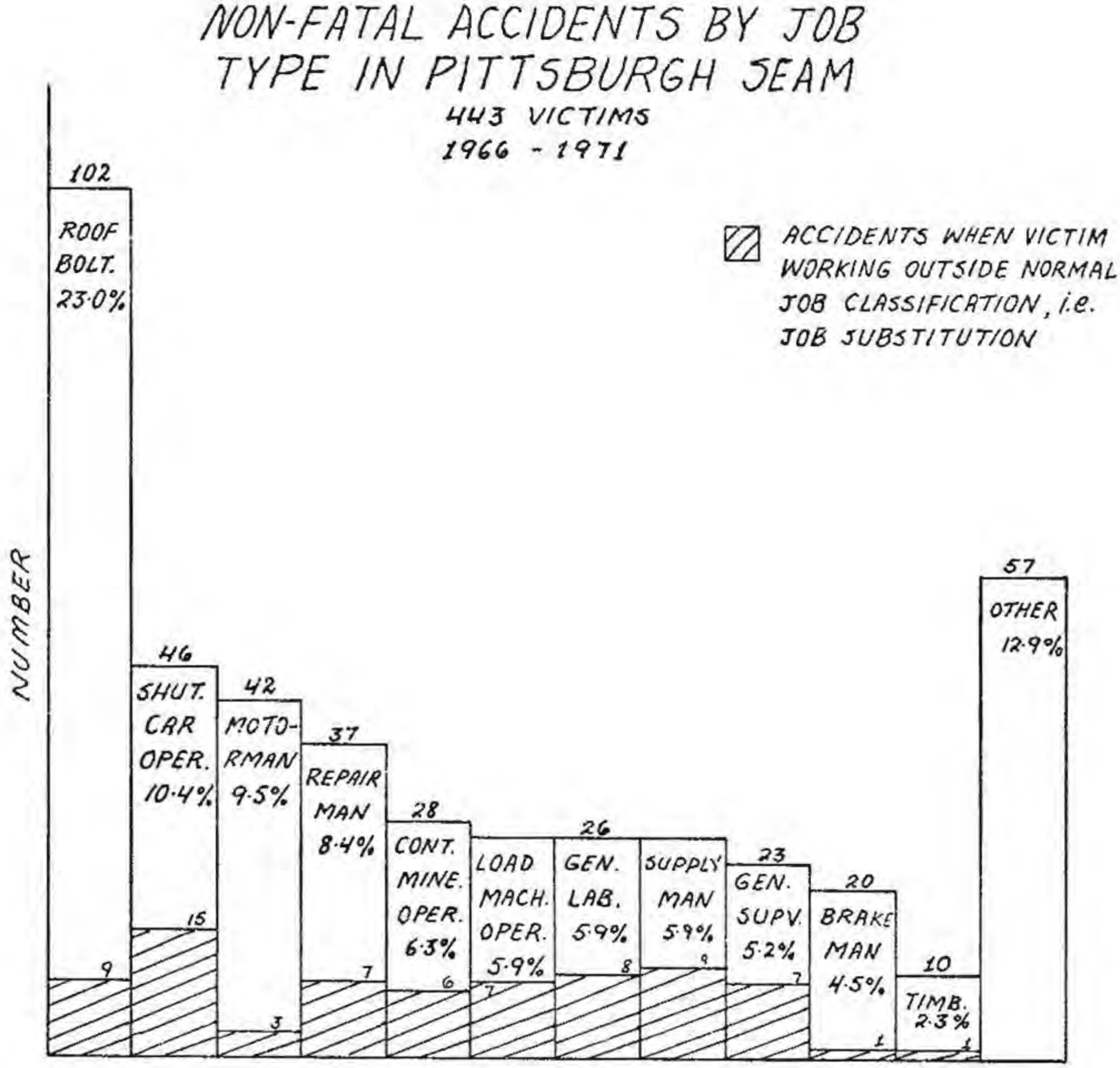
PREPARED BY THEODORE BARRY AND ASSOCIATES

An examination of Exhibit 4-6 shows that the roof bolter is the job classification most frequently involved in accidents, followed by the shuttle car operator and motorman. The repairman or mechanic occupies fourth position. The shaded area at the foot of the graph is an indication of possible job substitution--an accident occurred when the victim was working outside his normal job classification. Note that 9 out of 102 roof bolters were injured while working at a job other than roof bolting, and that 15 out of 46 shuttle operators were injured while not operating a shuttle car.

The normalized data in Exhibit 4-7 shows some most revealing changes in the ranking of occupations. Roof bolter drops to second place and loading machine operator advances to first place from fifth in Exhibit 4-6. This indicates that the number of accidents occurring per 1000 loading machine operators is greater than for the other occupations in the Pittsburgh Seam, although the total number of loading machine operators injured each year is not as great as the total number of roof bolters injured.

The normalized data on job categories for the whole U.S.A. is shown in Exhibit 4-8. This is somewhat similar to the Pittsburgh Seam normalized data. Roof bolter takes first place and loading machine operator drops back to second place. A few job categories show big changes in their rank position. Timbermen are in the upper quartile while motormen are in the lower quartile for the national data. This order is reversed for the Pittsburgh Seam. The reasons for this lie in the realm of speculation.

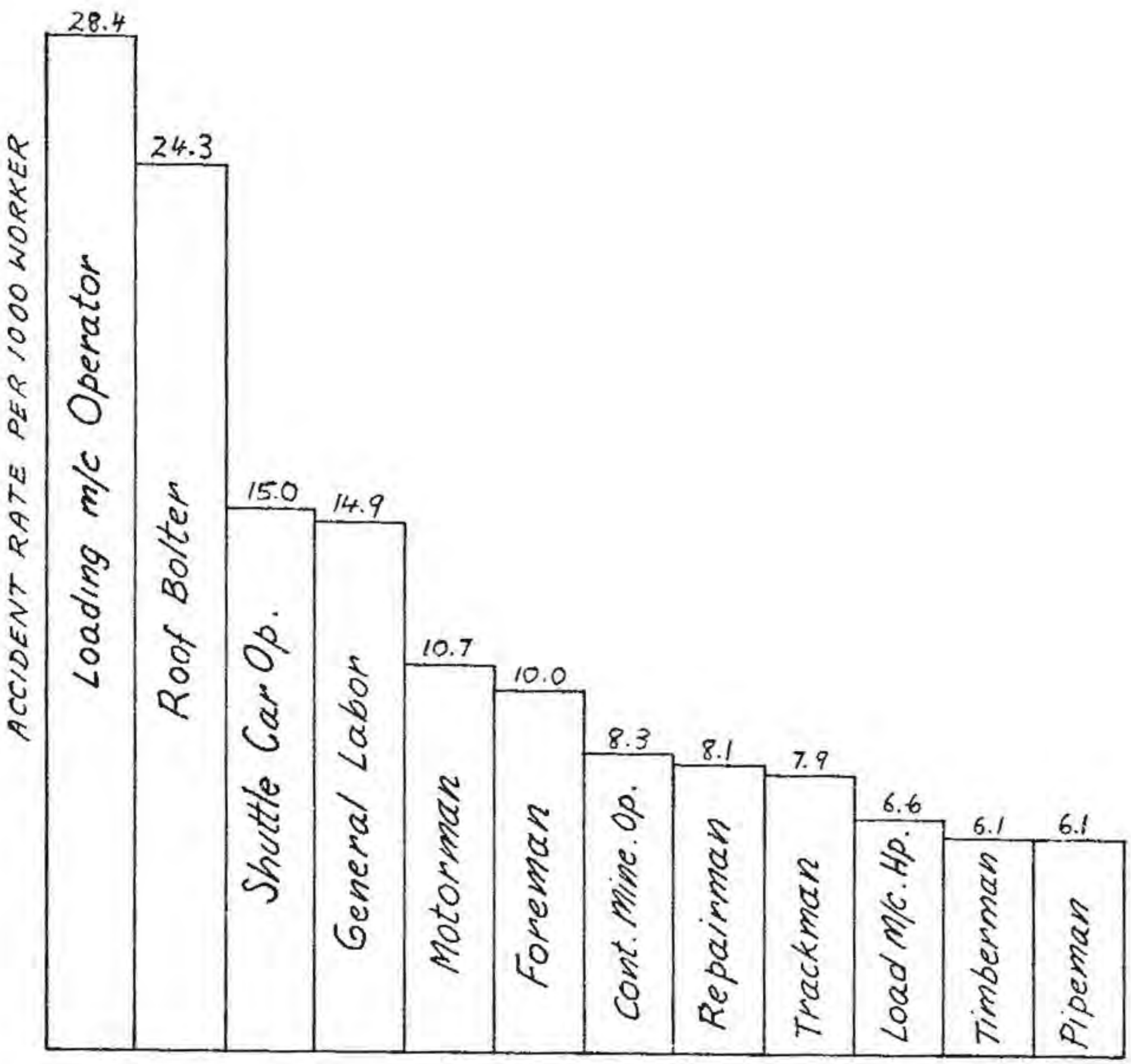
Positive roof support and the many rail transportation systems used in the Pittsburgh Seam may have a bearing on this reversal. Note that the number of accidents per 1000 workers is much higher for the national data than for the Pittsburgh Seam, which reflects the lower accident frequency rates for the Pittsburgh Seam in general.



PREPARED BY THEODORE BARRY AND ASSOCIATES

AVERAGE ACCIDENT RATE PER YEAR BY JOB CATEGORY PER 1,000 WORKERS

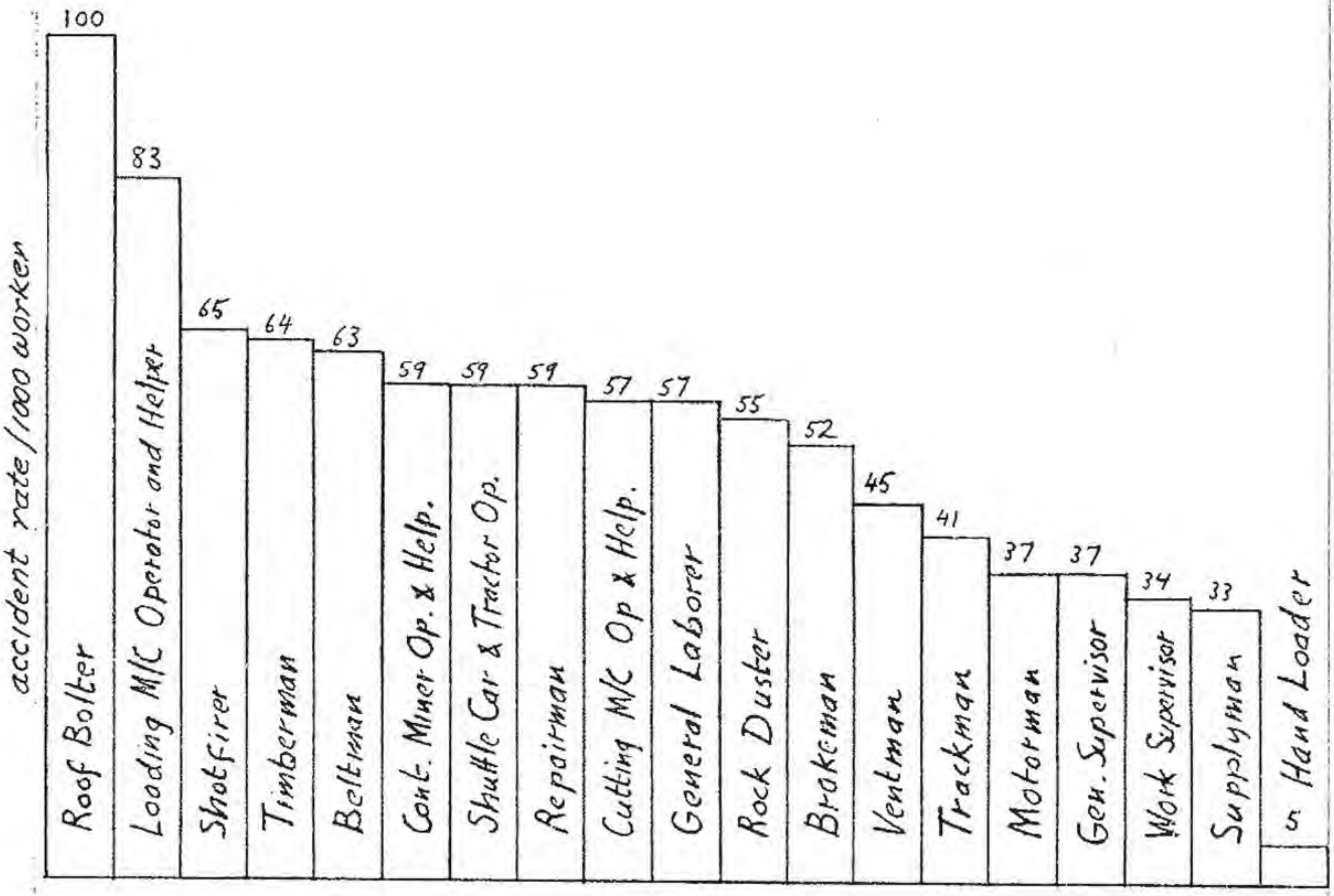
Pittsburgh Seam - 1966 to 1971



PREPARED BY THEODORE BARRY AND ASSOCIATES

Underground Bituminous Mines in the U.S.A.

AVERAGE ACCIDENT RATE FOR 1971
BY JOB CATEGORY PER 1,000 WORKERS



PREPARED BY THEODORE BARRY AND ASSOCIATES

VICTIM DOING

An analysis of what the victim was doing at the time of the accident is informative insofar as it reveals those activities in the work cycle that are most likely to contribute to accidents. When coupled with the victim's occupation, the victim-doing analysis is most informative in revealing possible job substitution situations.

A list of the 21 top ranked victim activities, out of 90 different classifications, is shown in Exhibit 4-9. This shows the percentage of accidents occurring in each category together with the actual count. The full listing of victim activities is shown in Appendix 4-1. Note the high incidence of accidents associated with roof control, viz: drill roof, set props, scale roof, insert bolt, relocate prop and roof bolt. The category of walking to or from the work location is also high on the list. Cases where it is possible to determine the presence of job substitution are shown in Exhibit 4-10. For example, it would normally be expected that a roof bolter would drill the roof. Of the 34 accidents where the injured victim was drilling the roof, 25 involved roof bolters. This implies that 9 of the accidents happened to men other than roof bolters who were substituting for roof bolters.

Accidents involving the operation of a shuttle car show that 30.8% of the victims were not shuttle car operators. Thirty-three and one third percent (33-1/3%) of the machine maintenance accidents happened to men other than mechanics. Twenty-six and one half percent (26-1/2%) of the drilling roof accidents happened to men other than roof bolters.

Job substitution problems, implied from the percentages above, are illustrated by the following percentages of the job classifications that were involved in job tasks other than their own regular job when the accident occurred:

- General Laborers - 68.9%
- General Supervisors - 34.6% (involved in performing production jobs)
- Shuttle Car Operators - 30.5%
- Loader Operators - 23.0%

As one can observe from the foregoing figures, job substitution does seem to be a very important factor for non-fatal injury accidents in the Pittsburgh Seam. One can certainly argue that there is a great deal of interchange on jobs in mining. However, we feel that it is significant that such a high percentage of the accidents involve job substitution. It is not likely that many of these workers in any of the job classifications spend as high a percentage of their time performing tasks outside their normal job as is reflected in the accidents.

EXHIBIT 4-9

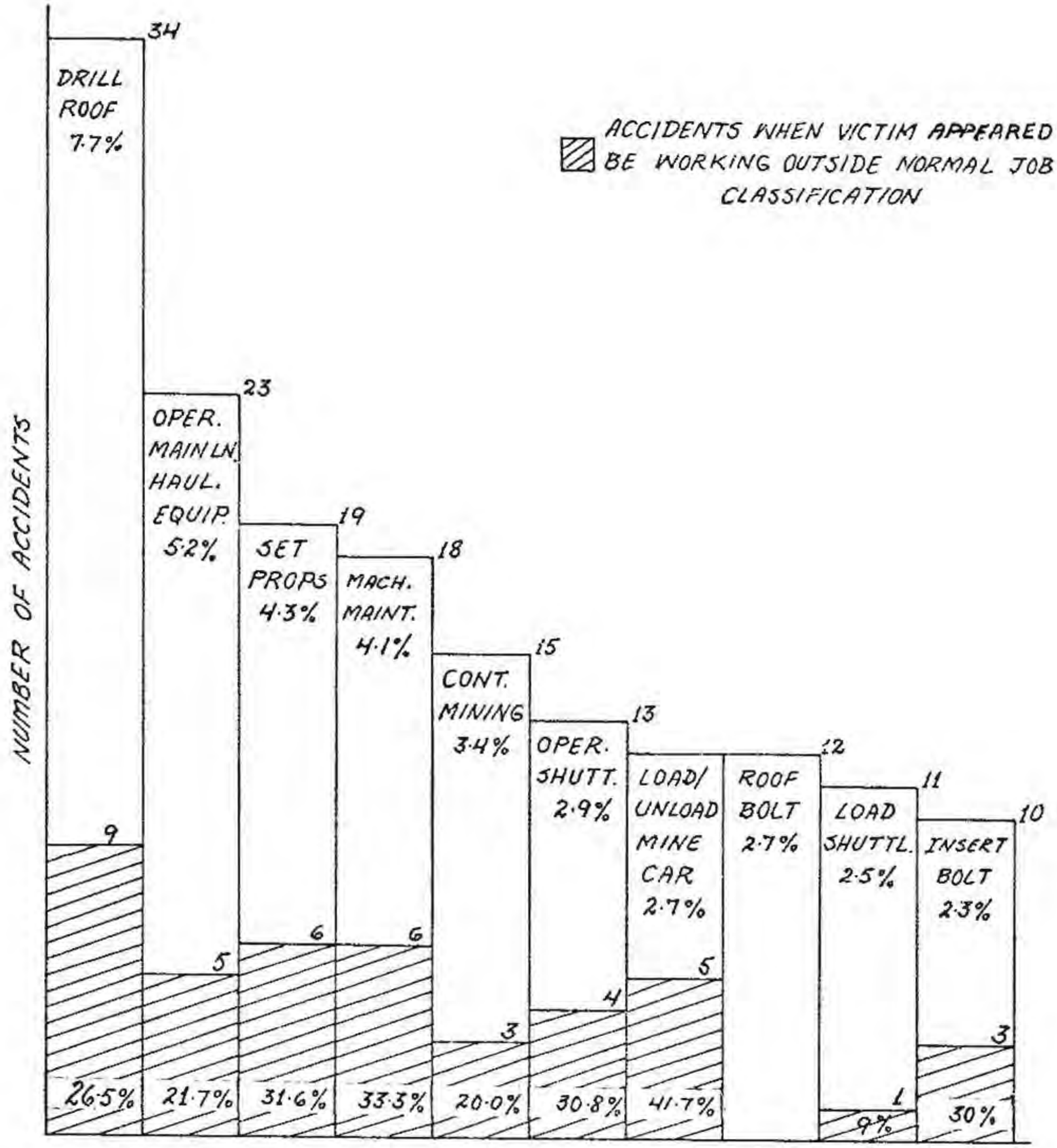
PITTSBURGH SEAM
VICTIM ACTIVITIES

Top 21 ranked in descending
order of frequency

Victim Doing	Frequency (%)	Actual Count
Drill Roof	7.7	34
Couple/Uncouple Mine Cars	6.1	27
Op. Mainline Haulage Equipt.	5.2	23
Set Props	4.3	19
Position Equipment	4.1	18
Machine Maintenance	4.1	18
Walk To/From Work	4.1	18
Continuous Mine	3.4	15
Tram In/Out	3.4	15
Transport Supplies	2.9	13
Operate Shuttle	2.9	13
Load/Unload Mine Car	2.7	12
Bolt Roof	2.7	12
Load Shuttle	2.5	11
Move Cables	2.5	11
Scale Roof	2.5	11
Insert Bolt	2.3	10
Service Machine	2.0	9
Remove Props	2.0	9
Lay Track	2.0	9
Ride Equipment	2.0	9

EXHIBIT 4-10

VICTIM DOING ACTIVITIES AND APPARENT CASES OF JOB SUBSTITUTION IN PITTSBURGH SEAM



PREPARED BY THEODORE BARRY AND ASSOCIATES

JOB EXPERIENCE

Workers in underground coal mines traditionally enter at the unskilled or laborer level and work their way into more skilled job classifications. They learn their skills through "on-the job" training and develop their ability to operate complicated machinery at lunch time breaks or at other slack periods. All this leads to a fair degree of job mobility or turnover as workers progress from one job to another. When a worker starts in a new job his experience is often very limited. By the time he has gained proficiency and several years' job experience, it is probable that the worker will move to another job. In the Pittsburgh Seam roughly 20% of the workers will be in their first year on the job (nationally it is between 30% and 40%). This does not mean that their total underground experience is so limited. On the contrary, the average underground mine experience of miners in the Pittsburgh Seam is 25 years (nationally it is 16 years), while their average age is 50 years (nationally it is 40 years). Thus the miner with many years of underground experience will not necessarily have many years of job experience.

The job experience of injured miners at the time of accident in the Pittsburgh Seam is shown in Exhibit 4-11. This indicates that 27.8% of the accident victims have one year or less job experience and 7.4% of the victims have one month or less job experience. Similar graphs showing the job experience of the five occupations showing the highest probability of accident are given in Exhibits 4-12 and 4-13. These were loading machine operators, roof bolters, shuttle car operators, motormen and continuous miner operators. The exponential nature of all the job experience curves by both month and year tends to indicate an accident avoidance learning curve phenomena on the part of miners: the greater the job experience, the less likelihood of an accident. However, this hypothesis can not be proven until the total job experience of all miners is known. Then, if there is significant difference between the job experience curve of injured miners and the other miners, it may be possible to state that the more experienced miners have a tendency to avoid accidents.

To obtain complete data on all the miners in each mine in the Pittsburgh Seam would present a formidable and time-consuming task. In order to collect some representative data on job experience and meet the time constraints of this report, it was decided to survey only the miners in the above 5 occupations. Their graphs of job experience are shown in Exhibits 4-14, 4-15, and 4-16. Note that the greatest percentage of miners change their job in the first year, and that after 5 years the job experience distribution remains fairly constant. This could appear to indicate that once a miner has been on the same job for 5 years, the probability of his moving to another job decreases and he is likely to stay in the same job for the next 5 years, and so on, until he retires.

The table below compares the job experience of injured miners and all miners for the five surveyed occupations for the first month and first year of job experience.

PITTSBURGH SEAM JOB EXPERIENCE

Occupation	Less than 1 Year Experience		Less than 1 Month Experience	
	Injured Miners 1966-1971	All Miners 1972	Injured Miners 1966-1971	All Miners 1972
Roof Bolter	36.4%	19.8%	15.9%	1.65%*
Shuttle Car Operator	28.5	19.6	11.4	1.78
Loading Machine Operator	21.0	12.19	10.5	1.02*
Motorman	20.0	12.35+	2.5	1.03*
Continuous Miner Operator	7.6	12.9+	0	1.29
Above Occupations Combined	26.9	16.0	10.1	1.33
All Injured Miners	27.8	--	7.4	--

* Computed from annual percentage, e.g., for roof bolter, 19.8/12 = 1.65%

\+ Second year rate as the first year rate for 1972 is less. Men in their second year in 1972 would have been in their first year in 1971. The data on injured miners covered the period 1966 to 1971.

It is immediately apparent from the above table that the proportion of injured workers who are injured in their first month or first year of job experience is significantly greater than the number of miners who have only one month or one year of job experience. The one exception is in the case of continuous miner operators, and this is probably due to the small sample size. Only two out of 26 injured continuous miner operators had one year or less of job experience.

National data on the job experience of non-fatally injured miners is not available. However, a similar pattern is found in the case of fatal accidents for the whole U.S.A. The number killed in their first month or first year of job experience is greater than the national population having one month or one year job experience. The following table illustrates the case.

JOB EXPERIENCE OF FATAL ACCIDENT VICTIMS
1966 - 1971

Occupation	First Month (%)	First Year (%)
Roof Bolter	9.4	46.9
Shuttle Car Operator	7.0	30.2
Motorman	2.5	17.0
Loading Machine Operator	6.1	26.1
Continuous Miner Operator	11.4	35.2
Above Occupations Combined	6.7	31.8
All Occupations	7.8	37.9

Note that nearly 16% of the roof bolters were injured in their first month on the job and 9% were killed in their first month. The first month and the first year seem to be the most dangerous. And, although the turnover in mining jobs is high, injuries in the first month and first year are proportionately higher than the number of men in their first month or first year of experience. This may represent a form of accident avoidance learning. As experience is gained, the propensity for accidents decreases.

Although figures on the job experience of all miners in the United States are not available to permit normalization on a national scale, it is possible to calculate the number of miners who change their job each year. This gives an indication of job mobility since first year job mobility and job experience may be considered nearly analogous. A man who changes his occupation every year can only accumulate one year of job experience at any given occupation, unless he returns to one of his previous occupations within a relatively short time period. Under these circumstances the calculations of national job mobility from the employee history file may be considered a first approximation to national job experience, although possibly on the high side. The method of calculating job mobility from the employee history file is discussed in Appendix 4-2.

Although the national figure for the number of miners in their first year on the job (between 30% and 40%) is higher than for the Pittsburgh Seam (nearly 20%), it seems reasonable to suppose that the national job experience distribution is similar to that for the Pittsburgh Seam shown in Exhibit 4-14. Indeed, as can be seen from Exhibit 4-17, this is the case.

The occupations listed in Exhibit 4-17 are ranked in order of decreasing mobility. A few occupations occupy some unexpected positions. Roof bolters, commonly considered to be one of the least desirable occupations, and showing the highest non-fatal injury rate, are in the lower half of the table. Similarly, the occupation of laborer is third from the bottom while that of the foreman is sixth from the top. Motormen are one of the job classifications showing the least job mobility.

In seven cases the data on job mobility has been corrected for movement between the same or similar occupations (indicated in Exhibit 4-17 by an asterisk). Such movement was recorded as an occupational change in the original employee history file and occurred when the timberman, beltman, laborer, electrician, mechanic, supply/utility and vent/brattice categories working at the face transferred to the same occupation away from the face and vice versa. Certain conditions surrounding the job do change, but it is believed that the basic skills stay the same. Appendix 4-3 lists the original mobility factors for the above occupations together with the correction factors.

For every occupation listed in Exhibit 4-17, the percentage of miners killed or injured in their first month on the job is higher than the percentage of miners who may be expected to be working in their first month on the job (based on job mobility calculations). Again, as in the case of the Pittsburgh Seam previously discussed, this would tend to indicate the presence of an accident avoidance learning curve. The greater the job experience, the less the probability of accident.

JOB EXPERIENCE OF ALL INJURED MINERS AT ACCIDENT TIME FOR PITTSBURGH SEAM

363 VICTIMS

1966 - 1971

PREPARED BY THEODORE BARRY AND ASSOCIATES

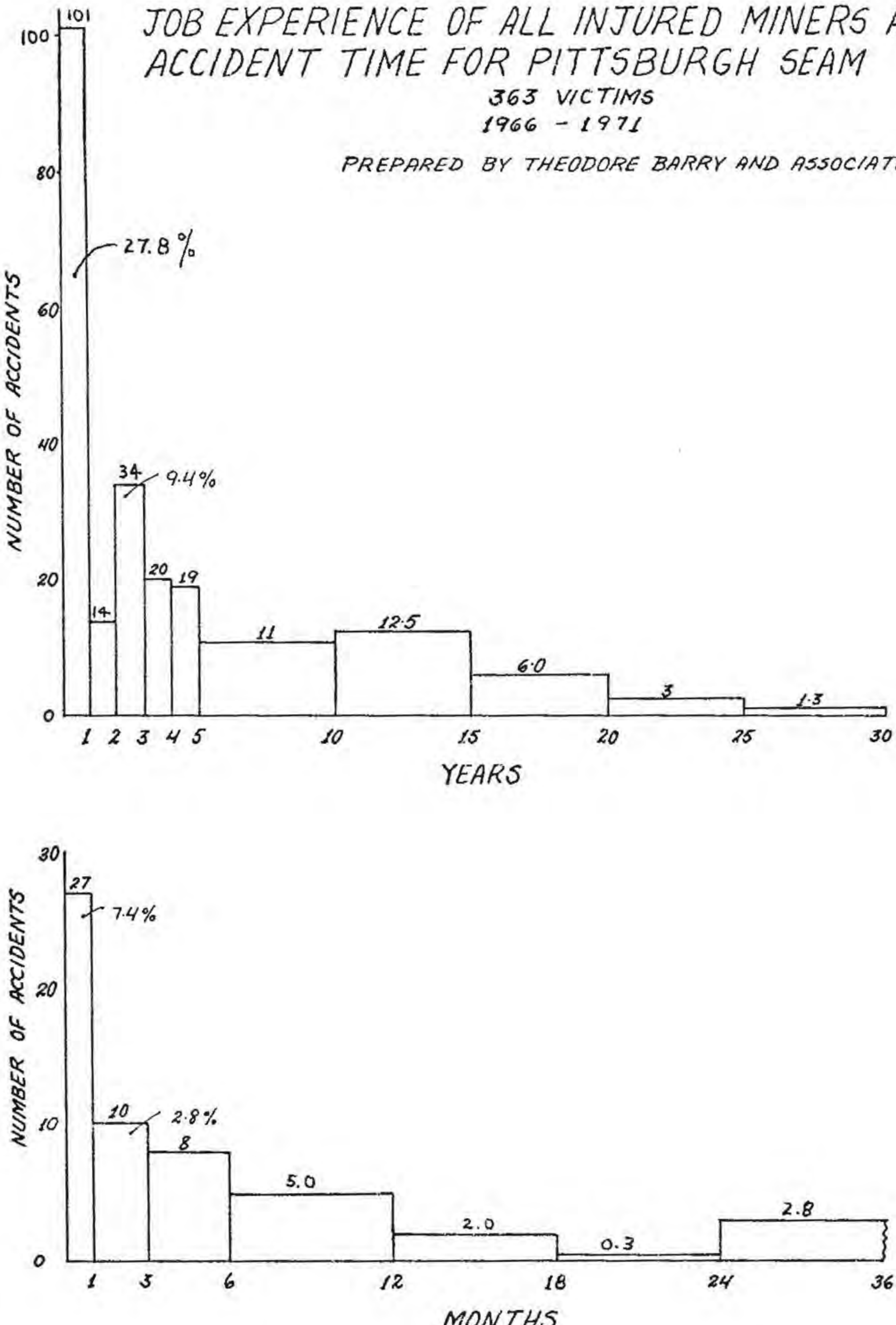
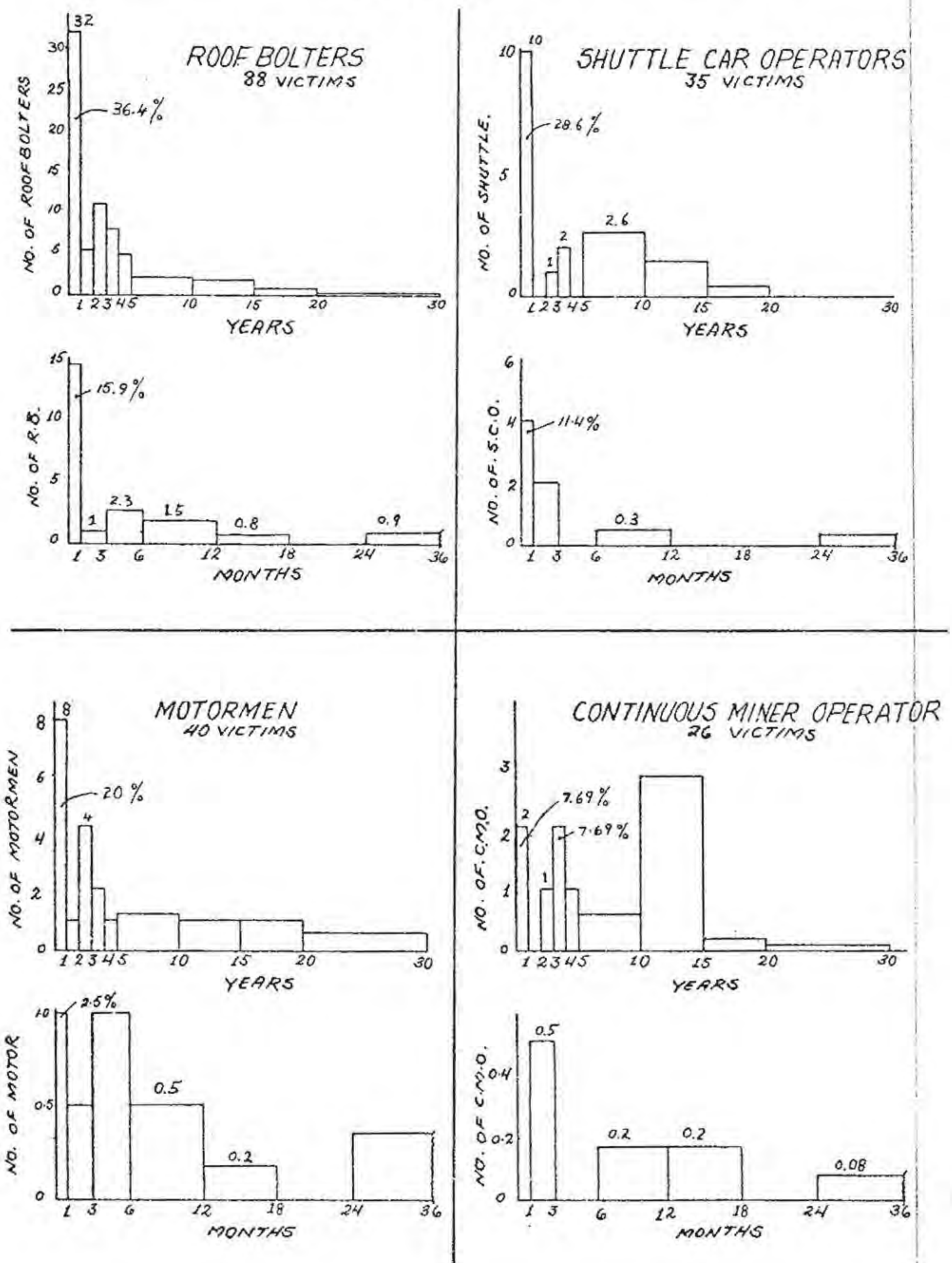


EXHIBIT 4-12

JOB EXPERIENCE OF INJURED MINERS AT ACCIDENT TIME FOR PITTSBURGH SEAM
1966 - 1971



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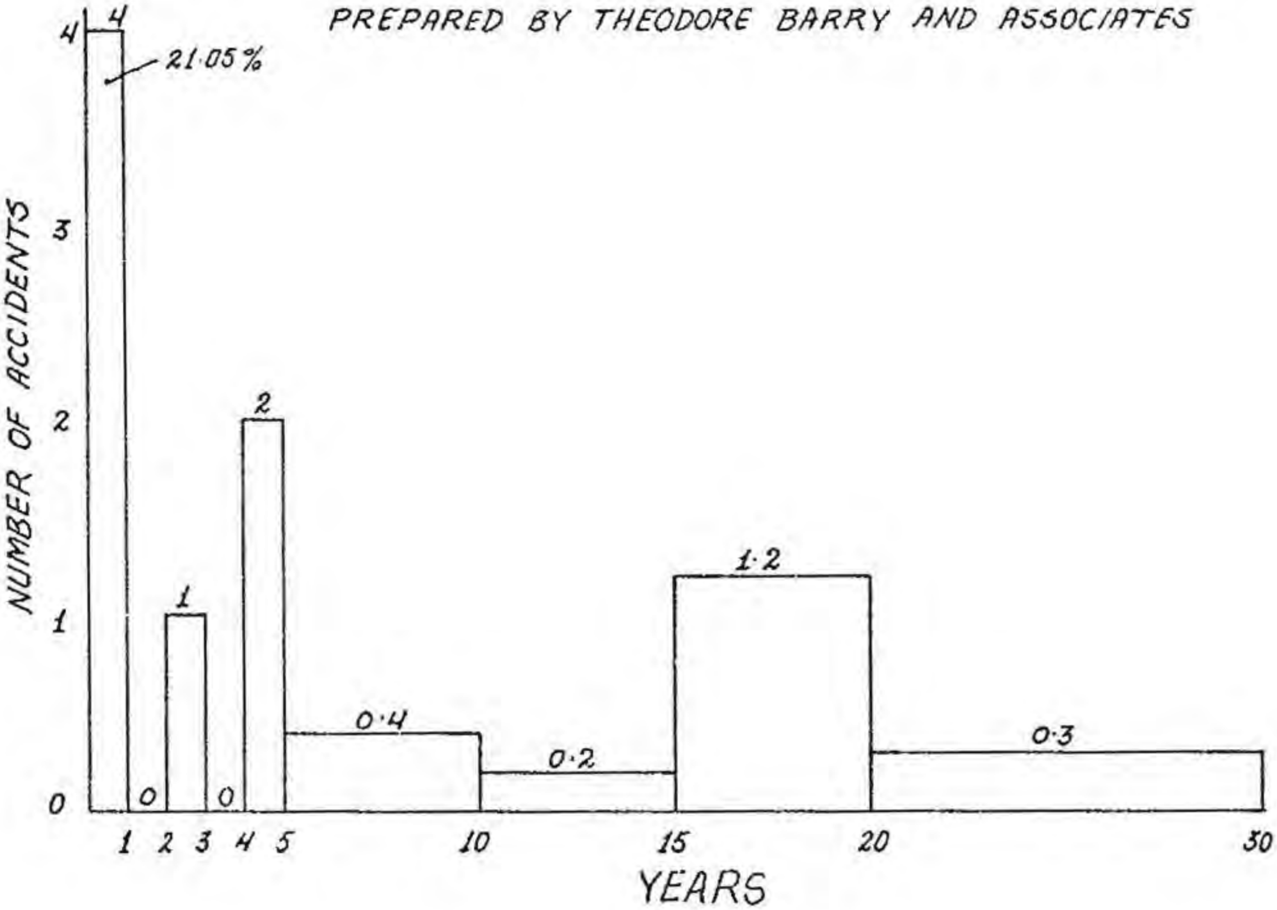
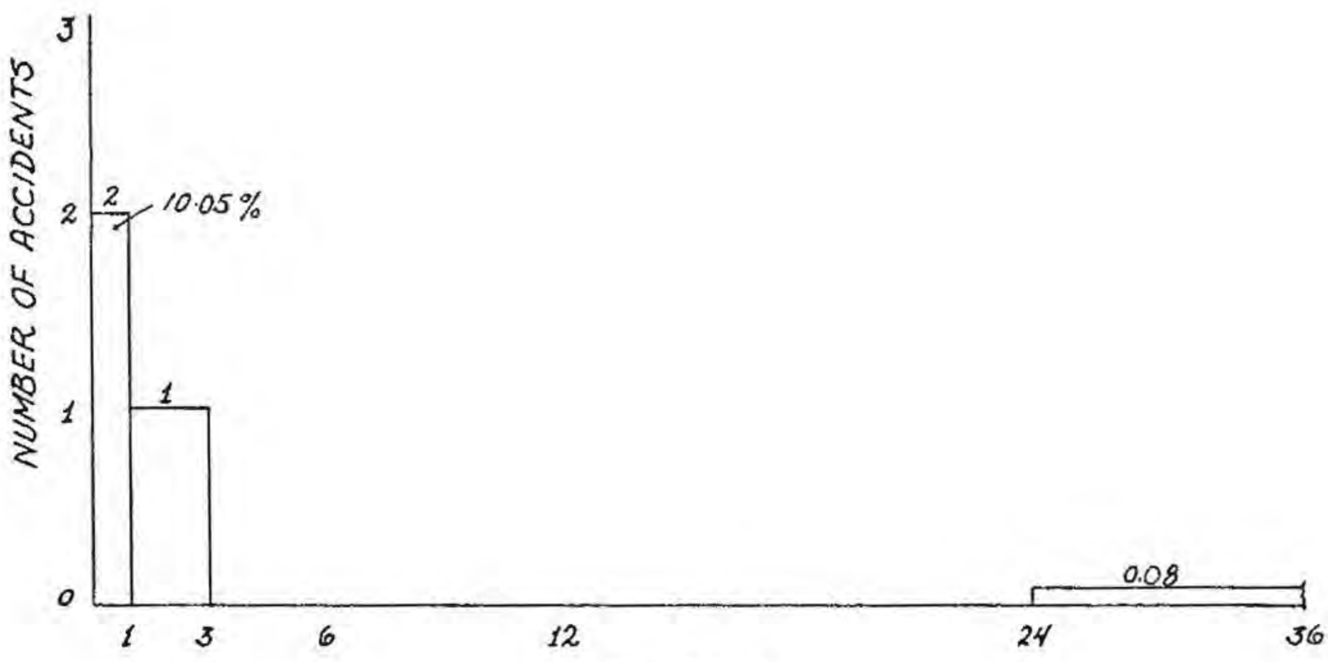
JOB EXPERIENCE OF LOADING MACHINE OPERATORS AT ACCIDENT TIME FOR PITTSBURGH SEAM

19 VICTIMS

1966 - 1971

PREPARED BY THEODORE BARRY AND ASSOCIATES

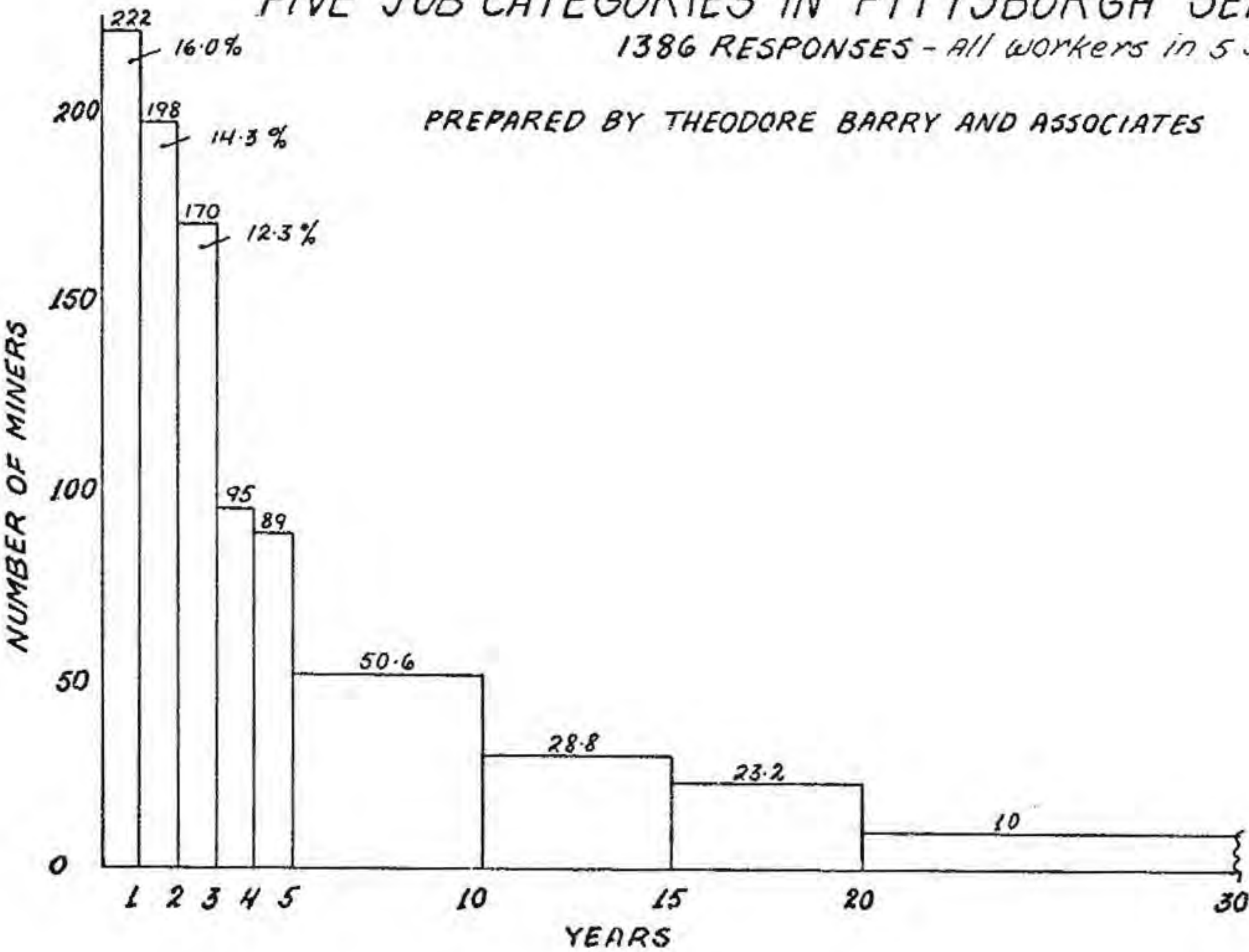




COMBINED JOB EXPERIENCE DISTRIBUTION FOR FIVE JOB CATEGORIES IN PITTSBURGH SEAM

1386 RESPONSES - All workers in 5 JOBS

PREPARED BY THEODORE BARRY AND ASSOCIATES



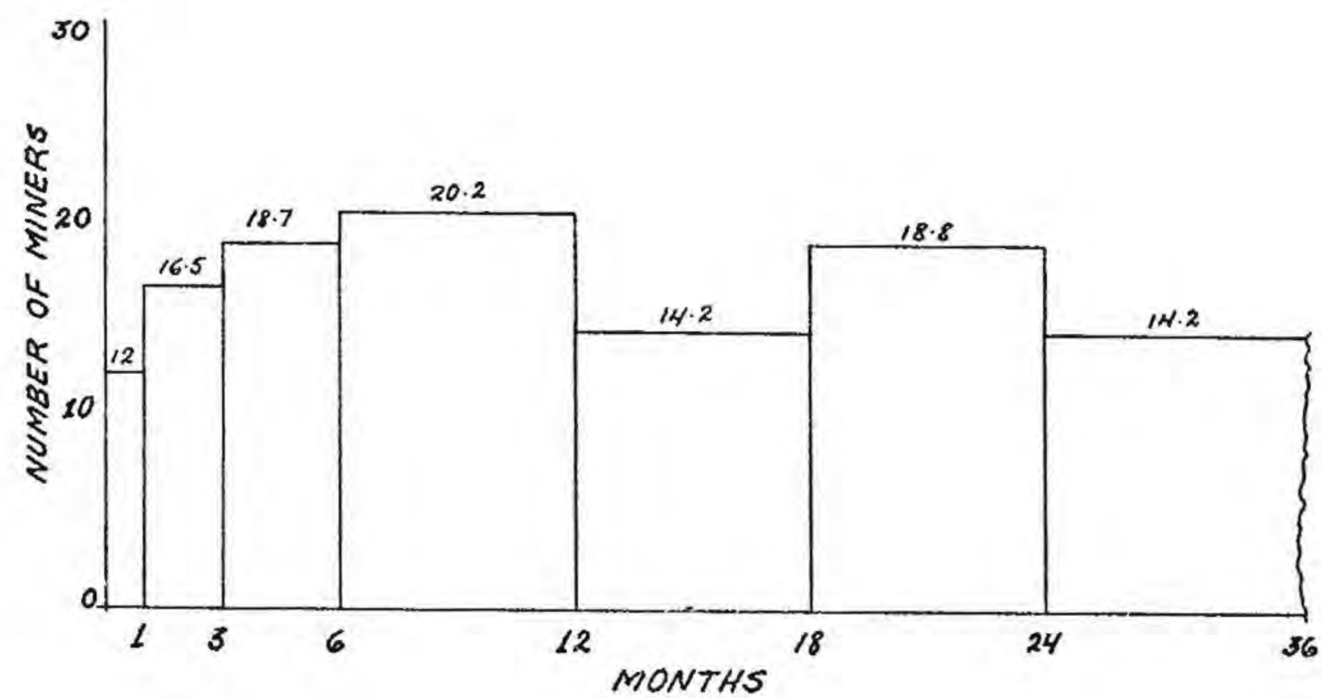
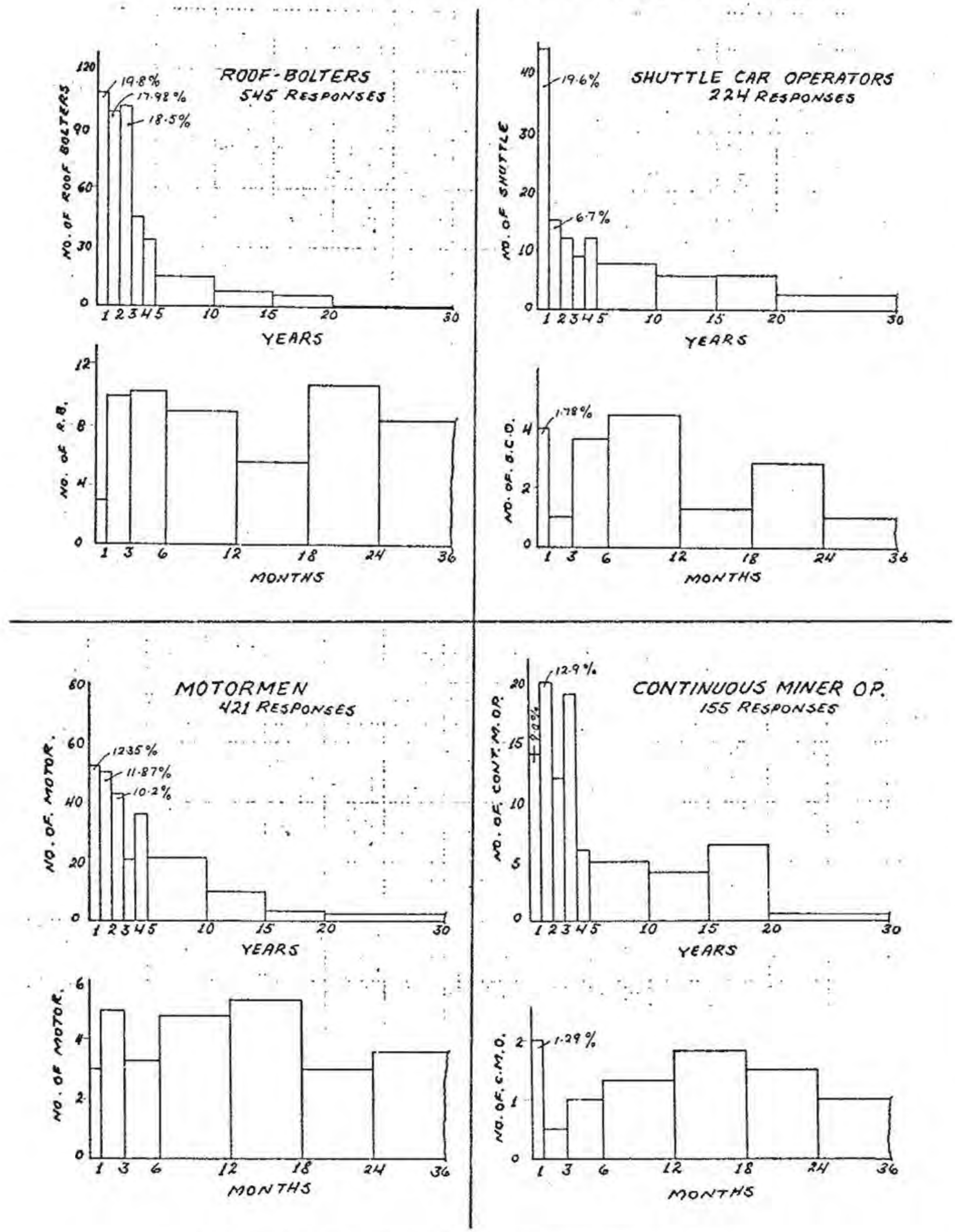


EXHIBIT 4-15

JOB EXPERIENCE DISTRIBUTION FOR FOUR JOB CATEGORIES IN PITTSBURGH SEAM

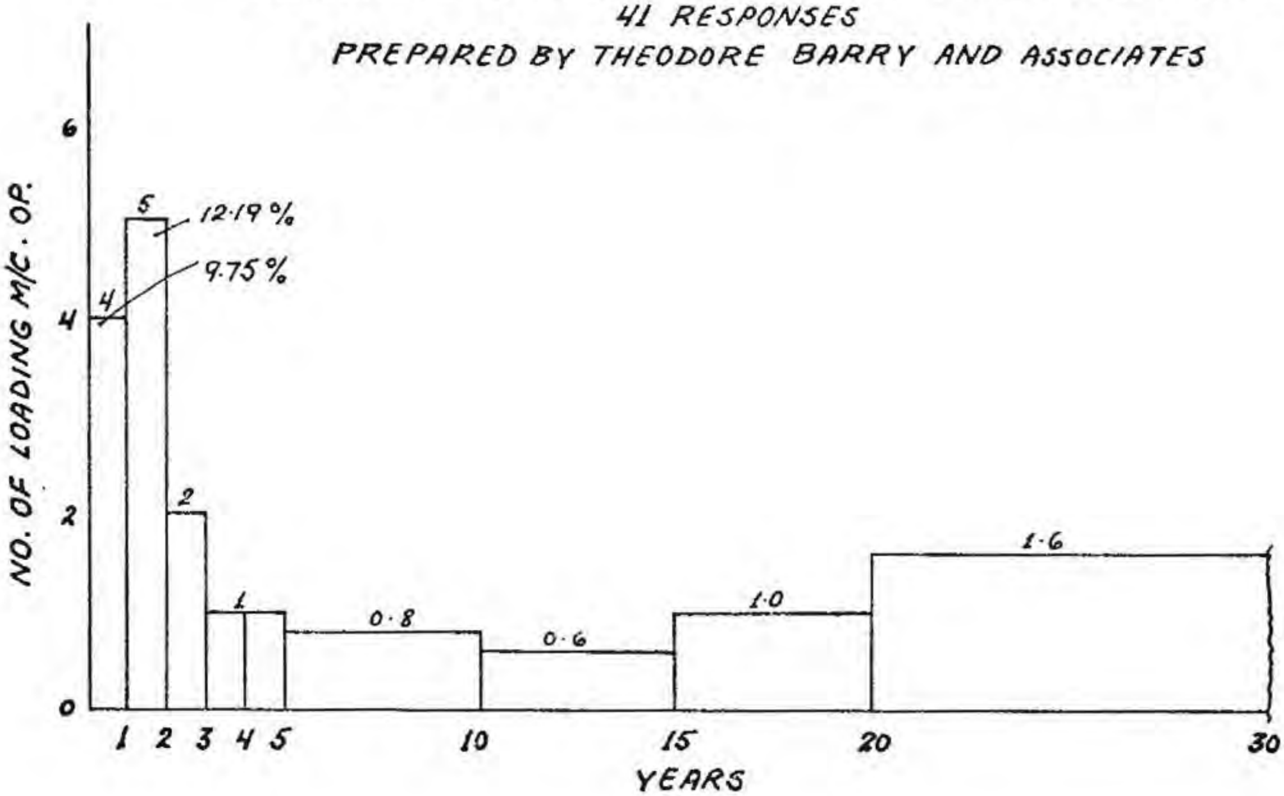


PREPARED BY THEODORE BARRY AND ASSOCIATES

JOB EXPERIENCE DISTRIBUTION OF LOADING MACHINE OPERATORS IN PITTSBURGH SEAM

41 RESPONSES

PREPARED BY THEODORE BARRY AND ASSOCIATES



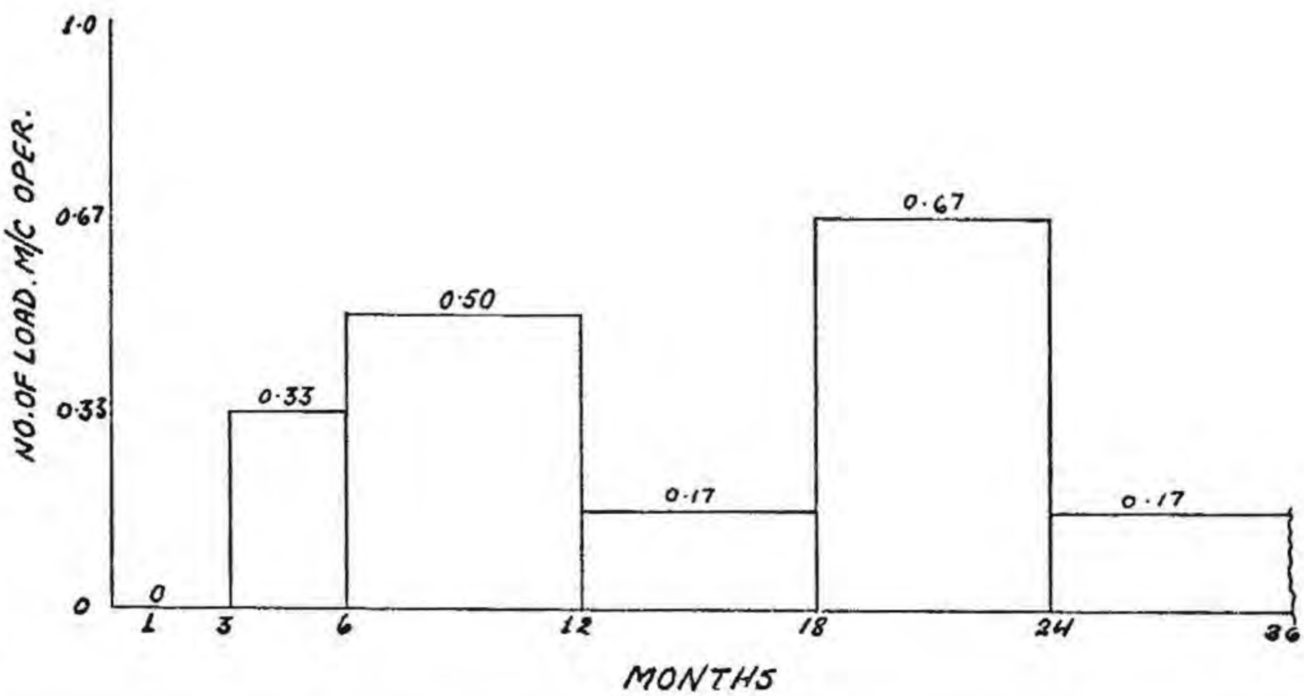


EXHIBIT 4-17

JOB EXPERIENCE & JOB MOBILITY BY OCCUPATION

Occupation	Job Mobility			Job Experience at Time of Accident			
	Employee History		Pittsburgh Survey	Total Fatal Accidents		Pittsburgh Non-Fatal	
	% Change in 1 Year	% Change in 1 Month	% Change in 1 Year	%≤1 Yr. Job Experience	%≤1 Mo. Job Experience	%≤ 1 Yr. Job Exp.	%≤ 1 Mo. Job Exp.
Hand Load	89.52	7.46		44.4	22.2		
Load M/C H.	63.60	5.30		70.0	10.0		
Coal Drill Op.	61.44	5.12		33.3	16.6		
Other Face	61.08	5.09		100	25	45.5	18.2
Cutting M/C H.	57.96	4.83		75	12.5		
Foreman	55.56	4.63		15.4	7.7	5.6	5.6
Fireboss	54.00	4.50		—	—		
Trackman	53.40	4.45		28.5	—	50.0	—
Continuous M Help.	52.68	4.39		44.4	5.5	33.4	—
Other N.F.	48.84	4.07		—	—		
Other Staff	46.32	3.86		100	—		
Surface	45.00	3.75		—	—		
Brakeman	44.16	3.68		62.5	—	5.6	—
Other Transport	44.04	3.67		48.2	17.2		
Timberman	43.44	3.62*		47.6	14.3	44.4	—
Ventman/Brattice	42.12	3.51*		50.0	50.0	22.2	—
Cont. Miner Op.	39.72	3.31	33.33	35.2	7.4	3.8	—
Cutting M/C Op.	39.24	3.27		26.3	5.3		
Beltman	35.28	2.94*		88.8	11.1	—	—
Supplyman	33.96	2.83*		38.1	—	25.0	5.0
Roof-bolter	33.84	2.82	25.86	46.9	9.4	31.9	15.9
Loading M/C Op.	33.72	2.81	9.76	26.1	6.2	21.0	10.5
Shotfirer	31.56	2.63		44.4	11.1	33.0	0
Section Foreman	29.40	2.45		44.8	6.89		
Shuttle Car Op.	27.96	2.33	21.05	30.2	6.9	25.7	11.4
Electrician	24.00	2.00*		33.3	—		
Laborer	23.88	1.99*		35.9	7.7	37.6	6.3
Superintendent	23.16	1.93		—	—		
Motorman	20.64	1.72	20.49	17.0	2.4	15.0	2.5
Mechanic	16.68	1.39*		44.8	6.89	11.7	2.9

* Corrected for face to non-face and vice-versa movement.

UNDERGROUND EXPERIENCE

The total underground experience of injured miners is shown in Exhibit 4-18. This shows that the majority of miners have between 20 and 40 years of total underground experience. The mean is 25 years. This is considerably more than the mean of 3 years for job experience. Although a miner may have many years of underground experience, he has probably had several different jobs and his current job experience averages 3 years at the time of injury. In other words, the total underground mining experience of both accident victims and all miners differs markedly from job experience.

The total underground experience for miners in the Pittsburgh Seam is shown in Exhibit 4-19. The breakdown by occupation is shown in Exhibit 4-20 and 4-21. These show an influx of new workers in the last three years, but the great majority of miners have between 20 and 40 years total underground experience. This is in conformity with the pattern of job experience for injured miners. Note that the number of new workers in the Pittsburgh Seam who became underground miners during the last year, August 1971 to July 1972, is less than half the number who entered in the prior year. This can be partly attributed to a prolonged strike in late 1971.

Comparing the total underground experience graph (Exhibit 4-19) and the job experience graph (Exhibit 4-14) for the percent of miners who have one year or less, one to two years, or three to four years total underground experience and job experience gives the results as shown in the following table:

PITTSBURGH SEAM		
Experience Category	Total Underground Experience	Job Experience
One year or less	4.09%	16.0%
1 to 2 years	8.89%	14.3%
2 to 3 years	6.88%	12.3%

This illustrates the point that job experience is not necessarily related to total underground experience. In July 1972, the date of the survey, only 4.09% of the miners had one year or less total underground experience. However, almost four times the number, or 16% were in their first year on the job.

Total underground experience was not coded onto the 1971 injuries tape. However, the employee history files contains a 20% response for total underground experience. By matching the 1971 injury tape to the employee history file we were able to obtain an indication of the experience of injured miners. The matching was done by social security number, and only 50% of the injured miners had social security numbers that matched the employee history. Hence our resultant response for the total underground experience of injured miners in 1971 is 50% of 20%, that is, 10%. And this cannot be considered a random sample. It is derived from: 1) those miners who have returned dust samples for their records to be included on the employee history file, 2) the limited number who answered the question regarding underground experience, and finally, 3) those injured miners whose social security number matched the employee history file.

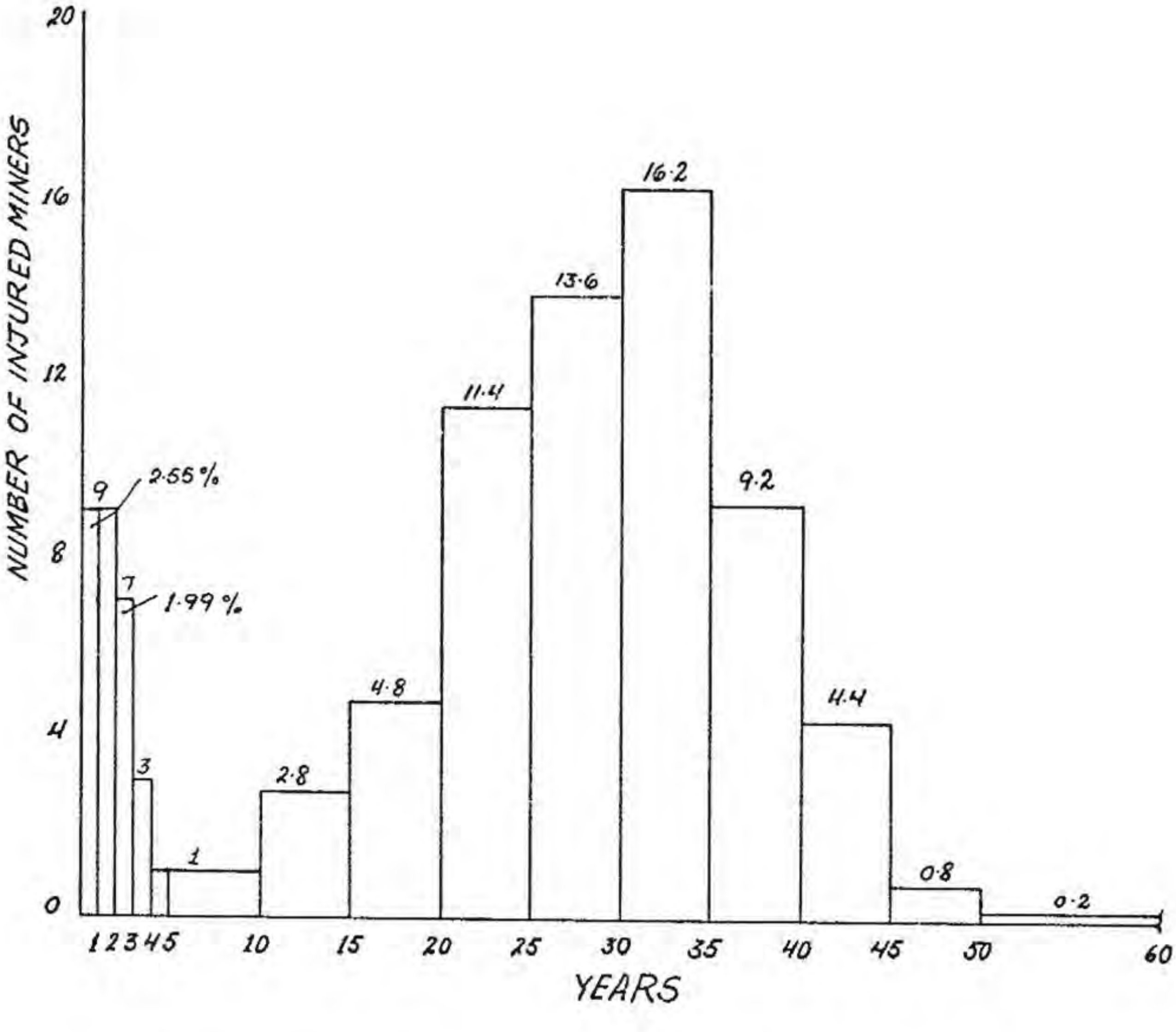
A comparison of the total underground experience of injured miners to the experience of the national population is shown graphically in Exhibit 4-22. Again it should be borne in mind that this is not a random sample. The graph does seem to show that a greater proportion of injured miners have one year or less of underground experience. This is in contrast to the Pittsburgh Seam where the proportion of injured miners with one year or less job experience is less than the total number of miners with one year of underground experience or less.

EXHIBIT 4-18

TOTAL UNDERGROUND EXPERIENCE OF ALL INJURED MINERS IN PITTSBURGH SEAM

352 VICTIMS

1966 - 1971

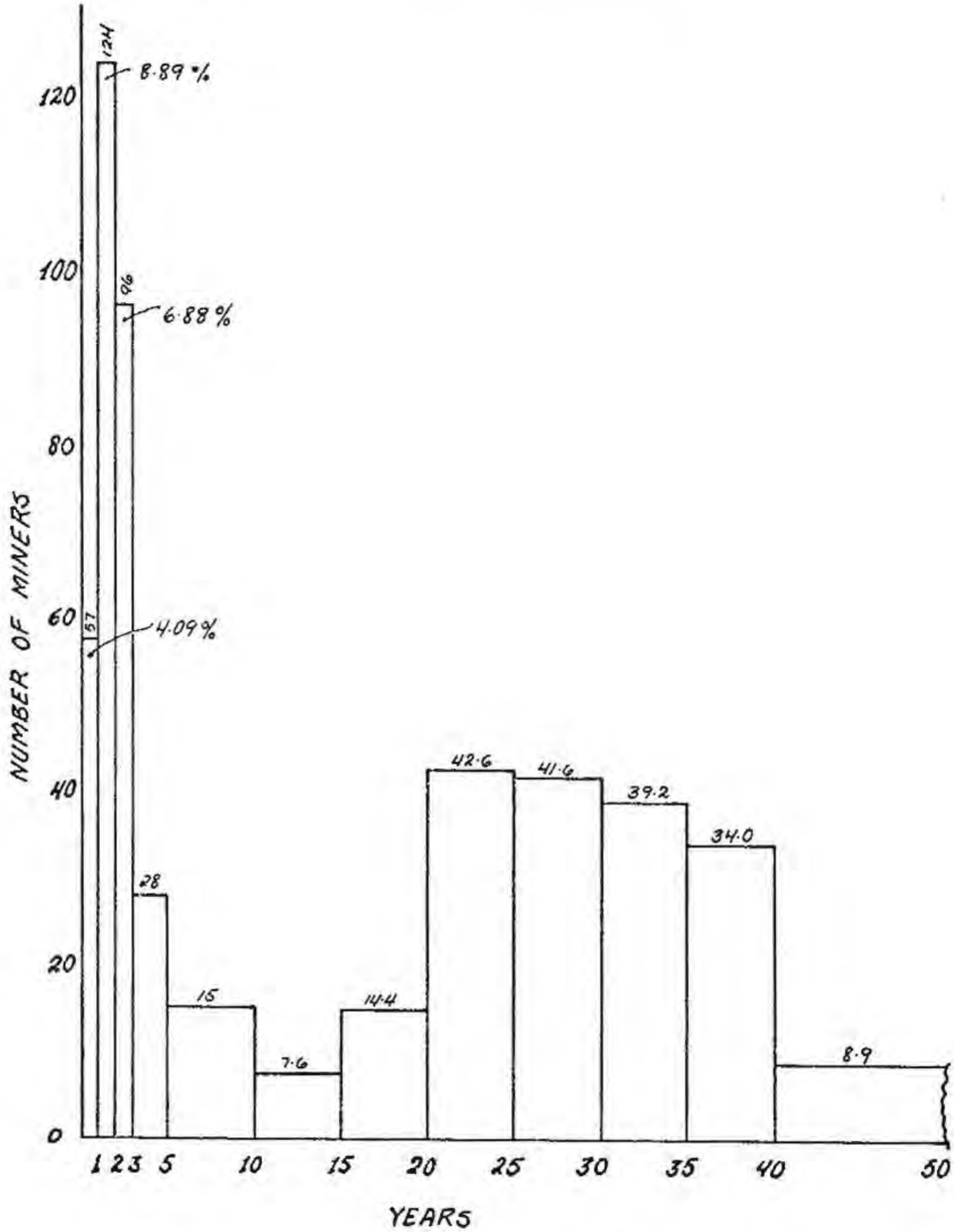


PREPARED BY THEODORE BARRY AND ASSOCIATES

EXHIBIT 4-19

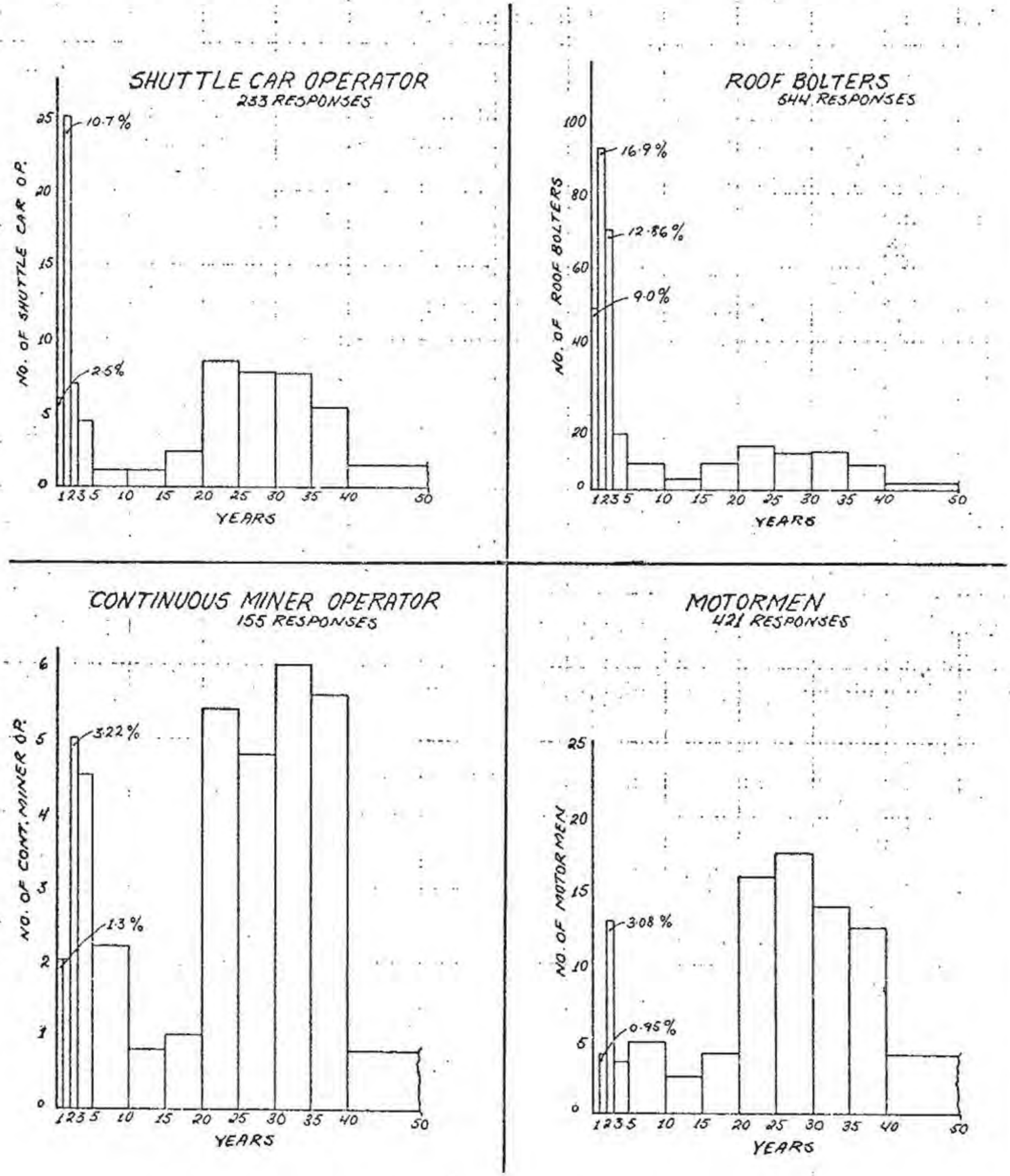
COMBINED TOTAL UNDERGROUND EXPERIENCE OF FIVE JOB CATEGORIES IN PITTSBURGH SEAM

1394 RESPONSES



PREPARED BY THEODORE BARRY AND ASSOCIATES

DISTRIBUTION OF TOTAL UNDERGROUND EXPERIENCE FOR FOUR JOB CATEGORIES IN PITTSBURGH SEAM

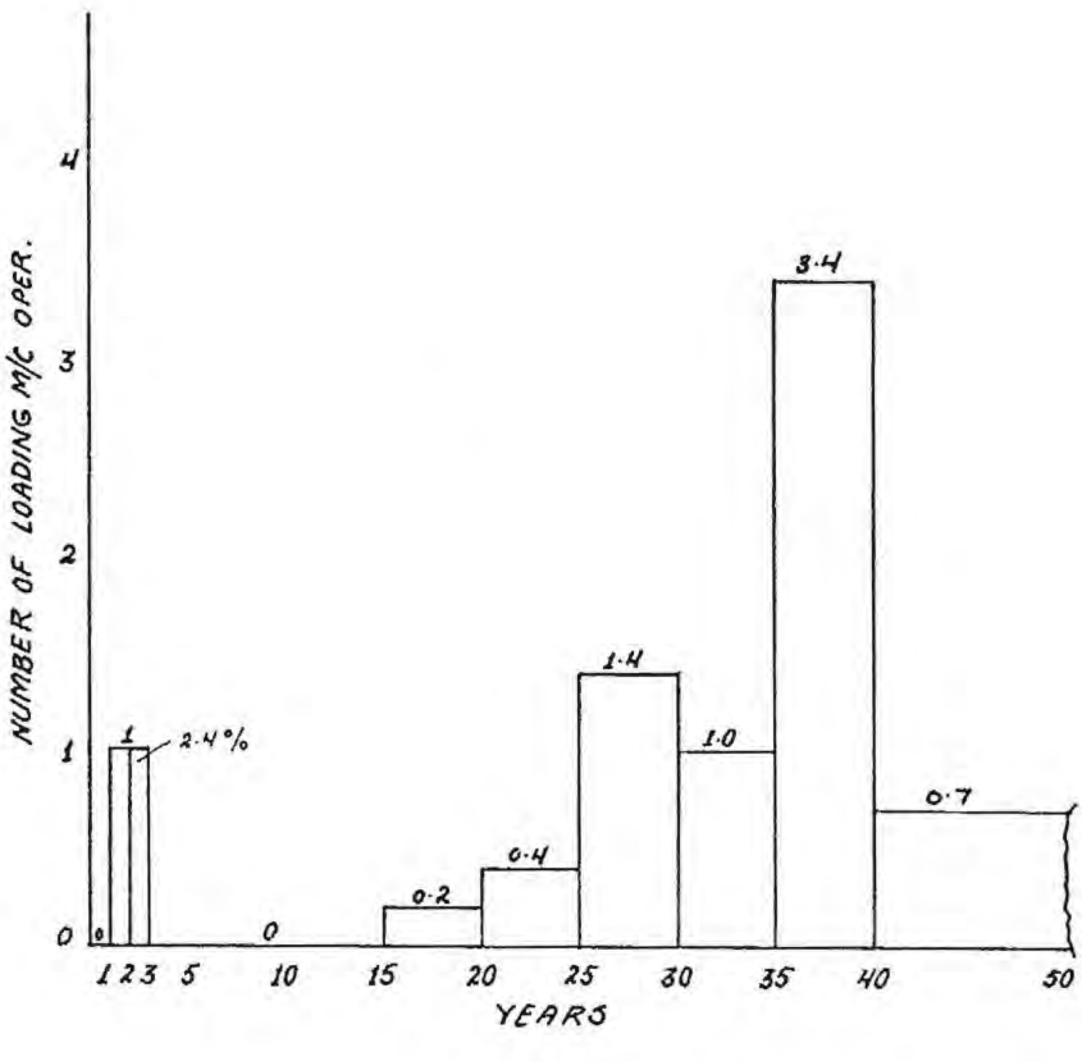


PREPARED BY THEODORE BARRY AND ASSOCIATES

EXHIBIT 4-21

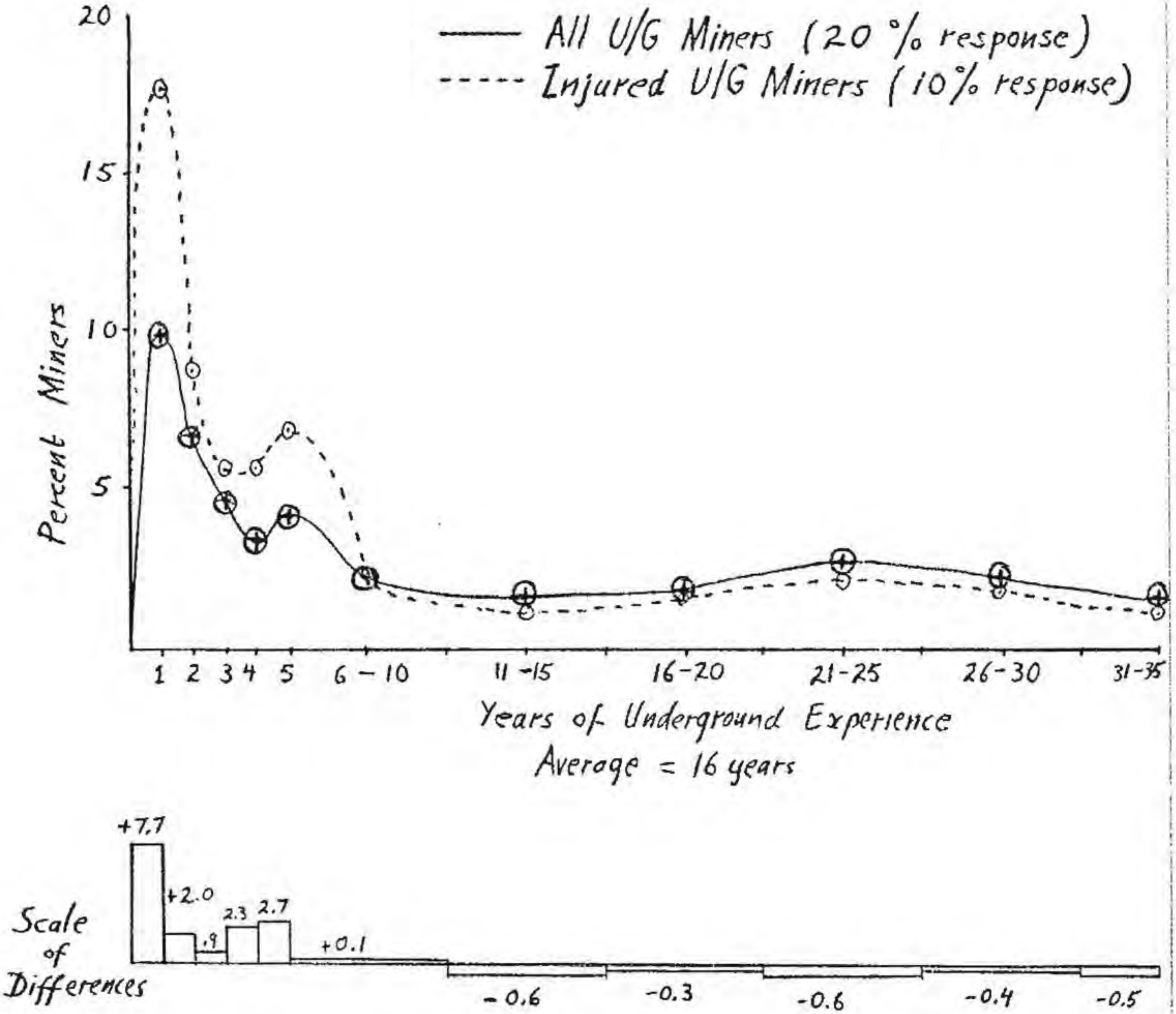
DISTRIBUTION OF UNDERGROUND EXPERIENCE FOR LOADING M/C. OPER. IN PITTSBURGH SEAM

41 RESPONSES



PREPARED BY THEODORE BARRY AND ASSOCIATES

COMPARISON OF TOTAL UNDERGROUND EXPERIENCE FOR INJURED AND ALL MINERS IN THE U.S.A. 1971



PREPARED BY THEODORE BARRY AND ASSOCIATES

AGE

The age distribution of all injured miners in the Pittsburgh Seam is shown in Exhibit 4-23. This shows that the majority of injured miners are in the 41 to 65 age bracket. Based on our survey of the age of five occupations in the Pittsburgh Seam, it would appear that the majority of miners are also aged between 41 and 65.

A comparison of the age distributions of injured and non-injured miners for the five job categories surveyed in the Pittsburgh Seam is shown in Exhibit 4-24. This shows that a slightly greater proportion of middle-aged miners are injured than younger or older workers. Note that the Pittsburgh Seam contains a much greater proportion of middle-aged workers than younger workers.

This is in contrast to the ages of all miners in the United States. Their distribution is shown in Exhibit 4-25 and contains a higher percentage of younger workers than in the Pittsburgh Seam, although the older workers still predominate.

Exhibit 4-25 also compares the ages of injured miners in the United States. As in the case of total underground experience, the age of injured miners was obtained from the employee history file (the original 1971 injury file did not show age), and this represents a 40% response. Note how a greater proportion of younger miners are injured than older miners. This is in contrast to the Pittsburgh Seam.

The age distributions of roof bolters, shuttle car operators, motormen, continuous miner operators and loading machine operators are shown in Exhibits 4-26 and 4-27. Note how roof bolters differ from the other four. Roof bolters include a high proportion of young workers. A similar, but more pronounced pattern exists for roof bolters on the national scale. There is a greater proportion of roof bolters in the 20 to 30 year age group than for any other occupation. Exhibit 4-28 shows the pattern, and also compares the ages of injured roof bolters to all roof bolters. Exhibits 4-29, 4-30, 4-31 and 4-32 show the ages of injured and non-injured loading machine operators, shuttle car operators, motormen and continuous miner operators respectively. A significantly greater proportion of shuttle car operators are injured than older shuttle car operators when compared to the total shuttle car population. Yet for roof bolters and loading machine operators there are no distinct patterns.

The employee history file contains information on the mining style where the miner is working, that is, whether it is a continuous, conventional, longwall or other type of mine. Exhibit 4-33 and 4-34 compare the age distributions in each of these categories. It is interesting to note that longwall mining, the newest style of mining to be introduced to the U. S. A., contains the highest proportion of young workers.

An attempt was made to classify the injury rates for each mining style. The 1971 injury file does not show the mining style. Merging the injury file with the employee history file by miners' social security number gives a resultant output showing the type of mine. However, it was felt that it would be misleading to present the results until a better match of injuries to the employee history file was obtained. The present 50% match probably discriminates against those mines that have accurate records of the employees' social security numbers and which have been returning the dust samples, as opposed to those mines which have not submitted accurate and complete information.

EXHIBIT 4-23

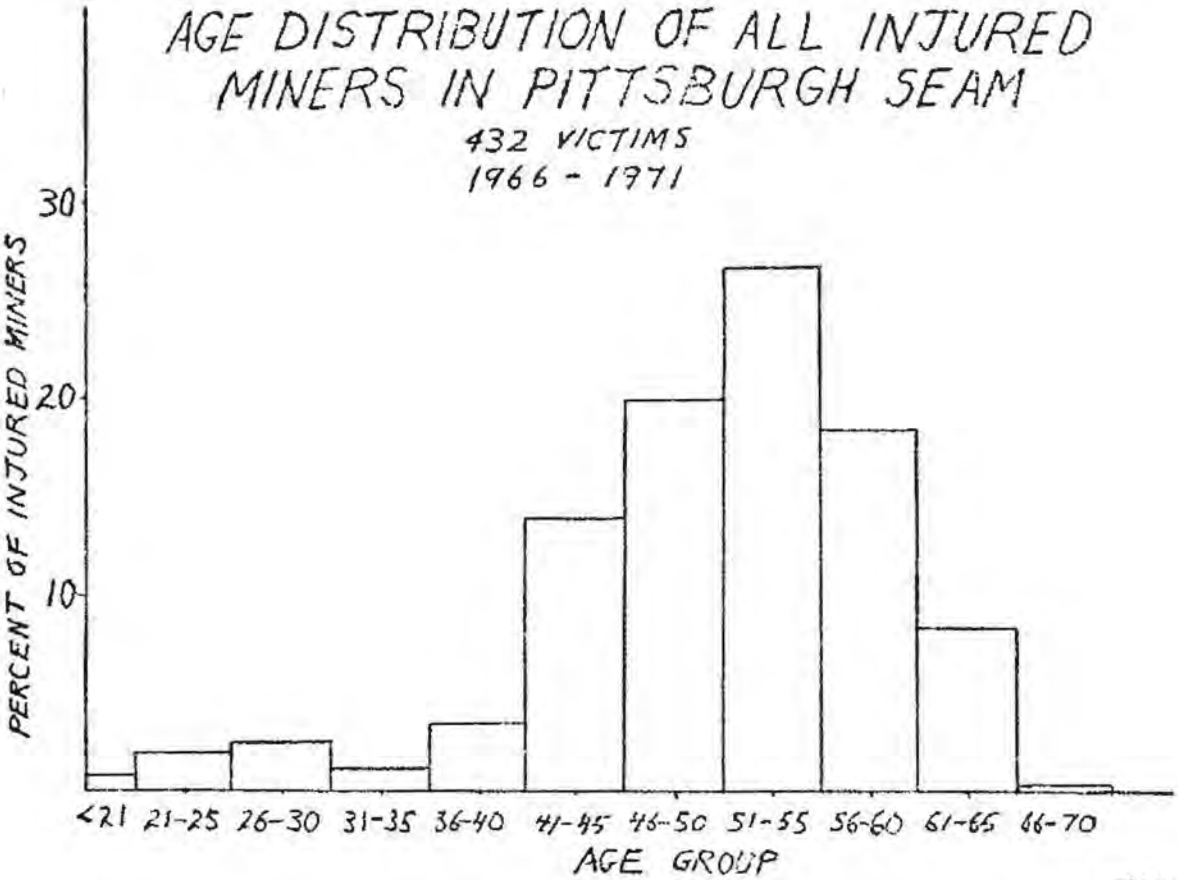
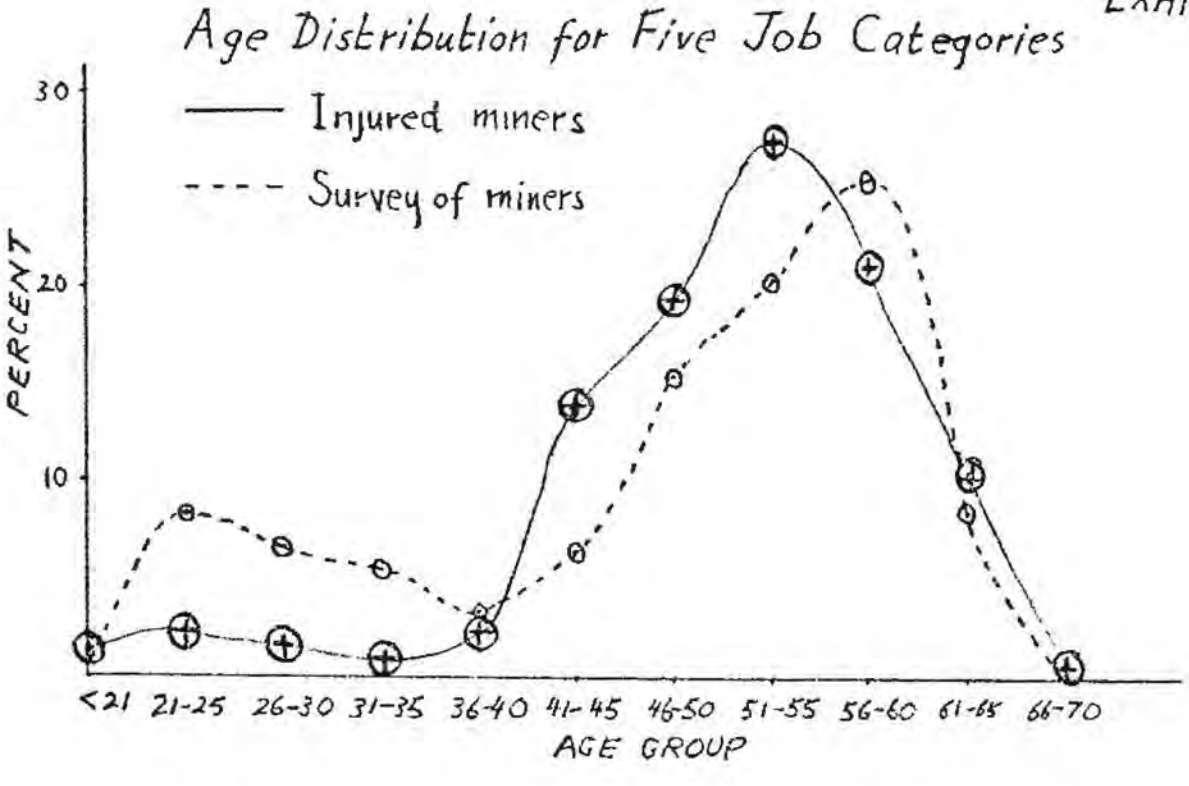
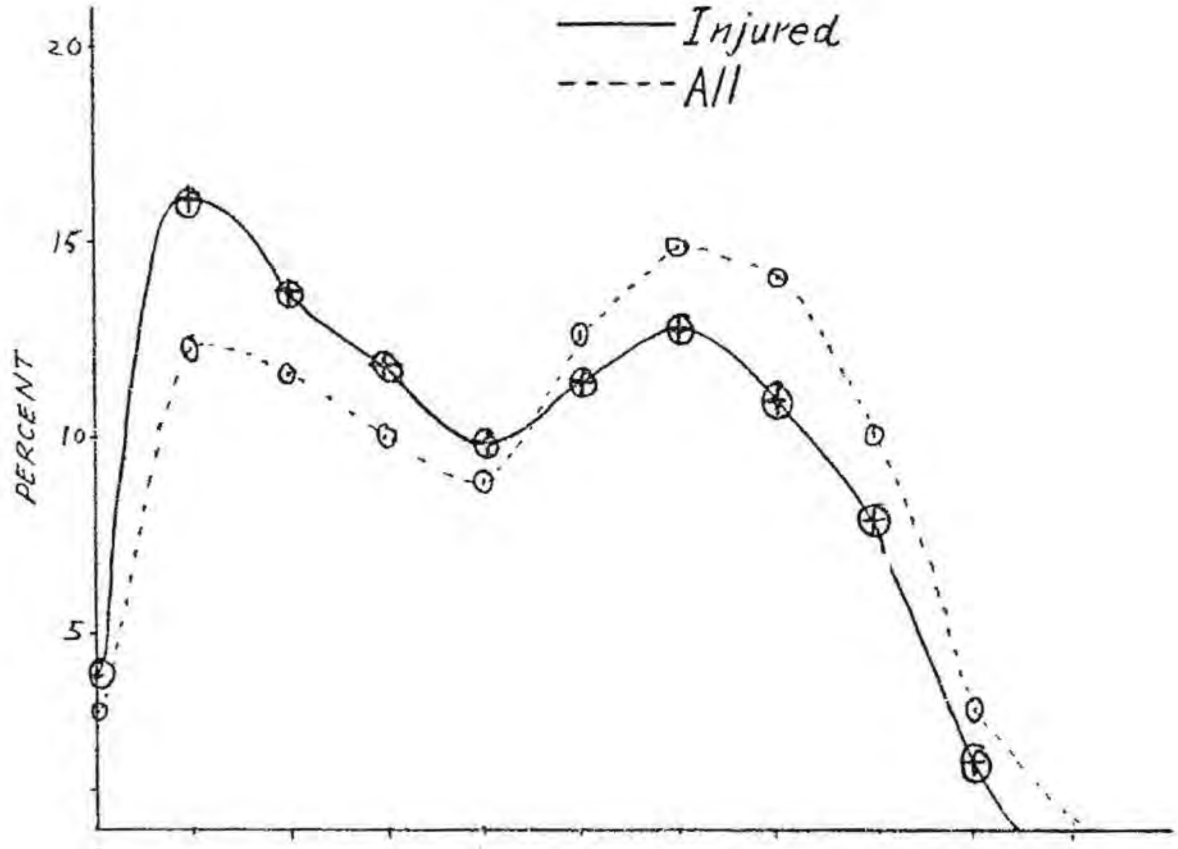
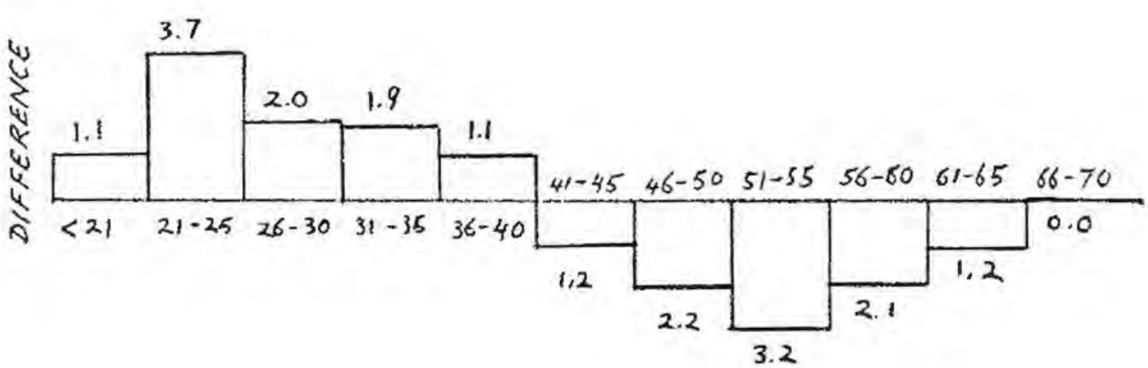


EXHIBIT 4-24



COMPARISON OF AGES
between
INJURED MINERS AND ALL MINERS





PREPARED BY THEODORE BARRY AND ASSOCIATES

AGE DISTRIBUTION OF FOUR JOB CATE-
-GORIES IN PITTSBURGH SEAM MINES.

PREPARED BY THEODORE BARRY & ASSOCIATES

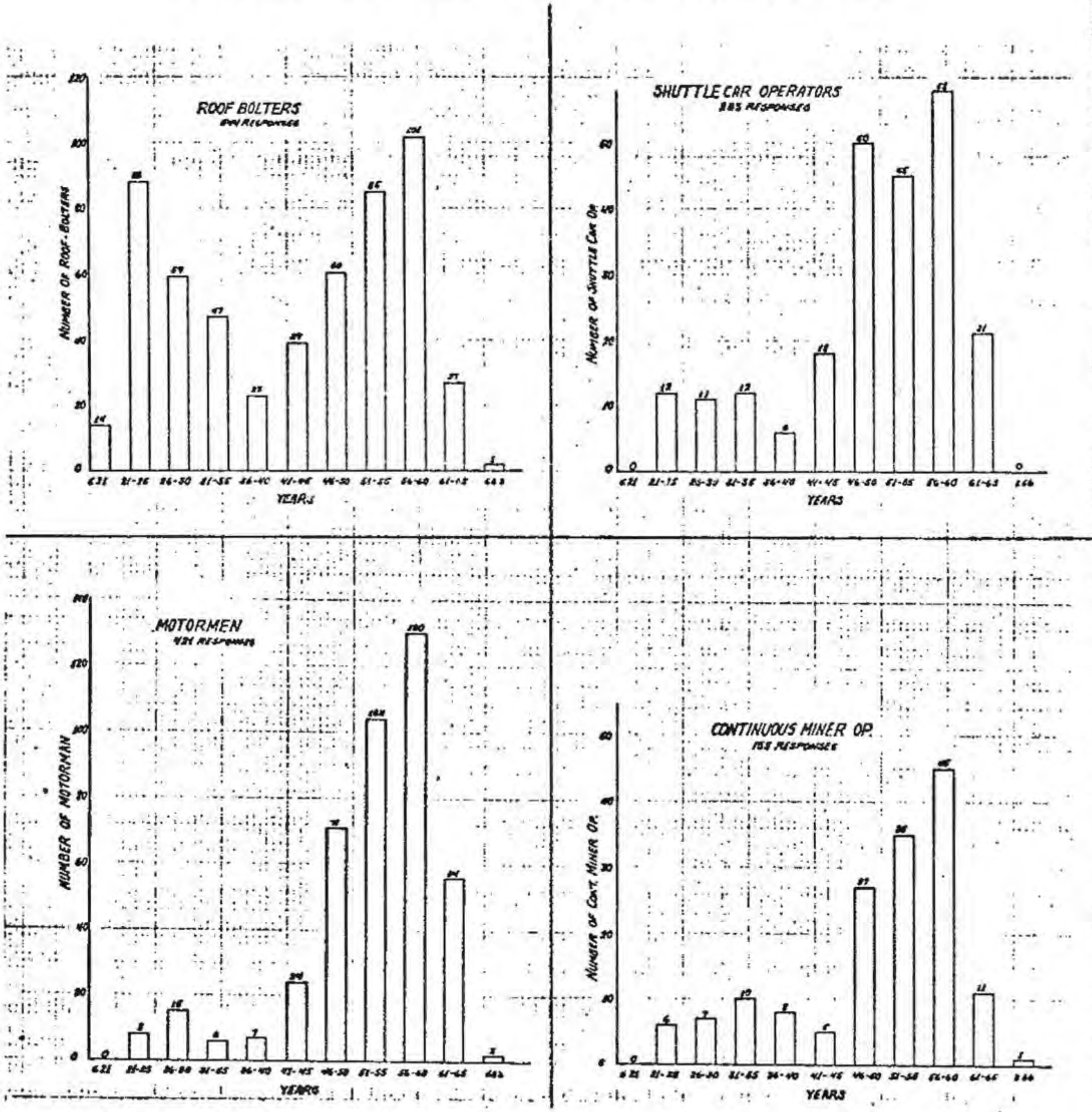
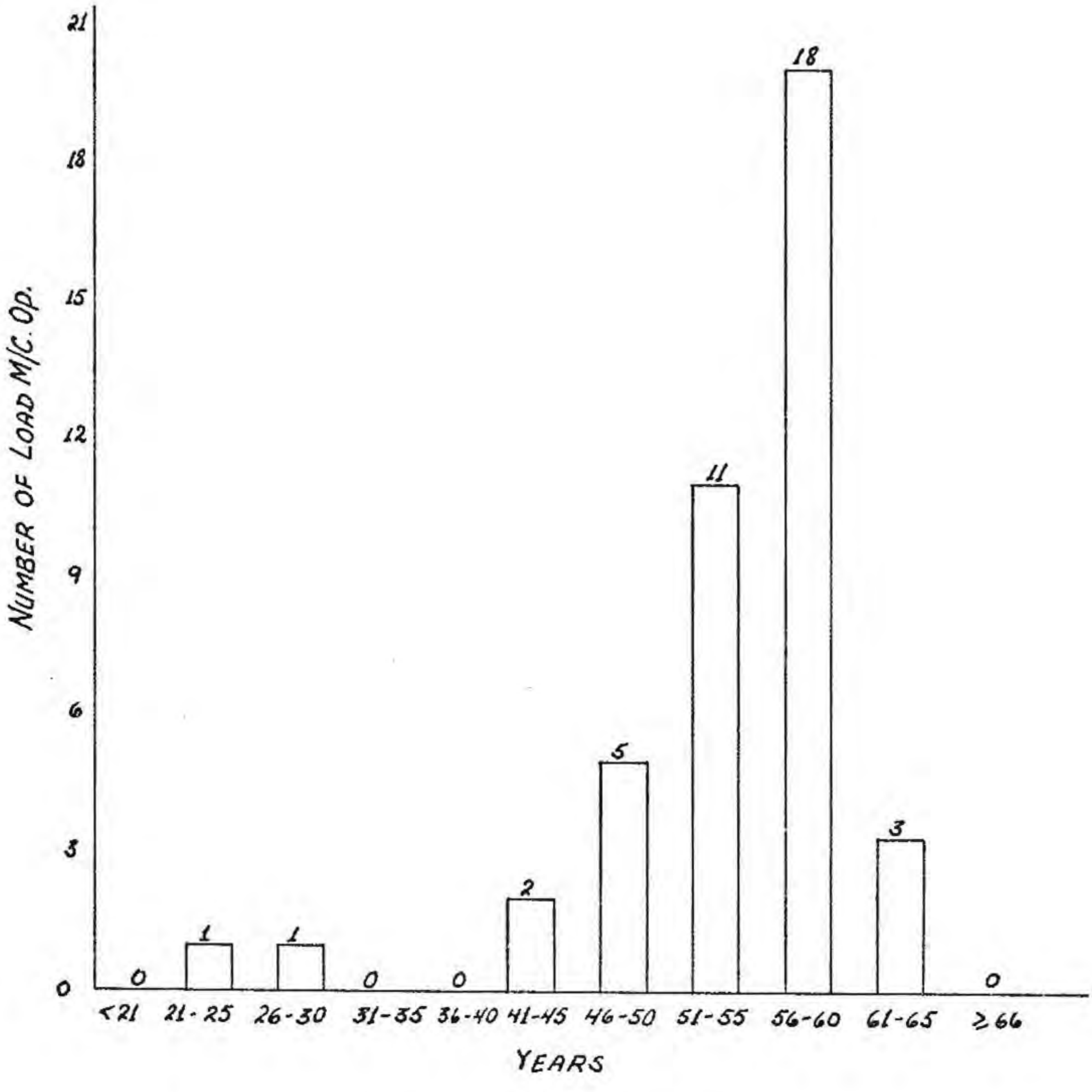


EXHIBIT 4-27

AGE DISTRIBUTION OF LOADING MACHINE OPERATORS IN PITTSBURGH SEAM - 41 RESPONSES



PREPARED BY THEODORE BARRY AND ASSOCIATES

EXHIBIT 4-28

AGE OF INJURED ROOF BOLTERS COMPARED TO AGES OF ALL ROOF BOLTERS

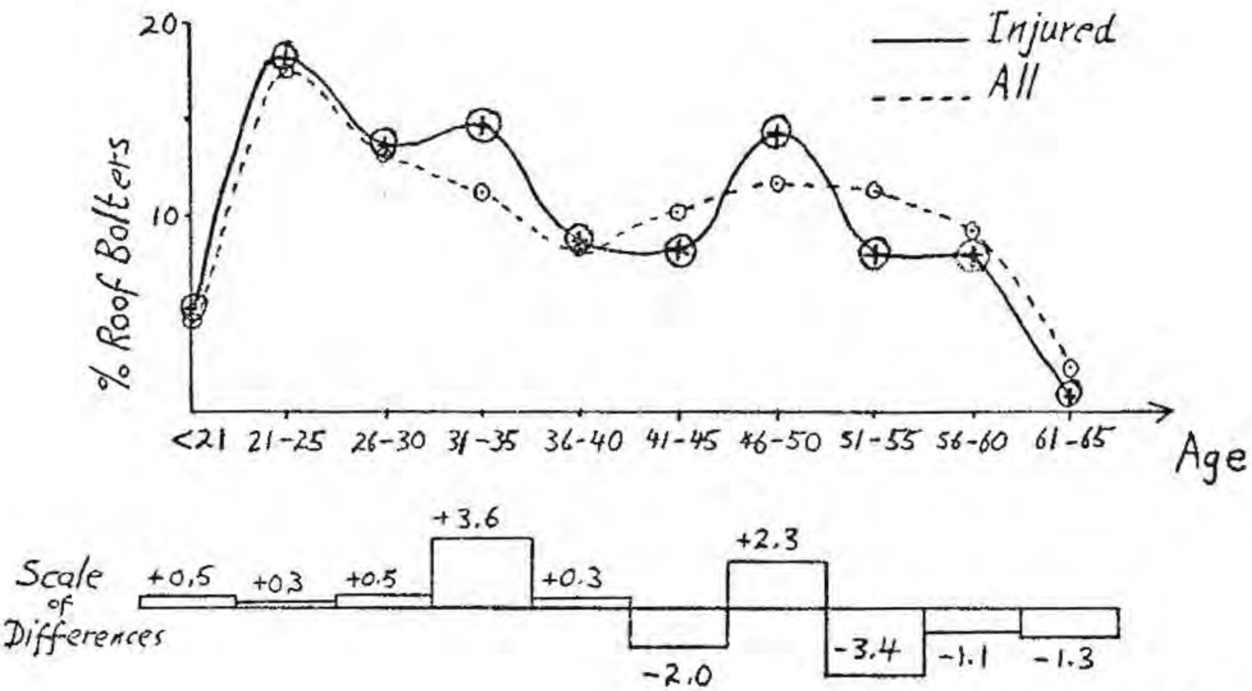
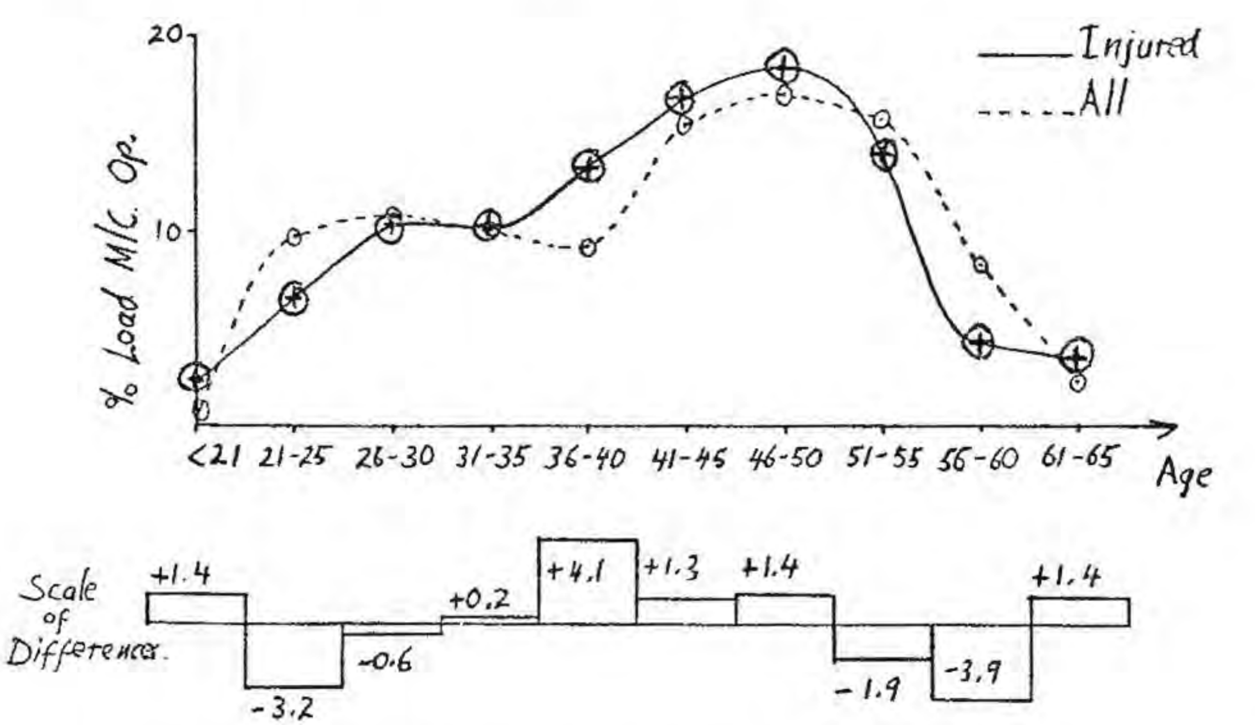


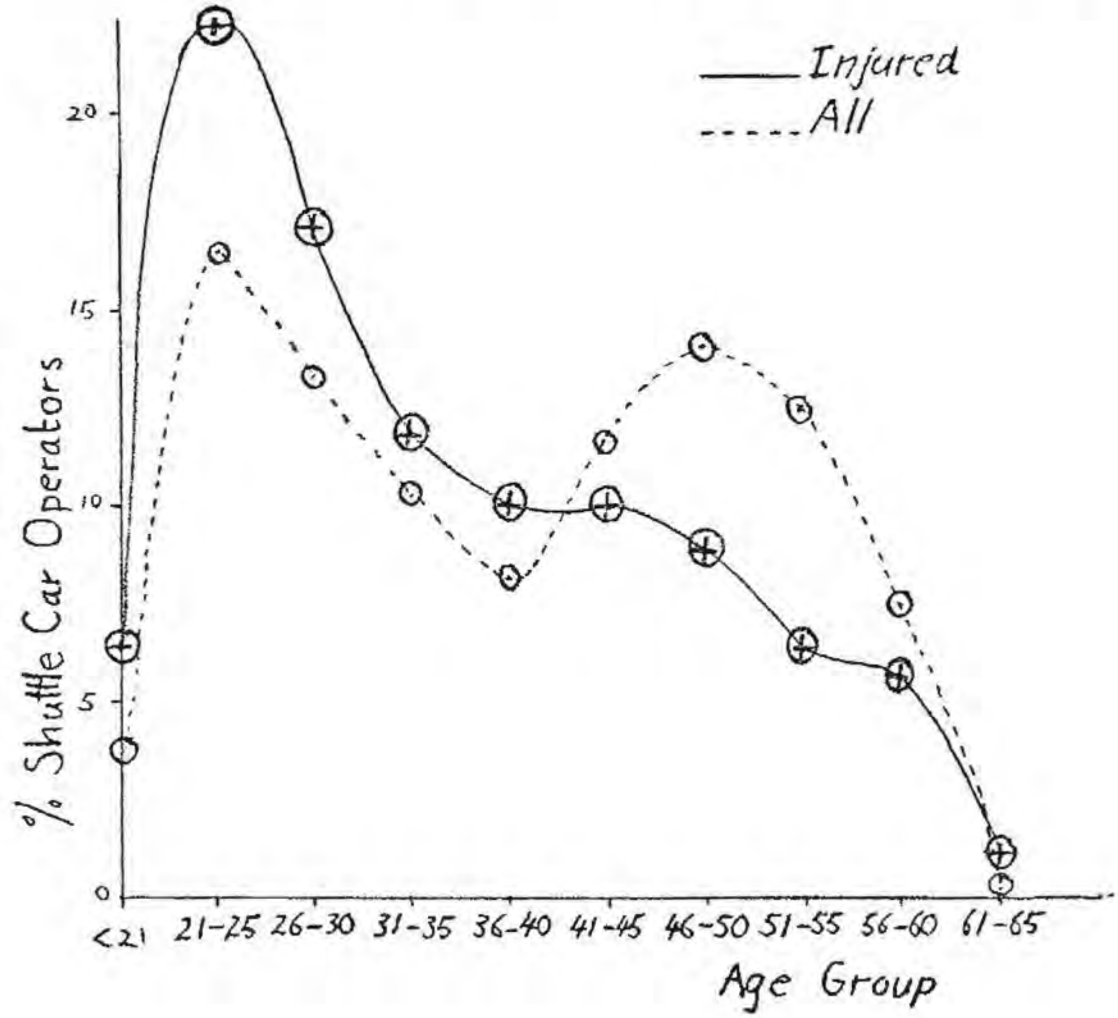
EXHIBIT 4-29

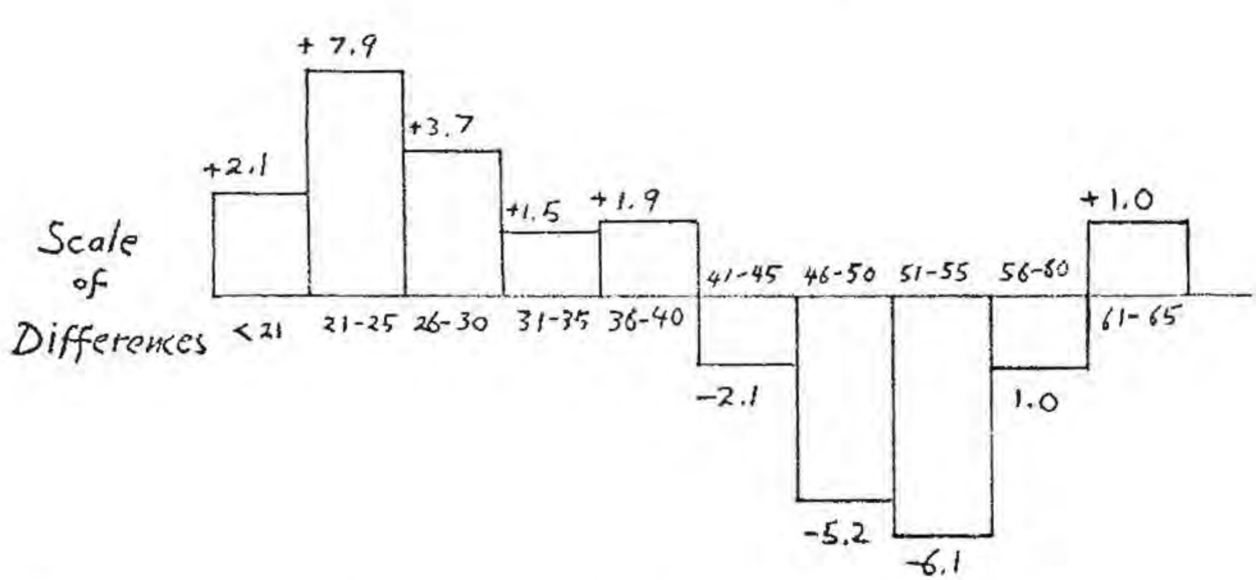
AGE OF INJURED LOADING M/C OPERATORS COMPARED TO AGES OF ALL LOADING M/C OPERATORS



Prepared by Theodore Barry & Associates

AGE OF INJURED SHUTTLE CAR OPERATORS COMPARED TO AGES OF ALL SHUTTLE CAR OP.





Prepared by Theodore Barry & Associates

EXHIBIT 4-31

AGE OF INJURED MOTORMEN COMPARED TO AGES OF ALL MOTORMEN.

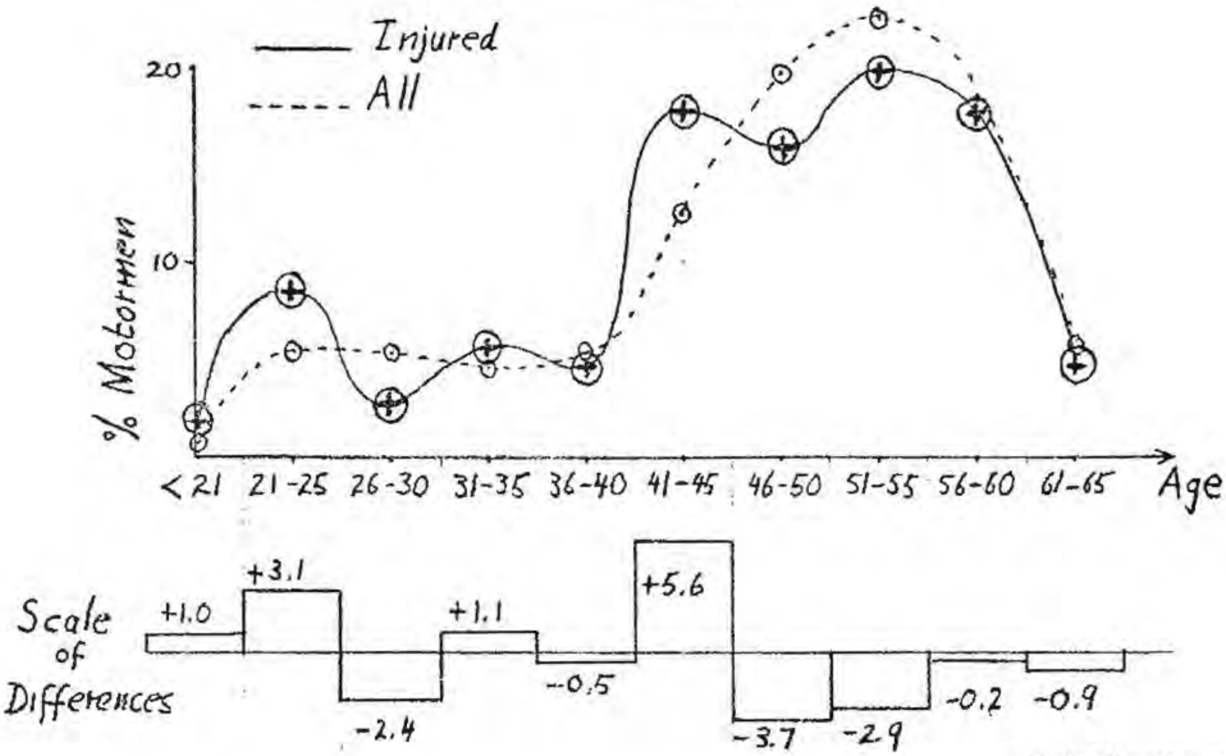
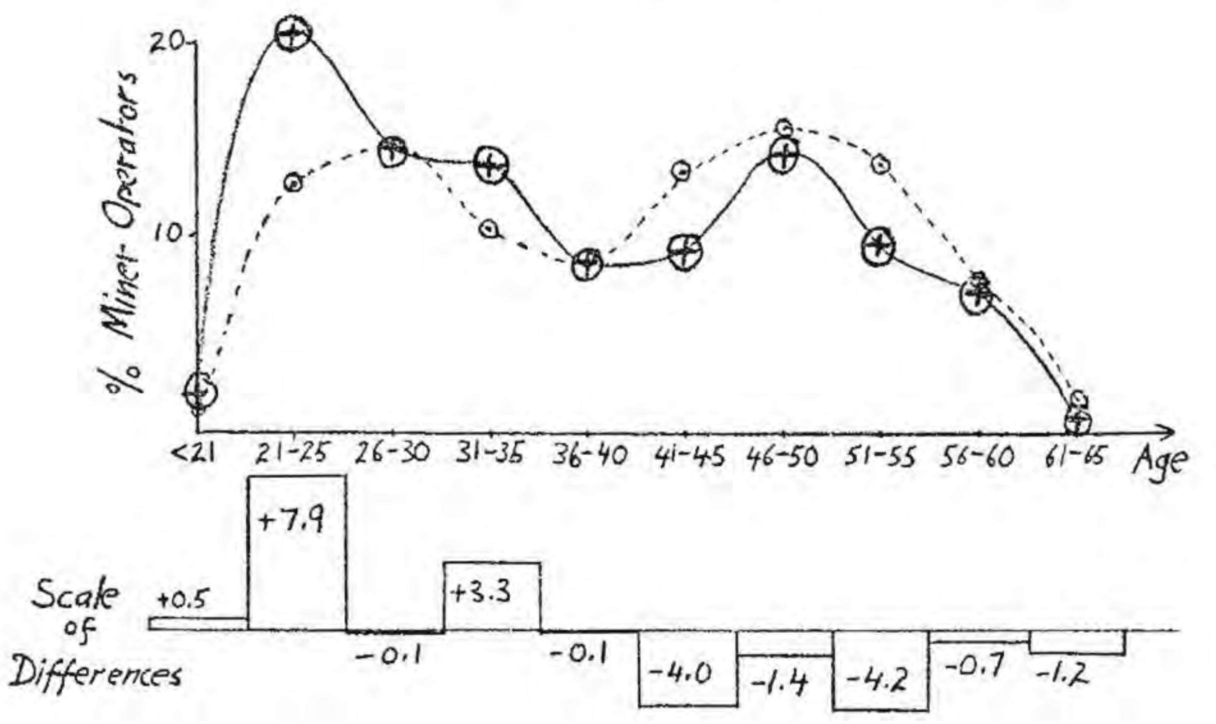


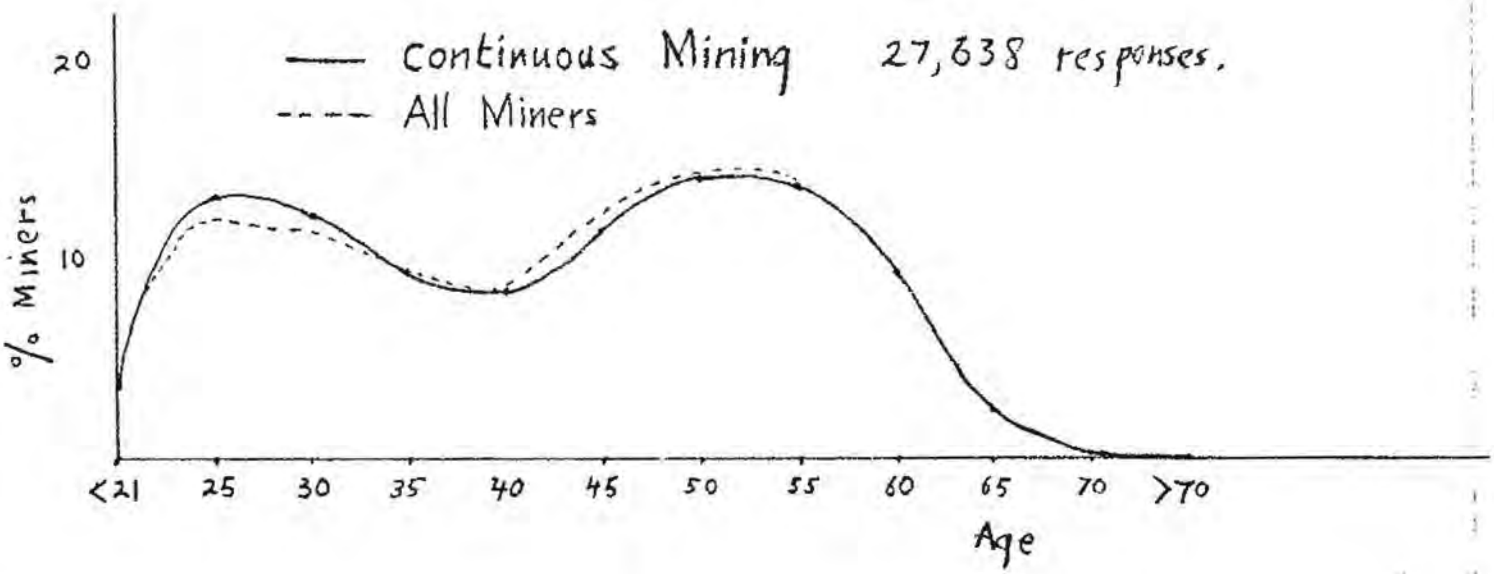
EXHIBIT 4-32

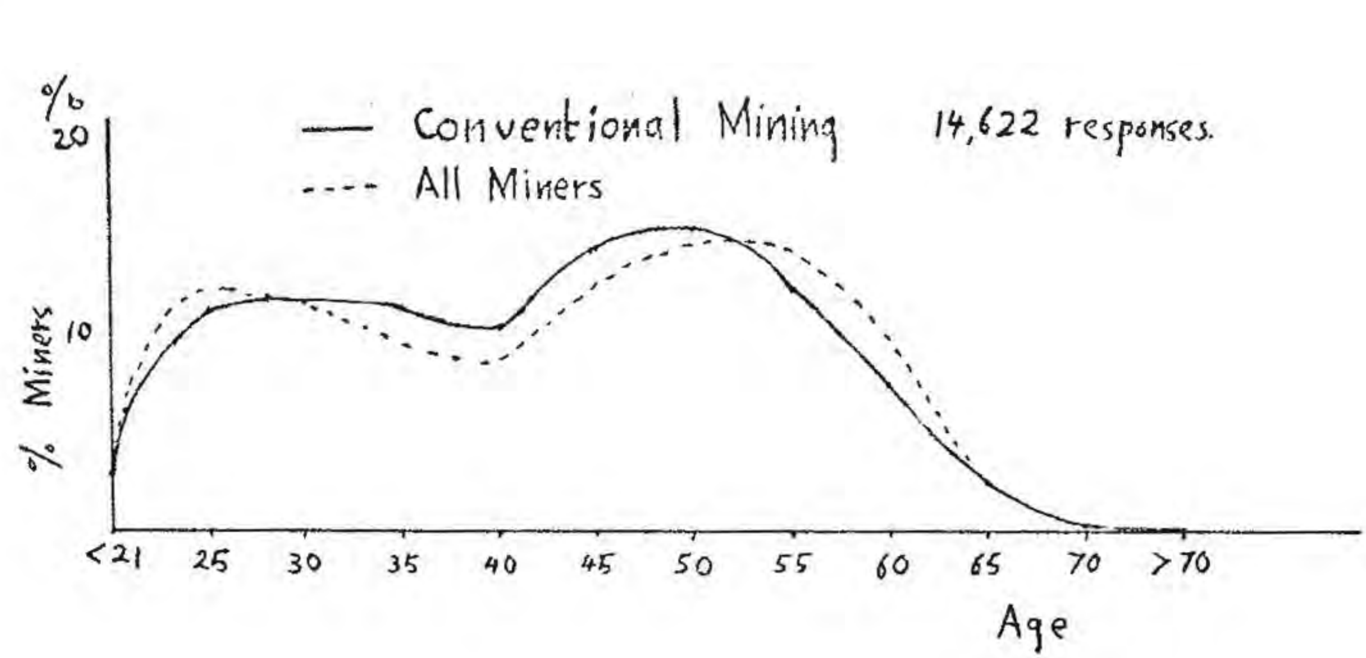
AGE OF INJURED CONTINUOUS MINER OPERATORS COMPARED TO AGES OF ALL CONT. MINER OP.



Prepared by Theodore Barry & Associates

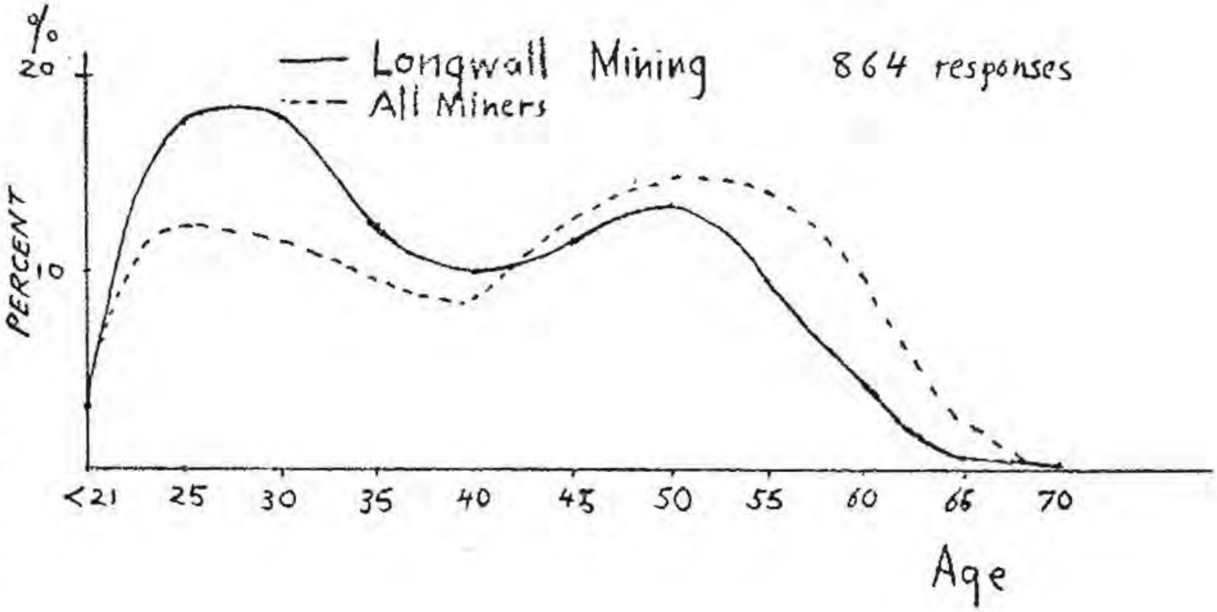
PERCENT MINERS IN EACH AGE GROUP FOR DIFFERENT MINING METHODS

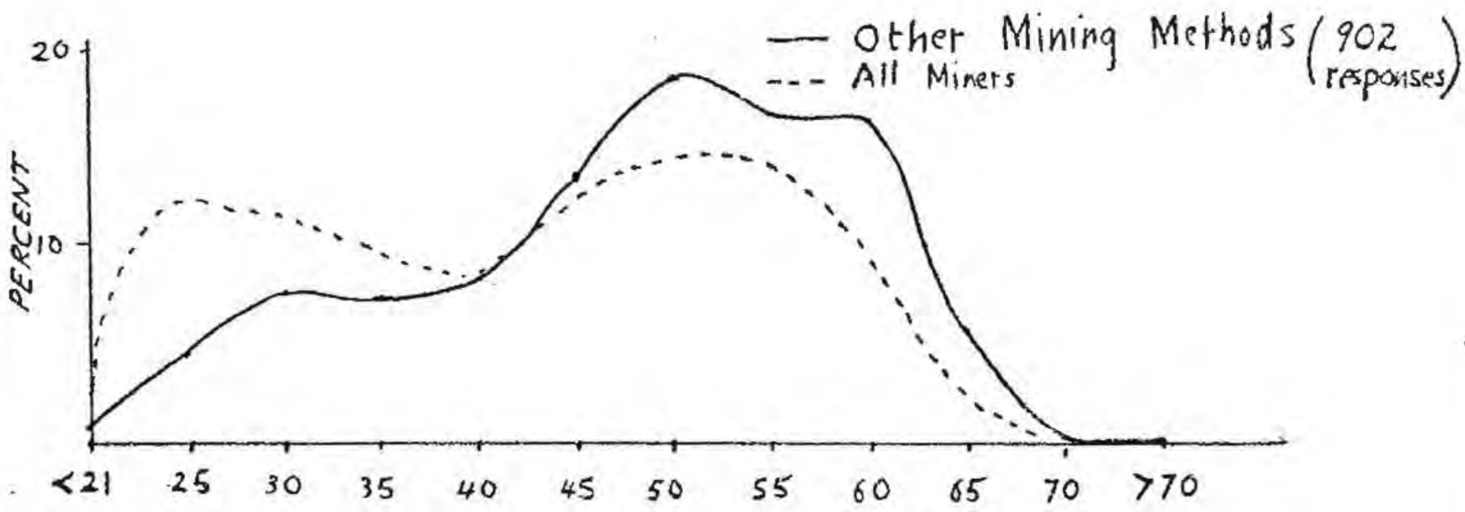




Prepared by Theodore Barry & Associates

PERCENT MINERS IN EACH AGE GROUP FOR DIFFERENT MINING METHODS





Prepared by Theodore Barry & Associates

TIME OF ACCIDENT

A theory of accident analysis that postulates randomness would require the time of accident to be random. An examination of the distribution of accidents by month, day of week, time of day and number of hours worked per shift prior to the accident shows this to be generally true (Exhibit 4-35 and Appendix 4-1). The 443 accidents in the Pittsburgh Seam have produced reasonably uniform distributions and all lie within the 95% confidence interval. That is, one can say with 95% confidence of being correct that the deviations that do occur are random.

The distribution of accidents by weekday is shown in Exhibit 4-36. Except for Saturday and Sunday the variation is not significant and is independent of the day of the week. Very few accidents are shown on Saturdays and Sundays, as these are not normal production days.

Many of the mines in the Pittsburgh Seam are on a three-shift production schedule. This results in accidents occurring throughout the 24 hours of the day as is shown in the frequency distribution in Appendix 4-1. Showing the number of accidents occurring in terms of the hours worked brings the different shifts and different start times to a comparable basis. The distribution is graphed in Exhibit 4-37. Note the peak for the period between 2 and 3 hours worked. The decline in the middle of the work period could possibly be attributed to the influence of lunch breaks. The second peak between 6 and 7 hours worked occurs just before the miners are preparing to end the shift.

An examination of the time of accident for various types of accidents shows an interesting pattern in the case of roof-fall accidents (Exhibit 4-38). Significantly more accidents occur in the period between 2 and 3 hours worked than at other times. Speculation as to the reason for this points to lack of adequate testing at the start of a shift. The miners have just started their daily tasks and the business of keeping an eye on the roof has been omitted. The low number of roof fall accidents at the start and end of a shift is probably due to the absence of workers in the main danger areas. Similarly, the slight decrease between 4 and 5 hours worked could probably be attributed to a larger percentage of men being away from the danger areas during their lunch breaks.

The national injury data for 1971 also indicates a randomness in the month of occurrence, except for the October-November 1971 period when the strike disrupted production. No national data is available on the hour of accident.

PERCENTAGE DISTRIBUTION OF NON-FATAL ACCIDENT IN PITTSBURGH SEAM BY TIME OF OCCURRENCE

443 VICTIMS - 1966 TO 1971

PREPARED BY THEODORE BARRY AND ASSOCIATES

EXHIBIT 4-35

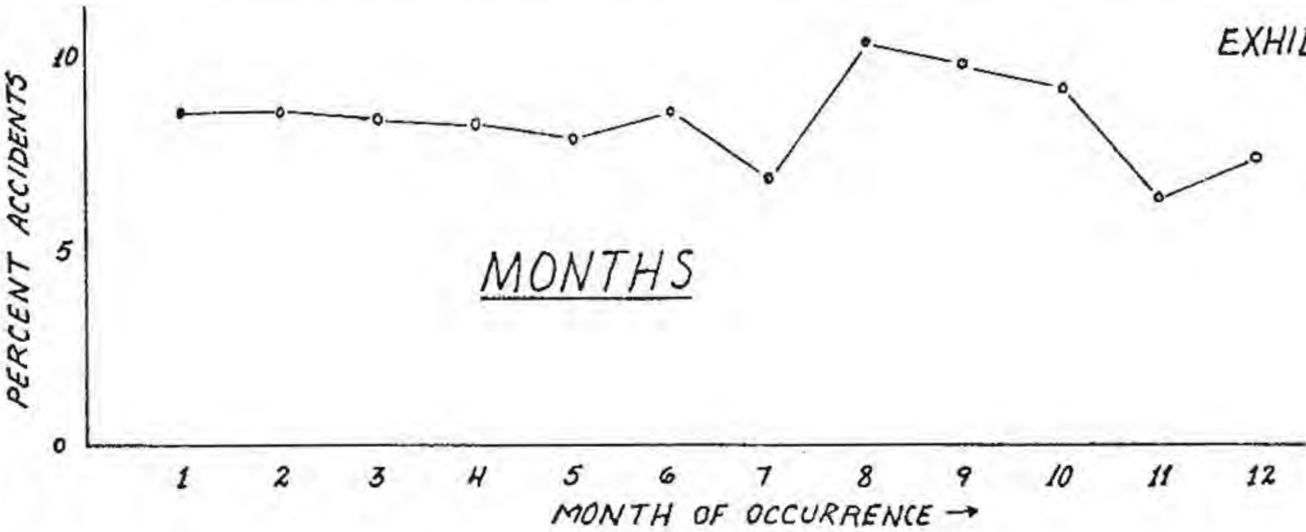


EXHIBIT 4-36

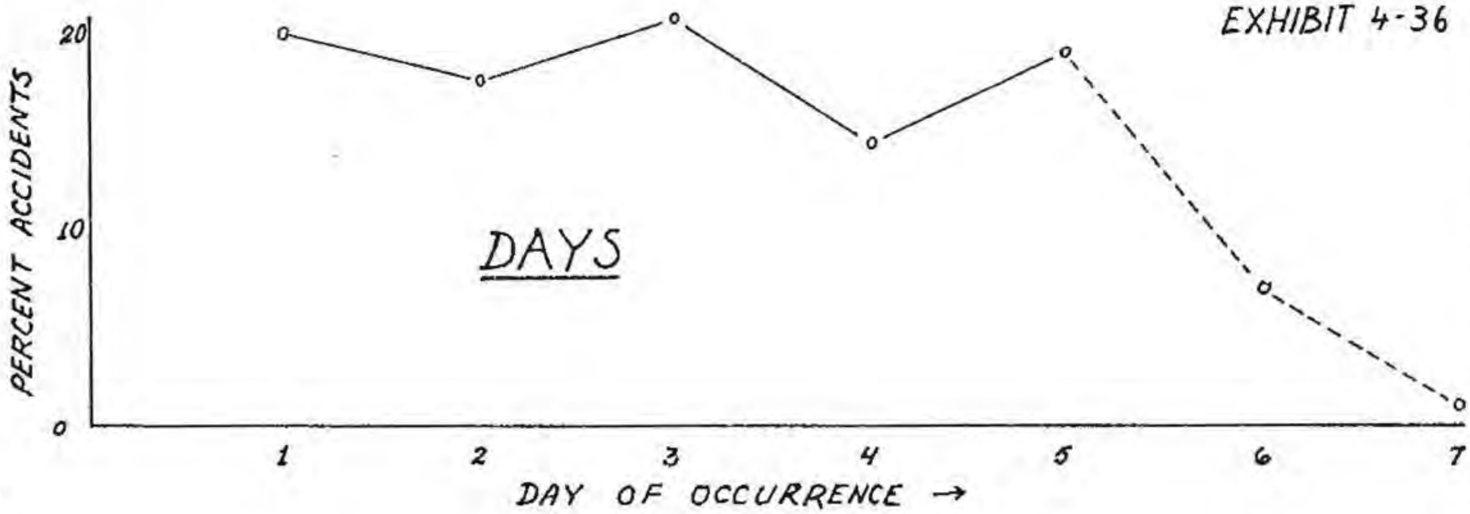


EXHIBIT 4-37

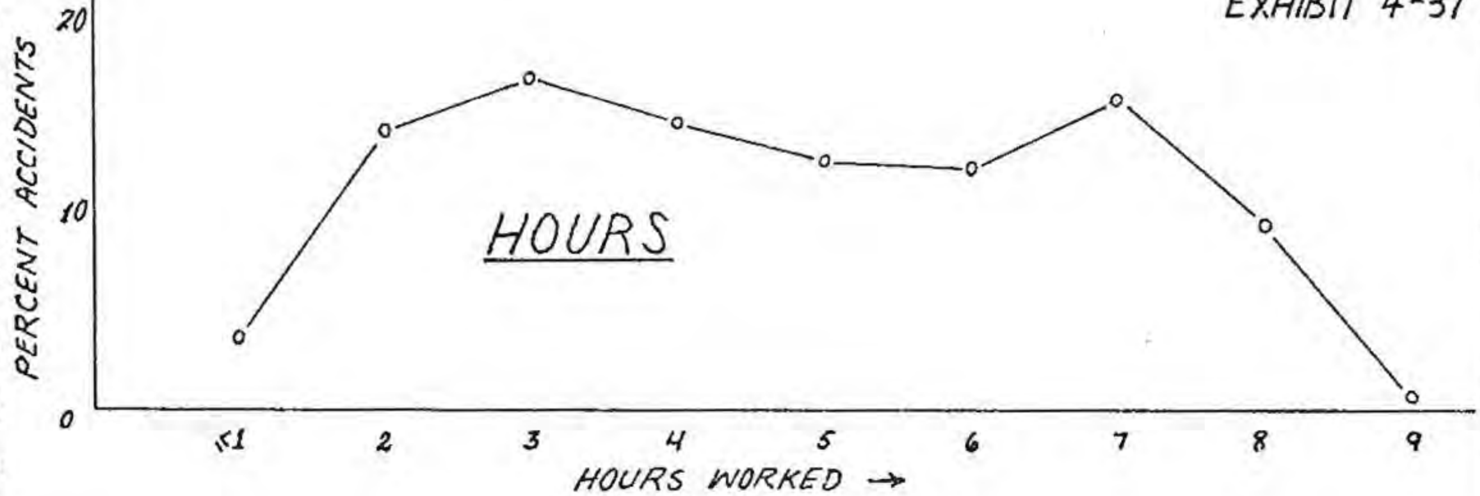
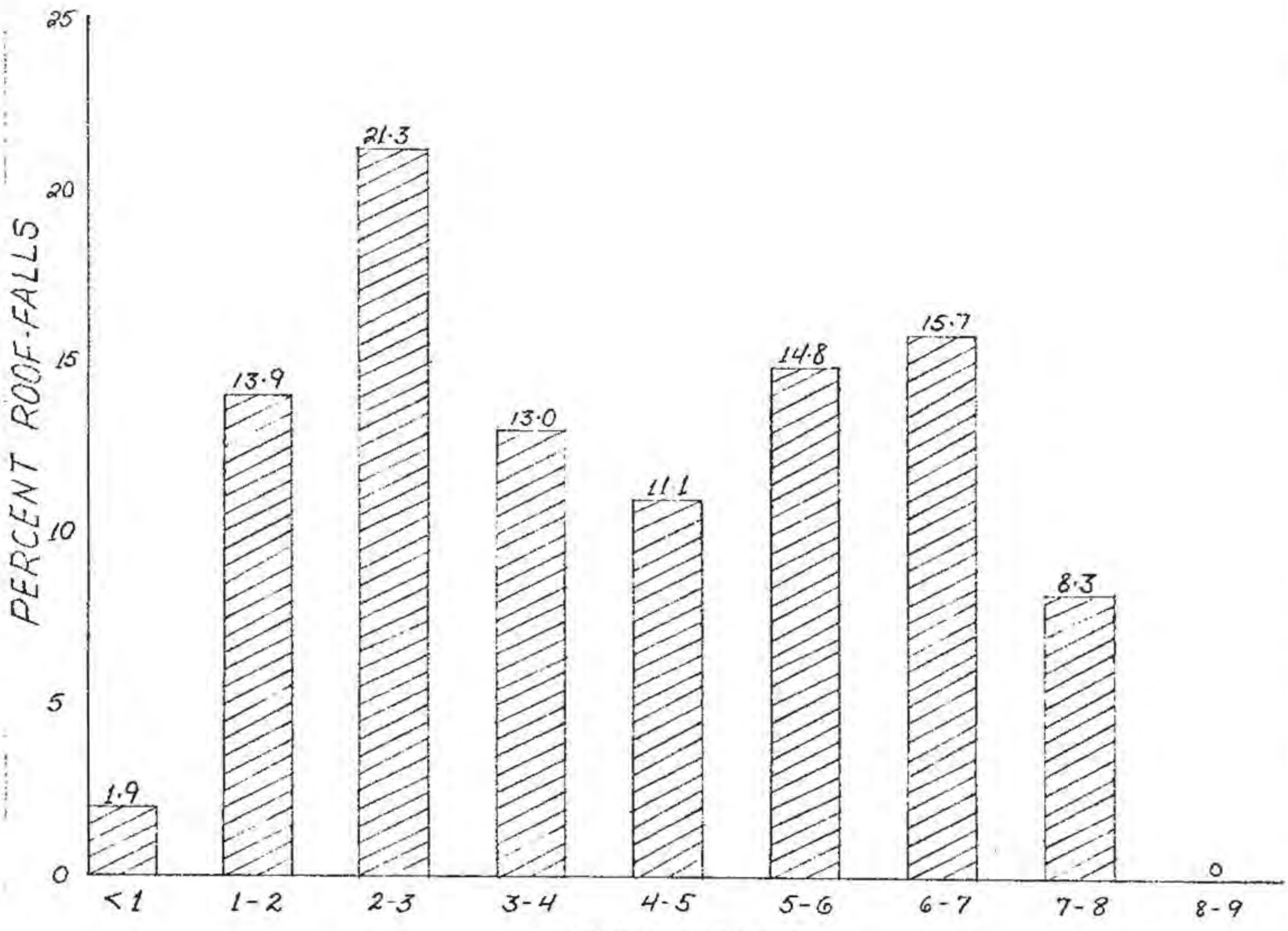


EXHIBIT 4-38

PERCENT OF ROOF FALL ACCIDENTS BY HOURS WORKED - PITTSBURGH SEAM

108 ACCIDENTS.



Prepared by Theodore Barry And Associates

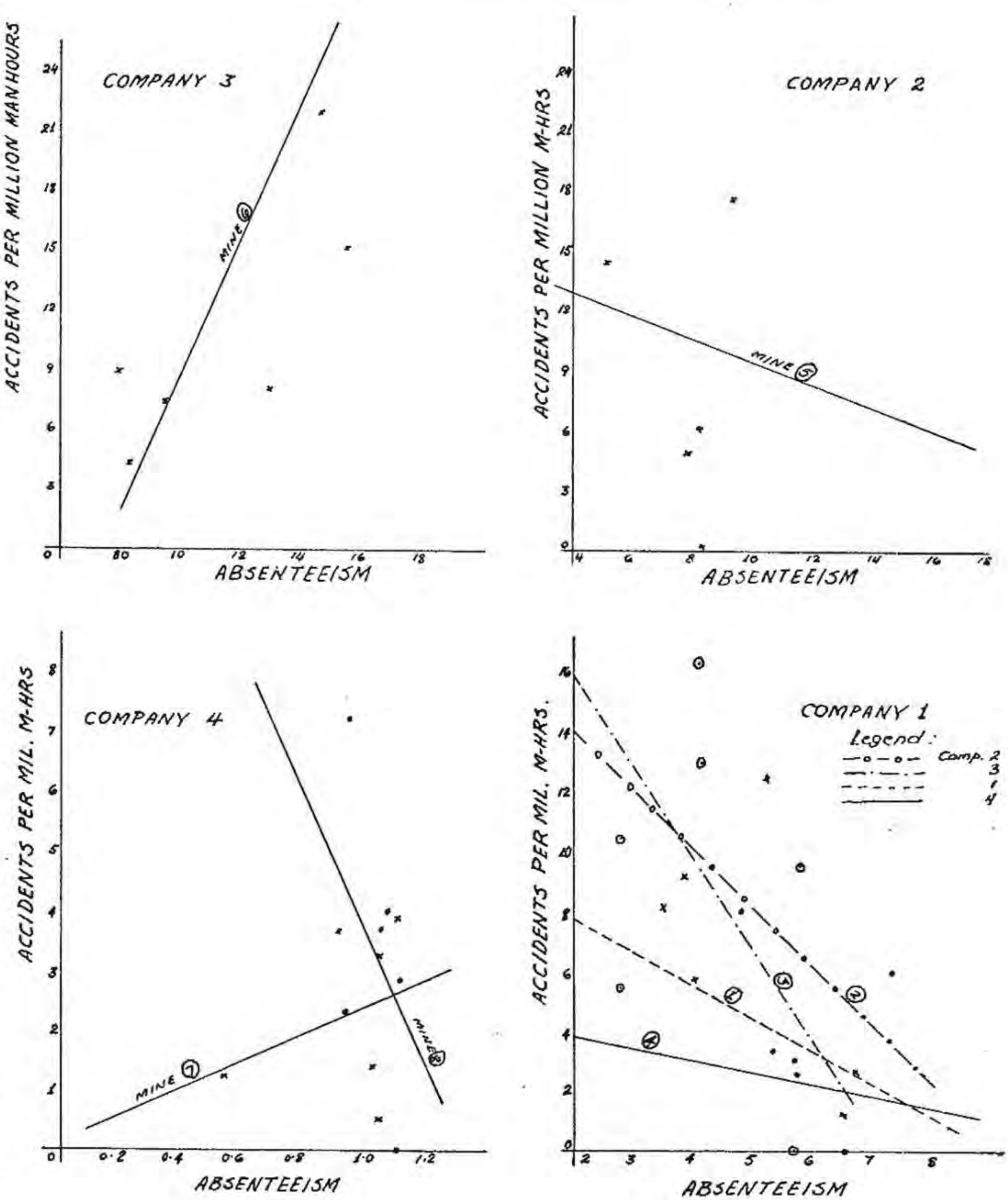
ABSENTEEISM

A mining production work crew may be considered as a group of men each working at different but interfacing tasks. The men form a team that can work efficiently and with a minimum of lost time and supervision only if each man knows and is experienced in his individual task. When a worker is absent from his normal task, another worker may be substituted to maintain production crew strength. And the substitute worker may not have had sufficient job experience to enable him to perform his temporary task safely. For this reason it was considered that a relationship might exist between the degree of job substitution that occurs in a mine and its accident rate. And it was believed that the closest indicator of the degree of job substitution in a mine would be its absentee rate.

Data was obtained from each cooperating mine in the Pittsburgh Seam on its absentee rate for each of the six years 1966 to 1971. This was correlated to its accident rate per million man-hours. The results are shown in Exhibit 4-39. For one mine the results were very encouraging with a positive correlation coefficient of 0.76. This showed that an increase in absenteeism correlated to an increase in the accident frequency rate. However, the results from the other mines were very disappointing with little or no correlation exhibited, and the slope of the curve varied from positive to negative. We now believe that if a direct relation between absenteeism and accidents exists, it would be shown by the degree of absenteeism on the day of the accident rather than the average absenteeism over the year. This information is not readily available on a historical basis, and could be worth requesting for any future mine accident study.

EXHIBIT 4-39

ABSENTEEISM VS. ACCIDENT RATE PITTSBURGH SEAM - 8 MINES

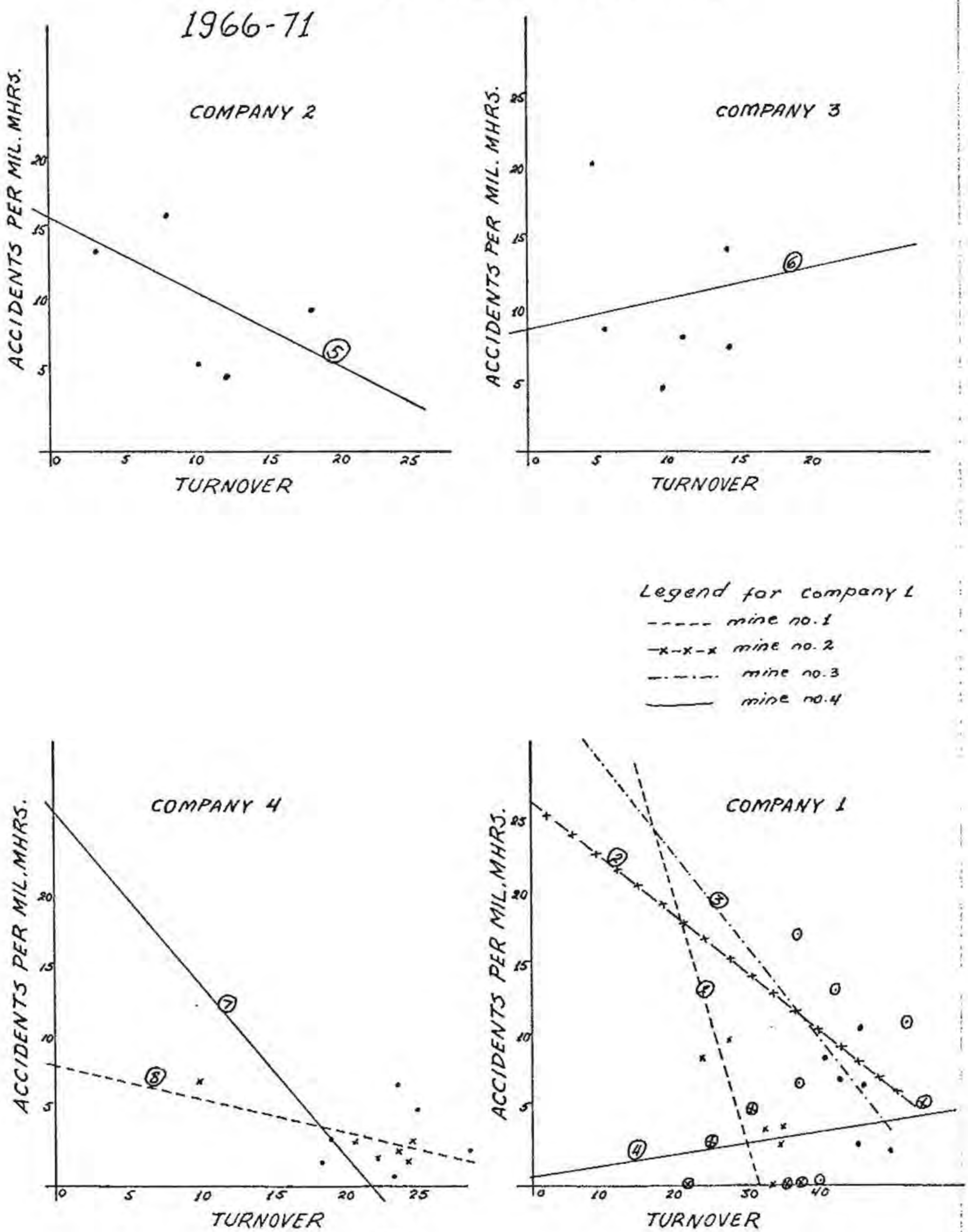


TURNOVER

Turnover is an indication of the number of men changing jobs in a mine. Men leave and new men are hired to replace them. The man who replaces a man who leaves will have little or no job experience. Hence, he should be more vulnerable to injury than an experienced worker, and it would be expected that a measure of turnover would relate to the accident frequency rate.

Information was obtained from the Pittsburgh Seam mines on turnover and job posting. Turnover was measured in terms of both men hired and men leaving. A plot of accident frequency against turnover, Exhibit 4-40, produced widely dispersed results with very poor fits. Two mines produced a slight positive correlation showing an increase in accident frequency as turnover increased, while the remaining six produced a poor negative correlation. This poor correlation indicates that turnover (as measured by men hired and men leaving) of mine workers do not significantly affect the accident rate in the Pittsburgh seam. Job posting was also viewed as a measure of turnover, and the effect of job posting on accident rates was also inconclusive. However, in this case it should also be noted that job posting was only introduced late in 1968 and did not show full momentum until 1971.

TURNOVER VS ACCIDENT RATE
PITTSBURGH SEAM - 8 MINES
1966-71



OTHER FACTORS

The influence of productivity; the combined factors of absenteeism, turnover and productivity; cyclical trends; and the time interval between accidents were examined for any relationship to the accident rate. Each is discussed separately below. These findings apply to the Pittsburgh Seam only. National data on these factors is not available.

Productivity

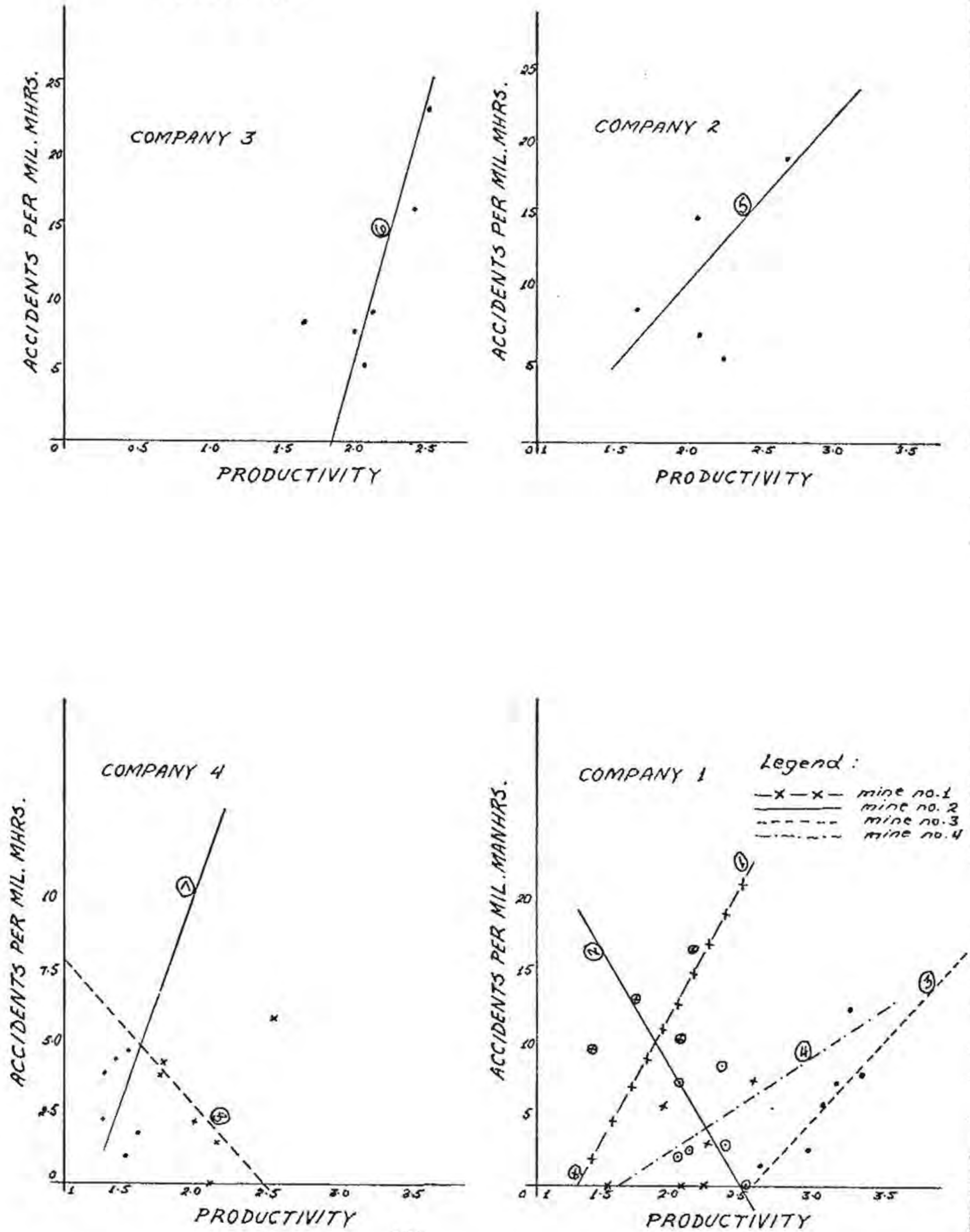
Productivity was examined to see if there was any relationship with accident frequency. A plot of productivity versus accident frequency rate is shown in Exhibit 4-41. For two mines there was a fair degree of correlation with accident frequency increasing as productivity increased, but the other mines showed poor fits and in two cases the curve was negatively sloped.

Combined Factors

An attempt was made to see if the combination of the variables absenteeism, turnover and productivity had any effect on accident frequency. A step-wise multiple regression was run using accident frequency as the dependent variable and absenteeism, productivity and turnover as the independent variables. The regression result turned out to be:

EXHIBIT 4-41

PRODUCTIVITY VS. ACCIDENT RATE
PITTSBURGH SEAM - 8 MINES
1966-71



$$F = 2.38 + 0.05A + 0.07P + 0.03T$$

where:

F = accidents/million man-hours

A = absenteeism in man-hours lost/1000 man-hours

P = productivity in tons/million man-hours

T = turnover in percent hired and leaving on total workforce

This regression explained only 20.7 percent of the variance, which indicates that other variables affect the accident rate.

Cyclical Trends

In the absence of any significant relationship between the accident rate and absenteeism, productivity and turnover, the distribution of accidents over time against these factors was examined to see if any trend existed. No trend could be located.

Time Interval Between Accidents

Since no significant relationship exists between any of the above variables and the accident frequency, the time interval between accidents was measured. This consisted of the number of days between accidents for each mine. Then an analysis was made to see if any significant difference resulted between the nature of an accident followed by a short interval. This was based on the hypothesis that miners would hear about severe accidents and generally be more cautious. Thus, a severe accident should be followed by a long-time interval before the next accident, and the longest time interval should follow a fatal accident. However, the results did not indicate this to be the case. There seems to be little evidence of any shock phenomenon throughout the mine population after serious accidents.

PITTSBURGH SEAM
NON - FATAL ACCIDENT FREQUENCY TABULATION
1966-1971

VARIABLE VAR011 MONTH OF ACCIDENT

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
JANUARY	1	38	8.6	8.6	8.6
FEBRUARY	2	38	8.6	8.6	17.2
MARCH	3	37	8.4	8.4	25.6
APRIL	4	36	8.1	8.2	33.8
MAY	5	35	7.9	7.9	41.7
JUNE	6	38	8.6	8.6	50.3
JULY	7	30	6.8	6.8	57.1
AUGUST	8	46	10.4	10.4	67.6
SEPTEMBER	9	43	9.7	9.8	77.3
OCTOBER	10	40	9.0	9.1	86.4
NOVEMBER	11	28	6.3	6.3	92.7
DECEMBER	12	32	7.2	7.3	100.0
NOT STATED	0	2	0.5	MISSING	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR013 YEAR OF ACCIDENT

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
	1970	86	19.4	19.4	19.4
	1971	41	9.3	9.3	28.7
	1966	50	11.3	11.3	40.0
	1967	97	21.9	21.9	61.9
	1968	84	19.0	19.0	80.8
	1969	85	19.2	19.2	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR014 WEEKDAY ACCIDENT OCCURED

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
MON	1	85	19.9	20.0	20.0
TUE	2	78	17.6	17.7	37.6
WED	3	92	20.8	20.9	58.5
THUR	4	63	14.2	14.3	72.8
FRI	5	84	19.0	19.0	91.8
SAT	6	31	7.0	7.0	98.9
SUN	7	5	1.1	1.1	100.0
NOT STATED	0	2	0.5	MISSING	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR015 TIME OF ACCIDENT

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
1:00 AM TO 2:00 AM	1	10	2.3	2.5	2.5
2:00 AM TO 3:00 AM	2	21	4.7	5.2	7.6
3:00 AM TO 4:00 AM	3	15	3.4	3.7	11.3
4:00 AM TO 5:00 AM	4	16	3.6	3.9	15.2
5:00 AM TO 6:00 AM	5	15	3.4	3.7	18.9
6:00 AM TO 7:00 AM	6	7	1.6	1.7	20.6
7:00 AM TO 8:00 AM	7	18	4.1	4.4	25.1
8:00 AM TO 9:00 AM	8	11	2.5	2.7	27.8
9:00 AM TO 10:00 AM	9	24	5.4	5.9	33.7
10:00 AM TO 11:00 AM	10	17	3.8	4.2	37.8
11:00 AM TO 12:00 PM	11	35	7.9	8.6	46.4
12:00 PM TO 1:00 PM	12	26	5.9	6.4	52.8
1:00 PM TO 2:00 PM	13	25	5.6	6.1	59.0
3:00 PM TO 4:00 PM	15	26	5.9	6.4	65.4
4:00 PM TO 5:00 PM	16	9	2.0	2.2	67.6
5:00 PM TO 6:00 PM	17	14	3.2	3.4	71.0
6:00 PM TO 7:00 PM	18	16	3.6	3.9	74.9
7:00 PM TO 8:00 PM	19	19	4.3	4.7	79.6
8:00 PM TO 9:00 PM	20	14	3.2	3.4	83.0
9:00 PM TO 10:00 PM	21	19	4.3	4.7	87.7
10:00 PM TO 11:00 PM	22	14	3.2	3.4	91.2
11:00 PM TO 12:00 AM	23	30	6.8	7.4	98.5
MIDNIGHT TO 1:00 AM	24	6	1.4	1.5	100.0
NOT STATED	0	36	8.1	MISSING	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR015 START TIME

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
7:00 AM	7	1	0.2	0.2	0.2
8:00 AM	8	186	42.0	43.3	43.5
9:00 AM	9	2	0.5	0.5	44.0
4:00 PM	16	132	29.8	30.7	74.7
MIDNIGHT	24	109	24.6	25.3	100.0
NOT STATED	0	12	2.7	MISSING	100.0
OUT OF RANGE		1	0.2	MISSING	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR017 HOURS WORKED

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
UNDER 1 HOUR	1	16	3.6	3.7	3.7
1 TO 2	2	61	13.8	14.2	17.9
2 TO 3	3	73	16.5	17.0	34.9
3 TO 4	4	63	14.2	14.7	49.5
4 TO 5	5	54	12.2	12.6	62.1
5 TO 6	6	53	12.0	12.3	74.4
6 TO 7	7	68	15.3	15.8	90.2
7 TO 8	8	40	9.0	9.3	99.5
8 TO 9	9	2	0.5	0.5	100.0
NOT STATED	0	13	2.9	MISSING	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR020 TYPE OF ACCIDENT

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
ELECTRICITY	1	8	1.8	1.8	1.8
EXPLOD BREAKING AGENT	2	4	0.9	0.9	2.7
FALL OF FACE OR RIB	4	25	5.6	5.7	8.4
FALL OF ROOF	5	111	25.1	25.1	33.5
HAND TOOL	6	22	5.0	5.0	38.5
HANDLING MATERIAL	7	39	8.8	8.8	47.3
HAULAGE-MAINLINE	3	64	14.4	14.5	61.8
MACHINERY	12	63	14.2	14.3	76.0
PRESSURE BUMP BURST	15	1	0.2	0.2	76.2
SLIDE-SLIP MATERIAL	16	6	1.4	1.4	77.6
SLIP OR FALL-PERSON	17	16	3.6	3.6	81.2
STEP-KNEL ON OBJECT	18	6	1.4	1.4	82.6
STRIKING-BUMPING	19	8	1.8	1.8	84.4
HAULAGE-SECONDARY	22	35	7.9	7.9	92.3
HAULAGE-?	23	11	2.5	2.5	94.8
HAULAGE-SQUEEZED	24	23	5.2	5.2	100.0
N. A.	0	1	0.2	MISSING	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR021 DAYS LOST

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
1 TO 7 DAYS	1	8	1.8	3.9	3.9
8 TO 21 DAYS	2	63	14.2	30.6	34.5
22 TO 60 DAYS	3	68	15.3	33.0	67.5
61 TO 180 DAYS	4	45	10.2	21.8	89.3
181 TO 365 DAYS	5	16	3.6	7.8	97.1
732 TO 999 DAYS	7	2	0.5	1.0	98.1
OVER 999 DAYS	8	4	0.9	1.9	100.0
NOT STATED	0	237	53.5	MISSING	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR022 PART OF BODY INJURED

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
HEAD&NECK	1	42	9.5	9.6	9.6
EYE	2	11	2.5	2.5	12.1
TRUNK	3	101	22.8	23.1	35.2
ARM	4	28	6.3	6.4	41.6
HAND	5	62	14.0	14.2	55.7
LEG	6	77	17.4	17.6	73.3
FOOT	7	95	21.4	21.7	95.0
MULTIPLE	8	22	5.0	5.0	100.0
	0	5	1.1	MISSING	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR023 LOCATION OF ACCIDENT

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
FACE	1	191	43.1	44.9	44.9
INTERSECT	2	7	1.6	1.6	46.6
CROSSCUT	3	7	1.6	1.6	48.2
HAULAGE	4	76	17.2	17.9	66.1
ENTRY	5	124	28.0	29.2	95.3
PILLER	6	10	2.3	2.4	97.6
BREAKTHRU	7	10	2.3	2.4	100.0
	0	18	4.1	MISSING	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR024 ENTRY WIDTH

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
WIDTH IN FEET	11	2	0.5	0.6	0.6
	13	2	0.5	0.6	1.3
	14	2	0.5	0.6	1.9
	15	19	4.3	5.8	7.8
	16	277	62.5	89.6	97.4
	17	3	0.7	1.0	98.4
	18	4	0.9	1.3	99.7
	19	1	0.2	0.3	100.0
NOT STATED	0	134	30.2	MISSING	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR025 ROOF HEIGHT

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
43 TO 48	5	1	0.2	0.4	0.4
49 TO 60	6	2	0.5	0.7	1.1
61 TO 72	7	74	16.7	26.0	27.0
73 TO 84	8	193	43.6	67.7	94.7
85 TO 96	9	10	2.3	3.5	98.2
OVER 96	10	5	1.1	1.8	100.0
NOT STATED	0	158	35.7	MISSING	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR026 WET OR DRY

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
WET	1	36	8.1	14.1	14.1
DRY	2	220	49.7	85.9	100.0
NOT STATED	0	187	42.2	MISSING	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR027 ROOF TYPE

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
SHALE	2	2	0.5	0.6	0.6
DRAWSLATE	4	224	50.6	70.7	71.3
BONE	5	15	3.4	4.7	76.0
SANDSTONE	6	2	0.5	0.6	76.7
SANDESHALE	7	70	15.8	22.1	98.7
COAL	8	4	0.9	1.3	100.0
NOT STATED	0	126	28.4	MISSING	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR028

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
BOLTS	1	239	54.0	70.7	70.7
RIB POSTS	2	1	0.2	0.3	71.0
BOLTS & POSTS	3	9	2.0	2.7	73.7
BOLTS & SAFETYJACKS	4	13	2.9	3.8	77.5
NONE	5	7	1.6	2.1	79.6
BOLT, CHANNEL, PLANKS	6	69	15.6	20.4	100.0
NOT STATED	0	105	23.7	MISSING	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR029 VICTIM JOB CLASSIFICATION

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
BRAKEMAN	0	20	4.5	4.5	4.5
C-M OP	1	28	6.3	6.3	10.8
C-M HLP	2	7	1.6	1.6	12.4
BELTMAN	3	2	0.5	0.5	12.9
CUTTERO	4	3	0.7	0.7	13.5
CUTTER H	5	2	0.5	0.5	14.0
GENERAL LABOUR	9	26	5.9	5.9	19.9
LOADM O	11	26	5.9	5.9	25.7
LOADM HELPER	12	2	0.5	0.5	26.2
MECHANIC	14	37	8.4	8.4	34.5
MOTORMAN	16	42	9.5	9.5	44.0
R DUSTER	17	3	0.7	0.7	44.7
RF BOLTER	18	102	23.0	23.0	67.7
SHOTFIRE	19	6	1.4	1.4	69.1
SHUTTLE	20	46	10.4	10.4	79.5
TIMBERMAN	21	10	2.3	2.3	81.7
TRACKMAN	22	6	1.4	1.4	83.1
VENTMAN	23	9	2.0	2.0	85.1
SUPPLYMAN-UTILITY	26	26	5.9	5.9	91.0
WORK SUPER	27	4	0.9	0.9	91.9
GENERAL SUPER	28	23	5.2	5.2	97.1
FIREBOSS	29	1	0.2	0.2	97.3
OTHER	32	12	2.7	2.7	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR030 VICTIM AGE

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
UNDER 21	1	4	0.9	0.9	0.9
21 TO 25	2	9	2.0	2.1	3.0
26 TO 30	3	10	2.3	2.3	5.3
31 TO 35	4	5	1.1	1.2	6.5
36 TO 40	5	15	3.4	3.5	10.0
41 TO 45	6	62	14.0	14.4	24.3
46 TO 50	7	88	19.9	20.4	44.7
51 TO 55	8	119	26.9	27.5	72.2
56 TO 60	9	82	18.5	19.0	91.2
61 TO 65	10	37	8.4	8.6	99.8
66 TO 70	11	1	0.2	0.2	100.0
	0	11	2.5	MISSING	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR032 TOTAL UNDERGROUND EXP

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
2 TO 3 MONTHS	2	4	0.9	1.2	1.2
4 TO 6 MONTHS	3	2	0.5	0.6	1.7
7 TO 12 MONTHS	4	4	0.9	1.2	2.9
12 TO 18 MONTHS	5	7	1.6	2.0	4.9
18 TO 23 MONTHS	6	1	0.2	0.3	5.2
2 TO 3 YEARS	7	7	1.6	2.0	7.2
3 TO 4 YEARS	8	3	0.7	0.9	8.1
4 TO 5 YEARS	9	1	0.2	0.3	8.4
5 TO 10 YEARS	10	5	1.1	1.4	9.8
10 TO 15 YEARS	11	14	3.2	4.0	13.9
15 TO 20 YEARS	12	24	5.4	6.9	20.8
20 TO 25 YEARS	13	57	12.9	16.5	37.3
25 TO 30 YEARS	14	68	15.3	19.7	55.9
30 TO 35 YEARS	15	81	18.3	23.4	80.3
35 TO 40 YEARS	16	46	10.4	13.3	93.6
40 TO 45 YEARS	17	22	5.0	6.4	100.0
NOT STATED	0	91	20.5	MISSING	100.0
OUT OF RANGE (OVER 45 YEARS)		6	1.4	MISSING	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR033 JOB EXPERIENCE

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
LE 1 MONTH	1	27	6.1	7.4	7.4
2 TO 3 MONTHS	2	20	4.5	5.5	12.9
4 TO 6 MONTHS	3	24	5.4	6.6	19.6
7 TO 12 MONTHS	4	30	6.8	8.3	27.8
12 TO 18 MONTHS	5	12	2.7	3.3	31.1
18 TO 23 MONTHS	6	2	0.5	0.6	31.7
2 TO 3 YEARS	7	34	7.7	9.4	41.0
3 TO 4 YEARS	8	20	4.5	5.5	46.6
4 TO 5 YEARS	9	19	4.3	5.2	51.8
5 TO 10 YEARS	10	54	12.2	14.9	66.7
10 TO 15 YEARS	11	63	14.2	17.4	84.0
15 TO 20 YEARS	12	29	6.5	8.0	92.0
20 TO 25 YEARS	13	16	3.6	4.4	96.4
25 TO 30 YEARS	14	8	1.8	2.2	98.6
30 TO 35 YEARS	15	4	0.9	1.1	99.7
35 TO 40 YEARS	16	1	0.2	0.3	100.0
NOT STATED	0	80	18.1	MISSING	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR034 THIS MINE EXPERIENCE

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
UNDER 1 MONTH	1	1	0.2	0.3	0.3
1 TO 3 MONTHS	2	9	2.0	2.4	2.6
4 TO 6 MONTHS	3	5	1.1	1.3	4.0
7 TO 11 MONTHS	4	7	1.6	1.9	5.8
12 TO 18 MONTHS	5	20	4.5	5.3	11.1
18 TO 23 MONTHS	6	3	0.7	0.8	11.9
2 TO 3 YEARS	7	23	5.2	6.1	18.0
3 TO 4 YEARS	8	7	1.6	1.9	19.8
4 TO 5 YEARS	9	8	1.8	2.1	22.0
5 TO 10 YEARS	10	21	4.7	5.6	27.5
10 TO 15 YEARS	11	29	6.5	7.7	35.2
15 TO 20 YEARS	12	41	9.3	10.8	46.0
20 TO 25 YEARS	13	67	15.1	17.7	63.8
25 TO 30 YEARS	14	53	12.0	14.0	77.8
30 TO 35 YEARS	15	56	12.6	14.8	92.6
35 TO 40 YEARS	16	20	4.5	5.3	97.9
40 TO 45 YEARS	17	7	1.6	1.9	99.7
45 TO 50 YEARS	18	1	0.2	0.3	100.0
NOT STATED	0	65	14.7	MISSING	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR035 VICTIM DOING AT TIME OF ACCIDENT

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
CHANGE BIT	2	1	0.2	0.2	0.2
CHANGE DRILL	3	5	1.1	1.1	1.4
CLEAN UP	6	2	0.5	0.5	1.8
CONTINUOUS MINE	7	15	3.4	3.4	5.2
EXTEND DRILL	9	1	0.2	0.2	5.4
DRILL ROOF	11	34	7.7	7.7	13.1
ELECTRCAL MAINTEN	14	2	0.5	0.5	13.5
GET READY	15	7	1.6	1.6	15.1
HANG TUBING	17	1	0.2	0.2	15.3
INSERT BOLT	19	10	2.3	2.3	17.6
INSERT CHARGE	20	2	0.5	0.5	18.1
INSPECT EQUIPMENT	21	1	0.2	0.2	18.3
INSPECT MINE	22	3	0.7	0.7	19.0
LOAD SHUTTLE	23	11	2.5	2.5	21.4
JACK SET	24	2	0.5	0.5	21.9
MOVE CABLES	27	11	2.5	2.5	24.4
MACHINE MAINTENANCE	29	18	4.1	4.1	28.4
SERVICE MACHINE	30	9	2.0	2.0	30.5
MARK ROOF	31	1	0.2	0.2	30.7
POSITION EQUIPMENT	33	18	4.1	4.1	34.8
PRY FACE-RIB	34	4	0.9	0.9	35.7
ROCK DUST	35	1	0.2	0.2	35.9
SET PROPS	36	19	4.3	4.3	40.2
RELOCATE PROPS	37	9	2.0	2.0	42.2
REMOVE PROPS	38	1	0.2	0.2	42.4
SET BRATTICE	40	7	1.6	1.6	44.0
SHOOT COAL	41	2	0.5	0.5	44.5
CLEANUP FALL	43	1	0.2	0.2	44.7
SWEEP FLOOR	44	1	0.2	0.2	44.9
SURVEY LAYOUT	45	1	0.2	0.2	45.1
SCALE ROOF	45	11	2.5	2.5	47.6
TRAM IN	50	14	3.2	3.2	50.8
TRAM OUT	51	1	0.2	0.2	51.0
TORQUE BOLT	52	2	0.5	0.5	51.5
TEST ROOF	53	2	0.5	0.5	51.9
TANSPORT SUPPLY	54	13	2.9	2.9	54.9
OPERATE SHUTTLE CAR	51	13	2.9	2.9	57.8
OPERATE JITNEY	52	1	0.2	0.2	58.0
OP MAIN-HAULAGE EQU	54	23	5.2	5.2	63.2
LAY TRACK	66	9	2.0	2.0	65.2
SUPERVISE	67	5	1.1	1.1	66.4
OBSERVE OPERATIONS	68	3	0.7	0.7	67.0
IDLE	69	6	1.4	1.4	68.4
RIDE EQUIPMENT	70	9	2.0	2.0	70.4
COUPLE-UN MINE CAR	71	27	6.1	6.1	76.5
SWITCH TRACKS	72	1	0.2	0.2	76.7
SPRAG-BK-CK MINE CAR	73	2	0.5	0.5	77.2
LOAD-UN MINE CAR	74	12	2.7	2.7	79.9
RERAIL EQUIPMENT	75	7	1.6	1.6	81.5
OTHER	76	26	5.9	5.9	87.4
RECOVER MATERIAL/EQUIPMENT	79	4	0.9	0.9	88.3
ESCAPING	81	7	1.6	1.6	89.8
UNKNOWN	82	4	0.9	0.9	90.7
REPLACE TROLLEY POLE	83	2	0.5	0.5	91.2
WALK	86	19	4.1	4.1	95.3
OPERATE LOADER	87	8	1.8	1.8	97.1
ROOF BUILT	83	12	2.7	2.7	99.8
N.S.	90	1	0.2	0.2	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR036 TASK EXPERIENCE

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
LE 1 MONTH	1	25	5.6	8.6	8.6
2 TO 3 MONTHS	2	19	4.3	6.6	15.2
4 TO 6 MONTHS	3	23	5.2	7.9	23.1
7 TO 12 MONTHS	4	26	5.9	9.0	32.1
12 TO 18 MONTHS	5	11	2.5	3.8	35.9
18 TO 23 MONTHS	6	1	0.2	0.3	36.2
2 TO 3 YEARS	7	28	6.3	9.7	45.9
3 TO 4 YEARS	8	14	3.2	4.8	50.7
4 TO 5 YEARS	9	17	3.8	5.9	56.6
5 TO 10 YEARS	10	40	9.0	13.8	70.3
10 TO 15 YEARS	11	45	10.2	15.5	85.9
15 TO 20 YEARS	12	20	4.5	6.9	92.8
20 TO 25 YEARS	13	14	3.2	4.8	97.6
25 TO 30 YEARS	14	1	0.2	0.3	97.9
30 TO 35 YEARS	15	4	0.9	1.4	99.3
35 TO 40 YEARS	16	2	0.5	0.7	100.0
	0	153	34.5	MISSING	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR037 NATURE OF INJURY

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
FRACTURE	4	103	23.3	45.6	45.6
BURNS	6	7	1.6	3.1	48.7
COMBO & OTHER	7	3	0.7	1.3	50.0
CUTS STRAIN BRUISE	8	85	19.2	37.6	87.6
AMPUTATION	9	28	6.3	12.4	100.0
NOT STATED	0	217	49.0	MISSING	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR038 FOREMAN PRESENT

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
NO	1	267	60.3	98.5	98.5
YES	2	3	0.7	1.1	99.6
INJURED	3	1	0.2	0.4	100.0
NOT STATED	0	172	38.8	MISSING	100.0
	TOTAL	443	100.0	100.0	

VARIABLE VAR039 JOB VICTIM SUBSTITUTING FOR

CATEGORY LABEL	CODE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (PERCENT)	ADJUSTED FREQUENCY (PERCENT)	CUMULATIVE ADJ FREQ (PERCENT)
C-M HLP	2	1	0.2	9.1	9.1
CUTTER H	5	1	0.2	9.1	18.2
LOADM O	11	2	0.5	18.2	36.4
RE BOLTER	18	4	0.9	36.4	72.7
SHUTTLE	20	1	0.2	9.1	81.8
TIMBERMAN	21	1	0.2	9.1	90.9
N. A.	33	1	0.2	9.1	100.0
NOT STATED	0	432	97.5	MISSING	100.0
	TOTAL	443	100.0	100.0	

CALCULATION OF JOB MOBILITY

The employee history file maintained by the U. S. Bureau of Mines contains information on the latest job category, the date the first record was entered onto the file and the number of occupation changes as reported from respirable dust sample data submitted to the Bureau. It is possible to calculate job mobility for approximately 85,000 underground coal miners by noting the number of job changes in the dust sample data over the period starting with the first dust sample. The initial samples were distributed over 18 months, beginning July 1970.

The procedure for estimating job mobility involved dividing the year into quarters, and comparing the number of job changes between the quarter in which information was first entered into the file and the date of file processing to calculate job mobility. The number of miners entering the file each quarter were divided into two categories: those who had no job changes and those who had one or more in this or any succeeding quarter. The total number of miners who had changed jobs was shown as a percentage. This percentage was divided by the number of succeeding quarters between that quarter and the second quarter of 1972 which yielded an average percent change each quarter. The average quarterly in figure was divided by three to give the monthly percent change. For example, of the 3,653 miners entering the file in the third quarter 1970, 1,753 or 48% changed their job in this or one of the succeeding six quarters until 1972. Dividing 48 by 6 gives a quarterly change of 8%. In a similar way the change for the other quarters was calculated. The average quarterly change was 9.70%, the average monthly change was 3.23% and the annual change 38.81%. Table A shows the approximate job mobility of all underground miners. Table B shows the job mobility for some selected job classifications. This was calculated in a similar manner to the overall underground miner job mobility in Table A.

TABLE A

JOB MOBILITY OF ALL MINERS

Calculated from the Employee History File

Date first entered into file	3rd Quarter 1970	4th Quarter 1970	1st Quarter 1971	2nd Quarter 1971	3rd Quarter 1971
Number entering each quarter	3,653	14,403	11,605	8,101	6,021
Number of changes up until 1972	1,753	7,159	5,503	2,864	836
Percent change	47.99%	49.70%	47.42%	35.35%	13.88%
Number of quarters to 1972	6	5	4	3	2
Percent change per quarter	8.00%	9.94%	11.85%	11.78%	6.94%

Average percent change per quarter = 9.70%

Average percent change per month = 3.23%

Average percent change per year = 38.81%

TABLE B

JOB MOBILITY FOR SELECTED OCCUPATIONS

Calculated from the Employee History File

	Monthly Average	Quarterly Average	Annual Average
Motorman	1.72%	5.17%	20.68%
Shuttle Car Operator	2.33%	7.00%	28.00
Loading M/C Operator	2.81%	8.42%	33.68%
Roofbolter	2.82%	8.46%	33.84%
Continuous Miner Operator	3.31%	9.94%	39.76%
Timberman	3.74%	11.23%	44.92%
All Mines	3.23%	9.70%	38.81%

JOB MOBILITY FACTORS
CORRECTED FOR FACE/NON-FACE
MOVEMENT AND VICE VERSA

Occupation	Original Monthly % Change	Correction Factor	Final Monthly % Change
Vent/Brattice	4.41	0.2033	3.51
Beltman	4.05	0.2737	2.94
Supply/Utility	3.95	0.2837	2.83
Laborer	3.93	0.4944	1.99
Timberman	3.64	0.0441	3.62
Electrician	2.77	0.2786	2.00
Mechanic	2.56	0.4574	1.39

The correction factor was obtained by examining the cross-tabulation of occupation one by occupation two for the percent change between face and non-face categories, and vice versa.

CHAPTER 5

THE SAFETY PROFILE ANALYZER

THE ORIGINAL STUDY CONCEPT

Theodore Barry and Associates proposed in early 1971 to develop a pre-accident safety analysis device which would allow mine managers and inspectors to assess the accident producing potential of a given mine more accurately and to take steps to correct the identified hazardous conditions before an accident occurs. The proposed device, originally known as the Safety Profile Analyzer (SPA), would also serve as a tool for measuring the effectiveness of various accident prevention and safety programs.

The SPA was to consist of an interrelated set of factors that were found to contribute to all underground bituminous coal mine accidents. Fires and explosions were excluded. These factors would take on a range of values from very safe to extremely hazardous and would be scaled according to their importance as accident predictors relative to the other factors. When applied to a specific mine or mine section, the device would describe the safety profile of the mine, highlighting those factors that have become critical from a safety viewpoint and indicating the most appropriate kind of remedial action to take.

Initially the model was to be developed, tested, and implemented in mines in the Pittsburgh Seam in Pennsylvania. A specific seam was selected to permit an in-depth and more detailed study of accident problems in specific mines. Restricting the study to the same seam provides some commonality of geological characteristics if not uniformity. For example, the coal characteristics, the seam height, the roof conditions, the overlying and underlying strata, and the ground pressure and overburden tend to be relatively similar. Moreover, and just as important as the geology, the mining practices, the equipment, the state mining laws, the labor practices, the state and Bureau of Mines inspection and enforcement policies, and the myths and the well-founded beliefs of safe mining practice, all tend to be more uniform in a restricted geographical area. By keeping all these factors relatively consistent, it was felt that the potential effect of management policies and safety practices on accident rates would be easier to identify.

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1. The Pittsburgh Seam is part of the Main Bituminous Coal Field of Pennsylvania, and it extends into West Virginia. Pennsylvanian Reserves are now mainly in the Washington and Greene Counties with small areas in adjacent counties. Although the Pittsburgh Seam is restricted to a relatively small part of the Main Bituminous Field, the persistant 4 to 6 foot thickness makes it one of the main sources of mineable coal. The geological structure is basically a series of broad, low, northeast-southwest trending anticlines and synclines. Dips are generally less than 2^{o} and rarely more than 8^{o}. There are no known significant geological faults to present problems in mining continuity. Production is almost entirely from large underground mines, many of which are captive or owned by large steel, oil, or utility companies.

Among candidate seams, the Pittsburgh Seam was selected for a number of reasons:

- The major mines in this seam are "captive" mines, i.e., mines which are owned by large steel, utility, oil or holding companies. These mines were judged more likely to have good internal recorded data germane to the study and were thought to be more willing to cooperate and be interested in the objectives of the SPA.
- A number of Bureau roof control experts recommended the seam as a seam with very difficult roof control problems. (Originally the SPA study was restricted to roof fall hazards.)

The initial methodology proposed for developing the SPA model involved determining quantifiable measures for safety factors. The measures would then be related to the probability of accidents via accident analysis and via the Delphi technique applied to interviews with mine safety experts and to published material on mine safety. Having developed a theoretical profile instrument for assessing the mine accident potential in the first phase of the study, a second phase would implement and test the instrument. The third phase of the study would consist of formulating revisions and providing an overall evaluation of the approach.

The steps to achieve the SPA model were as follows:

Task	Information Source
1. Identify potential accident factors	Interviews with experts, published material, contractor fatal accident data base, misc. data collection
2. Size factors, establish measurement scales 3. Estimate relationship of single factors to accident occurence 4. Estimate compound relationship of factors to accident occurence	Delphi technique on expert interviews, accident analysis, observation, mine data collection, and summary analysis.
5. Formulate the initial SPA model for mine	Development of simple formulae or weighting scales that approximate complicated probability relationships

The SPA model would hopefully have assembled all that was known about safety in underground coal mines in a more helpful form for both mine management and the inspector. The model would have resembled the rating form that fire inspection rating bureaus use to rate the fire classifications of cities. These fire classifications for cities significantly affect the fire insurance rates for an entire city and over the years have evolved by empirical evaluation. Each factor in the fire rating model is measured and assigned points and a complicated weighting formulae is used to derive an over-all rating number from 1 to 10.

The SPA model, like the city fire rating model, would have assessed the human element in addition to the physical factors. The fire rating model assesses the firemen training programs, including training records and standards, as a way of assessing the quality of the men. The assumption behind both the proposed SPA model and city fire rating model is that a large collection of mild hazards may equal the risk of a single severe hazard and that both human and physical dimensions must be measured to assess future risks.

The city fire classification model took years of trial and error development based on empirical data of fire losses and city scale ratings. It was hoped that the SPA model development could be essentially formulated in less than a year. However, after a few months of gathering data and assessing the information available for model development, it became clear that the data available was unsatisfactory and insufficient. For example, the model was to concentrate on roof fall accidents. In the available non-fatal injury accident data kept by the companies one could not determine whether the roof fall accidents had occurred under unsupported roof (a factor highly influenced by work procedures), temporarily supported roof, or permanently supported roof, (a factor highly influenced by support plans). Also one could not determine the pertinent physical dimensions such as entry width, intersection dimensions, roof height, thickness of overlying strata, etc. Finally, the initial interviews with the most knowledgeable people were not yielding much information as documented in the next section.

The contractor and Bureau officials considered the steps necessary to overcome these data problems and weighed the opportunities to assist the Bureau to revise their accident data and analysis system. The mutual decision was to revise the contract as described previously in Chapter 1. The decision likely resulted in greater progress for long range development of an SPA model, by helping the Bureau develop a new technical and organizational system to collect more comprehensive data and to perform more systematic analyses of safety problems.

We are hopeful that the Bureau will continue work on the development of a SPA model in the future whose potential rigor and effectiveness should substantially assist those attempting to evaluate the degree of hazard in the underground coal mines.

METHODOLOGY OF THE SPA INTERVIEWS

One of the primary methods to be used for collecting data to build the Safety Profile Analyzer was a series of interviews specifically designed to elicit information concerning 1) the factors that contribute to underground bituminous coal mine accidents, and 2) the degree of hazard associated with each. The interviews were held with persons from a wide variety of groups associated with the coal industry in order to bring the broadest possible spectrum of experience and knowledge to bear on the problem of identifying hazardous underground conditions. Included were mine safety inspectors, health inspectors, roof specialists, consulting mining engineers, university mining engineering professors, mine managers, foremen, and the miners themselves. The following will describe the philosophy and methodology of these interviews, along with the findings and conclusions.

Two types of interviews were employed in this study. The first type was a free format interview consisting of open ended questions. These were used with as wide a cross-section of coal mine representatives as possible in order to compile a complete list of all those factors believed to be critical factors in accident occurrences. The free format questions were also used with these same groups to obtain information which could later be used in the development of measures for each factor.

Once the list of factors had been established a second set of interviews were administered. The group interviewed in this series consisted primarily of inspectors who were familiar with the specific conditions in mines in the Pittsburgh seam. The purpose of the second series of interviews was twofold; 1) to determine the degree of hazard associated with each factor in order to rank the factors by importance, and 2) to develop a scale for each factor and identify the point at which it becomes critical. Because a wide range of responses to the questions in these interviews was anticipated, the Delphi Technique was to be used to obtain a definitive group consensus.

The Delphi Technique is an often used method for eliciting opinions from a panel of "experts". Briefly, it involves a series of interviews or questionnaires interspersed with selective feedbacks to those being interviewed of the earlier group responses. The goal is to "tighten" the range of answers and to reduce the variance in the group opinions in each iteration of interviews.

For successful application of the Delphi method three important conditions must hold. First, the group involved in the process must be knowledgeable in the subject areas so that it can reasonably be assumed that their combined wisdom will produce the "correct" answer. Second, there must exist a recognizable group consensus, however slight, on the first round of interviews. If the responses are dipolar of if they are uniformly distributed across a range of possible responses, the Delphi Technique may fail to deliver a group consensus.

Theoretically, an extremely divergent opinion, among the cluster of expert opinions, may be extremely useful because that expert may possess a superior insight into the problem. Presumably, as the expert panel members examine the various assumptions, facts and logic supporting the various positions, the panel members may clarify or modify their own position. In successive interviews, the opinions usually converge toward a group concensus. Usually the strongly divergent opinions shift toward the opinion cluster, but sometimes the opinion cluster moves toward the originally divergent position.

Finally, the consensus of the group in successive interviews must approach the "correct" answer. Suppose, for example, the roof support experts were asked to evaluate the relative degree of roof fall hazards associated with bolted intersections of 22 x 22 feet in a specific mine versus the same intersections being supported by yieldable steel arches. Suppose also that the experts' opinions converge on an estimate that 10% more roof falls will occur with the bolted support versus the arch supports and the facts are that 100% more roof falls will occur under the bolted roof versus the yieldable arches. In other words the Delphi technique applied to group expert opinions is not a substitute for good empirical data. Consensus opinion does not guarantee validity.

When the study methodology was first designed, it was assumed that all of the prerequisite conditions existed. Bureau inspectors were specifically selected as an appropriate group to interview because it appeared they were the most "expert" in the field of coal mine safety. It was felt that the inspector was in a position to have maximum exposure to the specific coal mines in the study because of the very nature of his work. He regularly visits a wide variety of mines in a given area using different mining styles under varying conditions. Furthermore, since his function is to enforce safety regulations, he is undoubtedly in one of the best positions to reflect on those conditions which create either a safe or an unsafe working environment.

As will be seen in the next section describing the results of these interviews and their shortcomings, the three criteria for successful application of the Delphi Technique seldom existed. In some cases, the inspectors were not able to assess the hazard potential of the factors. When they could, the answers were often inconsistent or contradictory and failed to converge around any specific response.

After the completion of the first round of interviews in which over thirty inspectors in the subdistrict offices of Washington, Waynesburg, New Kensington and Kittanning were interviewed, it became apparent that either the inspectors were not going to be "expert" enough or that we were not "expert" enough in obtaining the information to produce a group consensus using the Delphi method. The interview approach and the Delphi method was consequently abandoned. The information which had been obtained in the interviews was summarized and incorporated into the accident analysis approach which followed the Delphi experiment.

Perhaps, subsequent iterations of interviews with the inspectors and other knowledgeable experts would have yielded more satisfactory results. However, the interviews were costly and the accident analysis approach seemed more likely to yield more predictive information.

FINDINGS OF SPA INTERVIEWS

Based on the open-ended interviews with health and safety inspectors, roof specialists, safety engineers, mine managers, foremen, miners and various members of the USBM technical and research staff in the district offices, the following list of factors emerged in their collective opinions as potentially critical to mine safety.

<u>Physical</u>

Roof Composition
Mine Dimensions
Pillars
Season
Temperature & Moisture
Time of Day
Overall Appearance
Age of Mine

<u>Technical</u>

Roof Support Method
Implementation of Roof Support Plan
Roof Test Methods
Equipment (Operation & Maintenance)
Level and Rate of Change of Production

<u>Sociological</u>

Teamwork (Sense of)
Violation & Accident History
Management Policies and Attitudes
Crew Size
Crew Utilization

<u>Psychological</u>

Worker Skill & Judgment
Foreman Skill & Judgment

Each of these factors were then included in the second series of inspector interviews. The following paragraphs summarize the results of these interviews.

Roof Composition

Most inspectors agreed that clay veins and slips represent the greatest danger. Other hazards include kettlebottoms, cracks, and slickensides. Water dripping through the roof was also an indication of dangerous top.

Mine Dimensions

Sixteen-foot entry widths were generally considered superior to other sizes in the Pittsburgh seam, although some inspectors felt that wider entry widths could actually support dangerous roof just as well. Increasing the entry width from 16 to 18 feet was likely to increase the probability of a fall by 15% and the increase from 18 to 20 feet by another 15%. The probable effect of seam height and roof height variation in the Pittsburgh seam on accident probabilities was unknown.

Pillars

Many inspectors felt that there was a "right" pillar size which depended on roof conditions, but they did not know how to determine this optimal size. There was little danger associated with making the pillars larger than this "right" size; however, significant hazards were associated with making pillars so small that they would fail to provide adequate support.

Season

Winter was considered slightly more dangerous because the dryness made explosions more likely. It was unknown whether the seasons affected the incidence of roof falls.

Temperature and Moisture

Moisture or water dripping from the roof was considered a possible sign of danger since it could indicate broken strata above and a great deal of pressure on the roof, thereby increasing the possibility of a roof fall. No one could describe how to determine if the moisture was due to condensation or to water coming through the roof.

Time of Day

No one shift was considered intrinsically more dangerous than another. Lunch time and right after a shift change were felt to be slightly more hazardous time periods than other times during the shift.[1] During the lunch break roof was often left unsupported or only partially supported, thus increasing the probability of a roof fall. When a new crew came on they might not often hear about difficult conditions discovered by the outgoing crew or the outgoing crew might not have finished with some aspect of the support system, both creating more treacherous conditions.

Overall Appearance

This was believed to be a direct function of the Foreman's Skill and Judgment. Good housekeeping was believed to be evidence of an orderly and well managed operation which thus would experience fewer accidents.

Age of Mine

Unknown

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1. Note that this is directly contrary to actual facts. See section on Time Factors, Chapter 4.

Teamwork

Inspectors were almost unanimous in the belief that men working well together on a team created a safer working environment as well as higher production rates. It was felt that the men would help each other and look out for dangers to "the other guy" in addition to themselves. There may be a synergistic effect for men working together on the same shift for a few years. That is, the team accident avoidance learning curve may even look better than the individual's learning curve as time passes.

Violation and Accident History

Related to Management Policies and Attitudes.

Management Policies and Attitudes

"Good" management policies were considered to create a safer mine. A precise or specific definition of what constitutes good management was difficult to obtain but appeared to have at least the following characteristics: emphasis on production with safety, and sincere interest in safety.

Crew Size

Unknown

Crew Utilization

Related to Foreman Skill and Judgment.

Roof Support Method

It was generally agreed that bolts are better for roof support than posts. For example, posts get knocked out frequently. On the other hand, posts will give a better warning of impending falls by cracking and popping. Crossbars are considered to be better than bolts alone, and trusses may be better still, even though they are still in the experimental stage. How much hazard is associated with each method was unknown.

Implementation of Roof Support Plan

The inspectors could only assume that a mine following the roof support plan helped to create a safer environment since they had no way of knowing how much support was enough for any mine.

Roof Test Methods

It was generally felt that there was no accurate way of testing the roof and therefore the frequency with which it was done was irrelevant. Many inspectors spoke of the accuracy of pinging roof bolts or sounding the roof; however, just as many felt that these methods were worthless since the roof could look good and sound good but, in fact, be bad.

The following chart was developed with one experienced miner:

> 23% of roof is bad roof that is considered bad because the hazards can be detected. It will be made safe by the extra care given to its support.
>
> 75% of roof is bad roof that is considered good because the hazards cannot be detected. This is the roof that kills.
>
> 2% of roof is good roof that is considered to be good roof and is, in fact, actually safe.

Equipment

The kind of equipment was considered important for all accident categories except roof falls, but a quantitative estimate could not be given.

Production Level

The effectiveness of this factor on the hazard rating of the mine was difficult to determine since it was felt that both high and low production rates could be hazardous. What was suggested as perhaps more important to safety than the level of production was 1) whether there was a feeling of pressure to produce, in which case the miners were likely to hurry and take short cuts, or 2) changes in the production level. The effect of changes in the production level is particularly difficult to measure. There are so many potential reasons for the change such as a new man on the job, an inoperative machine or hitting a problem roof area, that is difficult to determine which is the primary and which is the secondary cause of any accident that occurs.

Worker Skill and Judgment

Two elements of this factor which inspectors uniformly agreed were important and significant in the overall safety of a mine were experience and training. At the same time each inspector could cite examples of men with years of underground and relevant job experience who foolishly go under unsupported roof unnecesssarily. Some expressed the belief that even those old timers could be retrained, although with some difficulty, to break these unsafe habits.

Foreman Skill and Judgment

Of all of the factors considered in the inspector interviews, this one emerged as the one judged most important. There was unanimous agreement among inspectors that the foreman was the key element in mine safety. Almost all could describe case histories of foremen who had never had an accident on any of their shifts. Three criteria were suggested for evaluating a foreman.

1) General cleanliness and appearance of the mine from the dinner hole to the ramp.

2) Crew Work. Is teamwork and cooperation present in the men? Are men well trained especially with regard to safety procedure, such as setting temporary support and checking regularly for gas? Is deadwork done voluntarily?

3) Foreman knowledge and managerial capabilities. Does the foreman know rules of accident prevention, the roof control plan, and the ventilation plan? Can he handle his men well? Is he a strong and effective supervisor?

SUMMARY

The findings described above have been summarized in Table 1 on the following page:

TABLE I

RESULTS OF INSPECTION INTERVIEWS

	Correlated with Safety	Unknown Relation to Safety	Unrelated to Safety
Roof Composition	X		
Mine Dimensions	X (Entry Widths)		
Pillars	X		
Season	(Explosions Only)		X
Temperature and Moisture	X		
Time of Day	X		
Overall Appearance	X		
Age of Mine		X	
Sense of Teamwork	X		
Violation and Accident History	X		
Management Policies and Attitudes	X		
Crew Size		X	
Crew Utilization	X		
Roof Support Method		X	
Implementation of Roof Support Plan		X	
Roof Test Methods			X
Equipment	X		

TABLE 1
(Continued)

	Correlated with Safety	Unknown Relation to Safety	Unrelated to Safety
Level of Production			X
Rate of Change of Production	X		
PSYCHOLOGICAL			
Worker Skill and Judgment	X		
Foreman Skill and Judgment	X		

From the description of the inspector responses towards each of the factors and from the summary presented in Table 1, it can easily be seen that most of the inspectors felt that the majority (14 out of 21) of the factors were related in some way to mine safety and the incidence of accidents. Three factors (season, roof test method, and level of production) were felt to be unrelated. The relation of the remaining four factors to safety was unknown.

Of the fourteen factors considered critical to accident occurrence, two emerge as particularly significant based on the results of these interviews: 1) Management Policies and Attitudes and 2) Foreman Skill and Judgment. Both of these factors were described as directly affecting several of the other factors on the list. Violation and Accident History and Level and Rate of Production were both considered a function of Management Policies. Overall Appearance, Crew Utilization, and Implementation of the Roof Support Plan were directly related to the Foreman's Skill and Judgment.

The inspectors were able to offer some suggestions concerning the dimensions which might be appropriate for use in evaluating the "goodness" of Management Policies and Attitudes and Foreman Skill and Judgment. Unfortunately none of these dimensions are reported in accident reports. As a result it is almost impossible to substantiate or disprove historically the inspectors' feelings about the importance of these two factors. We feel that more research into the composition of these behavioral factors and a determination of ways to measure the various elements would be of substantial benefit.

Six other factors, essentially related to Management or the Foremen, were felt to be related to safety by the inspectors: Equipment, Roof Composition, Mine Dimensions (entry widths), Pillars, Temperature and Moisture, and Time of Day. The inspectors could not describe the effect these factors had on safety, nor indicate how they could be meaured. Because each of these factors relate to physical aspects of the mine or to actual equipment in usage, these factors could potentially be analyzed to see if there was any statistical correlation with accident occurrence. This was done during the Accident Analysis phase and is described in Chapters 3 and 4.

COMMENTS CONCERNING USBM INSPECTORS

All of the consultants who performed the interviews were convinced that the inspectors were far more knowledgeable about safety than we were able to elicit in the interviews. Why was the information we obtained from the inspectors so inconclusive? The inspectors themselves suggested several reasons. First, the chief responsibility of the inspector is to deal effectively and efficiently with the required inspection provisions of the law. This is a time-consuming process in which much of the effort is expended in writing violations and reports rather than observing, analyzing, correcting, or studying general safety conditions in the mine.

Secondly, the inspectors complained they need more detailed and timely background information on the mine and especially analysis of its accident and violation history. This kind of data would enable them to focus on the specific problems which keep recurring in a given mine and to focus on the underlying problems. Without this information, they must rely on intuition, experience, and powers of observation.

Thirdly, the two safety factors universally believed to be the most important are almost outside of the inspector's control, i.e., foreman skill and judgement and management attitude and policy. Certainly the inspector can influence various management policies and attitudes, but he can't control these factors unless he assumes operational control of the mine.

Regardless of the problems facing the inspector, he still exudes the strongest interest in safety of all the groups interviewed during the course of this study. He can relate well to the underground miner and has a sincere interest in helping the miner do his job in the most efficient and safest manner possible. Freed from time-consuming constraints and armed with better material on the safety conditions and more detailed accident analysis of mine accidents in his area, the inspector feels he could be even more valuable in accident prevention.

The Bureau has devoted a considerable effort and expenditure of money to provide the inspector with greater knowledge of accident occurrence and inspection violation history of the mines he is inspecting. Beginning in April, 1972, all reported accidents on revised forms are forwarded to the inspection district offices, and a computer system of summarizing violations for each district is under development.

Unfortunately, at the time this research was conducted the inspectors were not yet receiving any helpful feedback summaries of accident information. Individual summaries of accident types at a given mine are helpful but must be compared to a larger sample of similar mines to more adequately determine significance. Moreover, the most recent data needs to be statistically compared with the past to determine if any significant increase or decrease in accident occurrence transpired. Without statistical control charts, the month-to-month or quarter-to-quarter shift in accident data tends to provoke under-reaction or more typically over-reaction to random fluctuations of accident occurrence.

We feel that the inspection efforts of the Bureau would be significantly improved by more detailed investigation into the factors associated with various kinds of accidents. This data must be provided to the inspectors if they are to exert an effective accident prevention influence. For example, mines with continuous auger or continuous ripper machines are classified together as mines with continuous equipment on the new

Bureau accident form. Similarly, no provision is made to determine if roof fall accidents occurred in intersections versus the entries and crosscuts, or whether the roof fall was under permanent roof support, temporary roof support or unsupported roof. Either special studies must be conducted to determine more specifically the related conditions associated with accidents, or more details are needed in the non-fatal accident reports forwarded to the Bureau. More precise information is needed to establish better roof control plans, equipment specifications, human performance criteria, and helpful inspection emphasis.

In West Germany, every disabling injury with an expected severity of greater than three days' time away from the job is investigated in detail either by a government inspector or a government certified company official. The benefit of this data is enormous to their mine inspectors. This detailed data identifies the most crucial safety factors and problems on which the inspector can then focus his attention. West Germany has an excellent safety record in underground coal mining compared to the U.S. and we believe that excellent accident data is an important part of their safety program. Similarly, in the U.S. we feel it is no coincidence that coal mine managements who gather detailed accident data and who analyze their data also achieve better safety records.