

A mining research contract report
NOVEMBER, 1980

EVALUATION OF THE SAFETY OF UNDERGROUND BLASTING PROCEDURES

Contract J0199012

International Mining & Consultants, Inc.

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1301 Airport Road
Beaver, WV 25813-9426
(304) 256-3266

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16. Abstract (Limit 200 words) This study provides recommendations for improved safety in underground blasting procedures based on in-mine observations of blasting practices in 30 underground metal, non-metal, and coal mines, and the analysis of blasting accidents since 1970 and existing state and federal regulations pertaining to the storage and use of explosives. Results of these analyses and observations indicate that 1) blasting accidents have declined but are an important contributor to the hazards of underground mining; 2) existing regulations are essentially adequate; 3) greater emphases should be placed on human errors and unsafe practices and the enforcement of existing regulations; and 4) future revisions of these regulations and standards should be organized, and their intent coordinated to eliminate ambiguities.				12. Type of Report & Period Covered
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FOREWORD

This report was prepared by International Mining Consultants, Inc., Suite 4-B, 26 Garden Center, Broomfield, Colorado, 80020, under USBM Contract Number J0199012. The contract was initiated under the Bureau of Mines Health and Safety Program. It was administered under the technical direction of the Bureau of Mines with Karl R. Becker acting as Technical Project Officer. Frank Naughton was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period February 1979 to October 1980. This report was submitted by the authors on November 1980. To the best of our knowledge and belief, there are no Subject Inventions made or have resulted from the performance of this contract.

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International Mining Consultants, Inc. (InMinCo) would like to express its appreciation to contributors of this report.

At the request of the majority of the contributing mining companies, their identities are withheld. Nonetheless it would have been impossible to complete this research study without the assistance and cooperation of the thirty-one mining operators who permitted visitations to their mines and co-ordinated with us in the discussion of blasting practices, safety programs and the impact of the Federal regulations in those areas. InMinCo is most appreciative of their assistance and candor.

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Contract Technical Project Officer

Mr. Karl R. Becker

Mine Visitation Teams

J. Babcock	Key Contributor, InMinCo
J. Biller	Consultant
M. Christo	Key Contributor, InMinCo
R. Murray	Consultant
R. Trent	Consultant
G. Chitombo	Researcher, InMinCo
W. Freeman	Key Contributor, InMinCo

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SECTION I

EXECUTIVE SUMMARY

The study for the "Evaluation of the Safety of Underground Blasting Procedures" was performed for the U. S. Bureau of Mines by International Mining Consultants, Inc. (InMinCo) between March 1979 and April 1980.

Objectives of Study

The purpose of this study was to identify and document commonly used underground blasting practices, to evaluate them in terms of their potential hazards, and to develop guidelines for improved safety in underground blasting.

Scope of Study

As a general guideline for the contract effort, only underground mines located within the continental U. S. were considered and a reasonable geographic balance was maintained in site selection.

The work performed was divided in five (5) sections:

- Task I (Section 3) An Accident Survey and an Analysis of Data
- Task II (Section 4) A Review and Reappraisal of Federal Regulations
- Task III (Section 5) Observing and Evaluating Safety in Mine Blasting
- Task IV (Section 6) Abbreviated Guidelines for Safer Blasting
- Task V (Section 7) Recommendations for Future Research

Task I An Accident Survey and an Analysis of Data

An analysis of blasting accidents which occurred subsequent to 1970 was prepared from data gathered at the Health and Safety Analysis Center (HSAC) and from mine inspectors' reports. Injuries were classified according to primary cause of accidents, i.e., drilling into missed holes, etc., and blasting accident data were compared to all underground accidents during the period 1970 to 1977.

The most frequent cause of injury in blasting accidents is flyrock: approximately 60.6% in coal mines and 26.1% in

metal/non-metal mines. Other principal causes of blasting accidents were: misfires and undetonated explosives, 4% for coal mines, 20.3% for metal/non-metal mines; premature detonation, 12.3% in metal/non-metal mines; shots breaking through ribs or pillars, 5.1% in coal mines; Airdox related, 9% in coal. Suffocation from explosive smoke was 18.8% in metal/non-metal mines but only 1.3% in coal mines. (Ref. Appendix B, Tables B3.2 and B3.3)

Comparison of explosives-related fatal accidents to all fatal accidents in the underground mining industry showed that the percentage of fatalities is approximately 6% for metal, 10% for non-metal and 5.5% for coal. The percentages of all explosives-related injuries compared to all industry injuries are: 0.9% for metal, 0.94% for non-metal and 0.50 for coal, or an overall average of .574% for the period of 1970-1977. (Ref. Appendix B, Table B3.4)

Mine Safety and Health Administration's analytical section, Health and Safety Analysis Center (HSAC), has a data base unsuitable for identification of accident causes (Ref. Section 3, Part 3.1). MSHA's mine inspectors' reports on fatal underground blasting accidents are the only source available which is adequately detailed to identify the probable cause of accidents. These reports were summarized for the period of 1970-1978 and the highlights are as follows (Ref. Section 3, Part 3.4):

- The fatal accident report analysis indicates that in every case there was a violation of an existing standard. It would appear that the underlying cause for this type of accident is either an inadequate appreciation of the potential consequences of unsafe acts or, more likely, an absence of training and a lack of motivation for safe work habits.
- It is apparent that human error is the prevalent cause of blasting accidents. Each individual, as part of society, is held accountable for his actions, and this should be included in mining operations. The mine labor force must be trained in the proper use of explosives through a continuous training effort. No person who has been trained and certified as competent should be absolved of all responsibility for his actions.
- Excluding coal dust explosions initiated by explosives, metal and non-metal mines have a higher number of explosives-related fatalities (thirty vs. twelve) than coal mines. This is reasonable due to the greater use and intensity of blasts

in non-coal mines.

- Conventional room and pillar mining has the highest incidence of fatalities - fifty-eight fatalities primarily due to:
 - A. Difficulties of guarding blast areas where there is multiple access.
 - B. Shooting through ribs and pillars.
 - C. Failure to withdraw and seek adequate "safe" shelter after igniting safety fuses.
- The use of blasting cap and safety fuse priming in metal and non-metal results in more fatalities than electric detonation due to:
 - A. Failure to withdraw or staying too long at the face, including
 - 1. igniting safety fuse alone
 - 2. too many safety fuses.
 - 3. safety fuses too short.
 - 4. lack of mobility because of injury or age.
 - B. Use of cap and fuse in difficult isolated blast sites where the electrical systems are impractical
 - C. Returning to blast site too soon when there are possibilities of:
 - 1. delayed explosions.
 - 2. misfires.
- There is no indication that explosives-related accidents or fatalities have increased in number, severity, or frequency in the underground mining industry in the past ten years.

Task II A Review and Reappraisal of Federal Regulations

Because of the diversity of underground explosive use no one system of mining can be successfully used as a standard for evaluation. As a consequence, state and federal regulations, "common sense", rules published by explosives manufacturers, and guidelines from explosive-use handbooks were used as bases against

which the observed procedures were compared.

Federal regulations pertaining to explosives storage, handling and use were tabulated and compared with regulations from eighteen states. Large differences, in both intent and stringency in regulations, were observed between state and Federal regulations as well as among various states' regulations. Federal standards are general and accepted as minimum, and any additional state or Federal regulations should enhance rather than detract from the safety of an operation.

According to the Health and Safety Analysis Center (HSAC) information, covering the period January 1972 to March 1978, violations of federal blasting standards comprised 8.6% of the total underground violations issued. For the period March 1978 through December 1979, 4.8% of all citations issued were for violations of blasting standards in underground metal and non-metallic mines. From January 1972 to December 1979 the blasting violations in underground coal mines were only .7% of the total violations (Ref. Appendix C).

The review of these comparison tables and the actual process of reviewing the statutes in preparation of the tables prompt several observations:

- Several states have regulations that are often broader in scope and are often more stringent than the minimum blasting safety federal standards, e.g., West Virginia, Pennsylvania.
- No uniformity of format or content exists between state and Federal regulations and the only uniformity among states appeared to be where the similarities in regulations suggested a total adoption of a neighboring state's regulation.
- Federal regulations are devoid of standards which set explicit minimum training and experience levels for persons handling or using explosives.

The investigations undertaken both in reviewing accident reports and at mine visits dramatically demonstrate that the current regulations are often ignored. A possible cause for this appears to be a failure of mine operators and Federal agencies to train the blasters about the hazards the regulations are designed to mitigate. The appraisal of the regulations has resulted in recommendations (Ref. Section 3, Part 4.5) and are highlighted as follows:

- That the enforcement effort be directed at principal causes of blasting accidents with the emphasis on the adherence to safer acts in handling of explosives.

- Explicit requirements in the regulations to define minimum blasting hazard training for new employees.

Task III Observing and Evaluating Safety in Mine Blasting

An integral part of this evaluation was the observation of blasting procedures in mining operations. The investigating mining engineer used a five-page mine visitation questionnaire. All of the assembled data and comments were included in this form. Most of the mines contacted were cooperative.

To eliminate any sampling bias, mines in different districts and geographic locations were chosen. The size of the mines visited varied from ten men working in three shifts on mine development to eleven-hundred men producing 27,000 tons of ore, plus development rock, per day. Ores mined, in the mines visited, are listed below:

<u>Metals</u>	<u>Non-Metals</u>	<u>Energy</u>
Uranium	Limestone	Bituminous coal
Copper	Potash	
Tungsten	Talc	
Lead, zinc	Colemanite	Anthracite coal
Silver	Trona	
Gold	Tremolite	
Molybdenum	Salt	

Thirty-one mines, ten each of non-metal and coal mines, and eleven metal mines were visited and the blasting/mining crews were observed as they performed the various blasting tasks. Most crews performed competently and professionally, however there were some exceptions.

Observations of blasting practices in metal/non-metal mines revealed that, while some mines appeared to have instituted excellent training and retraining programs with management taking a keen interest in safety programs that filtered down favorably to the attitude of the mining personnel, other mines quite clearly placed a greater emphasis on production with lesser emphasis on safety. A number of unsafe, unlawful or questioned practices were identified during the visits, ranging from the accumulation of a variety of different unidentifiable detonators in the magazine to poor accountability of personnel or lack of proper communications between maintenance and blasting personnel at the time of the blast.

Overall fewer unsafe acts or violations of regulations were observed in the conventional underground coal mines. None of these mines visited had experienced a fatality or even a serious

blasting injury.

The attitude of mine management and labor, properly managed safety training programs and adherence to existing regulations and company safety standards appeared to be key factors in providing a safe mining environment.

Task IV Abbreviated Guidelines for Safer Blasting

It is apparent from this study that the United States mining industry needs assistance in solving technical problems. The Federal Government could establish a technical review group for the mining industry, with co-ordination of MSHA and the USBM.

The abbreviated guidelines in this U. S. Bureau of Mines' contract report, offered in this section, will further fulfill the needs for improved safety in the blasting sequence of mining in metallic, non-metallic and coal mines.

The guidelines are not intended to supplement the extensive descriptions in the many books on blasting. The guidelines are based upon InMinCo's observations during its mine visits in this contract and the blasting experience of its staff. The guidelines are the highlights only to improve safety.

Most regulations and guidelines for safer blasting procedures are generally concerned with personnel protection during loading, blasting, and explosives handling. However, many hazards are a result of bad or improper round design, consequently several of the guidelines are for improvement in blast design, use of proper equipment and materials, and procedures, i.e., guarding, storage and transportation.

Explosives-related accidents appear to be caused by carelessness or by lapses in judgment, or, more precisely, human error. The most effective means of eliminating human error is to modify the behavior of the mining personnel through a continuous training effort. The Mine Health and Safety Act of 1977 established the standards for training and re-training programs which, within established guidelines, delineate skills and hazards associated with the specific operation. The constant awareness of risk coupled with good communications and well-established procedures provide the most effective approach to improving blasting safety.

Task V Recommendations for Future Research

The following recommendations for improvement in safety and future research include the strong recommendation that they be continually reassessed and evaluated to establish a consistency with current technology and state-of-the-art to assure maximum effectiveness on safety and compliances. (Ref. Section 7)

- Develop methods of handling deteriorated explosives
- Research the "shotgun effect" in the vertical crater retreat mining method.
- Research the effect of using pneumatic loaders using high pressure air
- Develop high visibility explosives/wrappers
- Improve accident investigating and reporting methods
- Encourage mine management to more precisely engineer blasting patterns and blasting safety zone perimeters
- Establish a means by which the miners share the burden of being assessed for infractions of safety standards
- Improved training of blasting personnel
- Study the effect of air annulus between the explosive and borehole-wall
- The Federal Government should provide active technical advice by establishing a blasting group co-ordinated between the Bureau of Mines and MSHA

SECTION 2

2.0 INTRODUCTION

InMinCo is pleased to present this final report of its contract research effort pursuant to the USBM Contract J0199012 entitled "Evaluation of the Safety of Underground Blasting Procedures." The study was performed during the period March 1979 to April 1980. The USBM Request for Proposal and the eventual contract provisions presented a clear definition of the background information which prompted this research effort and influenced the study's objectives and scope. This report section summarizes that information to provide an understanding of the starting point for this research effort.

2.1 Background of Contract Study

Current blasting practices in underground mines are based on the experience gained over many years of operation of such mines. This experience, coupled with the work of the Bureau of Mines, Mine Safety and Health Administration (MSHA), and the research and development sectors of the explosives industry, has resulted in various sets of regulations and/or recommendations for the safe and effective use of explosives in underground blasting.

The observance of these regulations and recommendations has resulted in a relatively high level of safety in the use of explosives for mining underground. However, there appears to be a recent upswing in the frequency of explosives-related accidents in mining, and this, coupled with the continual influx of new explosive materials and methods into underground mining, make it desirable to re-evaluate the scope and effectiveness of current blasting regulations and to document and analyze the present methods of underground blasting with the aim of improving the safety of these operations.

In a recent survey of the hazards of blasting in surface mines, it was found that nearly fifty percent of explosives-related accidents occurred during scheduled shot-firing and that the majority of these were associated with flyrock. The mechanical initiation of explosives in drilling and mucking operations accounted for twenty percent of the accidents while another twenty percent involved electrical mishaps of one kind or another. Undoubtedly some of these problems are common to underground blasting operations. However, the diverse types of explosive materials used underground, together with the difficult working environment, tend to compound the problem of blasting in underground mines.

2.2 Objectives

The purpose of this study is to identify and document commonly used underground blasting practices, to evaluate them in terms of their potential hazards, and to develop guidelines for improved safety in underground blasting.

2.3 Scope of Study

This study, except for occasional comparative purposes, deals exclusively with explosives-related hazards or information on underground mining operations performed within the continental United States.

The work performed is divided into five (5) sections:

Section 3 - a survey of all accidents that occurred since January 1970, and an analysis of the data collected.

Section 4 - A review and appraisal of Federal regulations.

Section 5 - mine visitations and documentation of practices with the aim of observing good practices as well as hazardous or questionable ones in the pre-blast, blast and post-blast cycle.

Section 6 - establishment of guidelines for safer practices in the blasting cycle and identification of practices that are deemed hazardous or questionable.

Section 7 - recommendations for future research that would have a favorable impact on safety in mining operations.

SECTION 3

ACCIDENT SURVEY AND ANALYSIS OF DATA

3.0 INTRODUCTION

This effort was to identify those practices, persons, locations, types of mining and other factors which had historically been the principal causes and victims of blasting accidents. Such an identification would enhance the effectiveness of the mine visits by allowing a more meaningful selection of mines to survey current practices to develop guidelines for improved procedures.

3.1 Analysis of Data Base System

Several serious obstacles that had an inhibiting effect on the gathering of statistics and successful completion of this report are enumerated below:

- There is only one source of accident/injury data for underground mine operations nationally. That source is the Health and Safety Analysis Center (HSAC) of the Mine Safety and Health Administration at Denver, Colorado.
- The few state accident summaries were equally brief as were MSHA's Non-Fatal Reports, so the data proved unproductive in making a determination of the principal cause of explosives-related accidents for the total country.
- MSHA's Health and Safety Analysis Center Data Bank's available data include summaries of the computer data bank, mine inspectors' reports of fatal accidents and microfilmed single page injury reports. Available for this study were:
 1. Injury experience underground explosion and explosives computer listings for metal and non-metal mines 1975-1978, coal mines 1972-1978.
 2. Fatal underground explosives-related mine inspectors' reports 1970-1978.
 3. MSHA, MESA and USBM Information Reports and Information Circulars 1966-1978 for HSAC Analysis of Metal, Non-metal and Coal Mines.

Special or multiple runs on the data base by contractors are prohibitively time consuming and were avoided by the HSAC personnel.

- The data base itself is not suitable for the identification of accident causes. This results from:

1. The injury report forms (Figures 3.1 & 3.2), used by industry to report injuries and non-injury accidents are insufficiently detailed in the description of the causes of explosive accidents to allow any useful conclusion regarding the unsafe act or blasting practice involved in the accident.
2. Discussions with HSAC revealed that, while the accident data file was classified and indexed on computer tape, it could not be accessed for the specific accident types. This situation existed because of limitations in the number and type of attributes that were selected from the raw accident reports for recording and encoding, the relative briefness of the reporting data and many incomplete reports. Until a revision of the classification system last year, the primary focus of the classification system was on the person sustaining an injury, the nature of the injury and its consequences to the injured person (fatality, lost time duration), the injury mechanism, and the possible injury-causing agent. This emphasis is brought out by the following excerpt from the classification standard used, "Recording Basic Facts Relating to the Nature and Occurrence of Work Injuries":

"2.7 The classification procedure is not designed to identify accident occurrences in terms of management or worker responsibility. Nor is it designed to establish primary causes of accidents in terms of hazardous conditions or unsafe acts. For recording purposes, these classifications are assigned without reference to their relative importance in the accident sequence. Any attempt to apply a subjective appraisal of relative importance in the application of these classifications would remove the records from the field of factual statistics and give them the

METAL - NONMETAL MINE INJURY AND ILLNESS REPORT

22

FIGURE 3.2
COAL ACCIDENT, INJURY AND ILLNESS REPORT

Form No. 3000-1
(October 1974)

UNITED STATES
DEPARTMENT OF THE INTERIOR
MINING ENFORCEMENT & SAFETY ADMIN.



COAL ACCIDENT, INJURY
AND ILLNESS REPORT

Form Approved
O.M.B. No. 42-R1640

Date of Accident or Illness _____ Time of Accident _____ A.M. ☐ P.M. ☐
Time shift started _____ A.M. ☐ P.M. ☐ (1) ☐ Production (2) ☐ Maintenance

MESA ID Number _____ Company Name _____

Mine Name _____ Mailing Address _____

(1) _____	(2) _____	(3) _____	(4) _____	(5) _____	(6) _____
(7) _____	(8) _____	(9) _____	(10) _____	(11) _____	(12) _____
(13) _____	(14) _____	(15) _____	(16) _____	(17) _____	(18) _____
(19) _____	(20) _____	(21) _____	(22) _____	(23) _____	(24) _____
(25) _____	(26) _____	(27) _____	(28) _____	(29) _____	(30) _____
(31) _____	(32) _____	(33) _____	(34) _____	(35) _____	(36) _____
(37) _____	(38) _____	(39) _____	(40) _____	(41) _____	(42) _____
(43) _____	(44) _____	(45) _____	(46) _____	(47) _____	(48) _____
(49) _____	(50) _____	(51) _____	(52) _____	(53) _____	(54) _____

A. LOCATION OF ACCIDENT OR ILLNESS (Circle the applicable code)	B. TYPE OF ACCIDENT (Circle the applicable code)	C. OCCUPATIONAL ILLNESS (Circle the applicable code)
(a) Underground Mine		
On Section (1) ☐ Section ID Number _____ Operator Section Number _____		
Off Section (2) ☐ Operator Location number or name _____		
(On Section, circle code for applicable method. Off Section, circle code for principal method used.)		
01 Continuous 02 Conventional 03 Hand 04 Longwall		
(Whether on section or off section, circle location codes describing accident)		
01 Shaft 02 Slope 03 Drift 04 Entry 05 Room 06 Face Area 07 Intersection		
(On section, circle applicable status code. Off section, circle principal status code.)		
01 Development 02 Retreat		
(b) Surface Mine 03 Strip 04 Auger 05 Culmbank 06 Dredge		
(c) Surface Operation 01 Tipple 02 Mechanical Cleaning Plant		
03 Preparation Plant or Breaker 04 Tramline or railroad 05 Central Shops		
00 Office at mine 06 Other surface operations: Specify _____		
14 Electricity	15 Machinery	21 Occupational skin diseases
13 Explosive & Breathing Agent	17 Mine Fire	22 Dust diseases of the lungs
12 Explosion of Gas or Dust	02 Pressure Bump or Burst	23 Respiratory diseases (toxic agents)
03 Fall of Face, Rib, or Side	05 Sliding/Falling Material	24 Poisoning (toxic materials)
01 Fall of Roof	06 Slip or Fall (Person)	25 Disorders (physical agents)
08 Handtool	09 Stepping/Kneeling on object	26 Disorders (repeated trauma)
07 Handling material	10 Striking or Bumping	29 All other occupational illness
11 Haulage	16 Suffocation	
20 Ignition of Gas or Dust	18 Other: Specify _____	
04 Inundation		
19 Lifting/Pulling		

D. ACCIDENT OCCURRENCE DATA: What brought about the accident or illness reported _____

What was unsafe physical or mechanical condition(s) contributing to accident _____

Name equipment, material, or tool involved _____ Model number _____

Describe any unsafe act(s) contributing to accident _____

Personnel injured (1) ☐ Yes (2) ☐ No Number of persons injured _____

COMPLETE DATA BELOW FOR EACH PERSON INJURED OR ILL

1. REGARDING INJURY OR ILLNESS

What was the agent, object, or tool inflicting injury _____ (1) ☐ Fatal (2) ☐ Nonfatal

Type of injury or illness _____ Part of Body injured _____

Amputation (1) ☐ Yes (2) ☐ No. If yes, part of body lost _____

2. REGARDING INJURED OR ILL PERSON

Full Name of Injured or ill person _____

Social Security Number _____ Sex _____ Age _____ Total years of mining experience _____ Total years experience in this mine _____

Regular job title _____ Years of experience on regular job _____ What was employee doing when injured _____

Was that activity part of regular job (1) ☐ Yes (2) ☐ No. If no, years of experience at that activity _____

Returned to regular job next regular shift (1) ☐ Yes (2) ☐ No. If yes, at full capacity (1) ☐ Yes (2) ☐ No. Returned to another job next regular shift (1) ☐ Yes (2) ☐ No.

Was employee transferred to another job or terminated (1) ☐ Yes (2) ☐ No. If yes (1) ☐ after last work days (2) ☐ because of injury or illness, but without last workdays.

Total number of lost work days _____ Number lost from regular job _____ Date returned to work _____

character of personal opinion records, thereby eliminating the accurate interpretation of the summaries by anyone other than the original analyst. Such treatment would also eliminate all comparability between the data compiled by different persons."

The new computer output format includes a brief narrative describing the accident.

But, the narrative is too brief to be useful in analysis of accident causes.

- The Mine Inspectors' Reports on fatal underground blasting accidents were the only source available which is adequately detailed to identify the probable cause of the accidents. The reports are highly subjective in some aspects. However, all were a sincere effort to identify the cause of the fatal accident and to recommend corrective action.

This data base represents:

- a. 26 metal and non-metal mine fatal accidents.
 - b. 12 coal mine fatal incidents.
 - c. Includes 50 coal mine fatalities with 38 from one disaster resulting from a coal dust explosion initiated by explosives.
 - d. Includes 30 metal and non-metal mine fatalities of which six were "hobbyists" working metal mine prospects.
- No data source was adequately detailed to provide man-hours or tons produced for the underground mines blasting crews only, so as to establish any valid accident trends associated with the use of explosives. No frequency based on man-hours or tons produced could be developed, either for the industry at large or at specific mines where injuries have occurred in the areas of blasting.
 - Summary tables of all accidents related to explosions and explosives in the computer data base exceeded 10,000 incidents. A review of the HSAC annual information reports indicated that less than 600 had been attributed to explosives. It was not possible within the limitations

of this research contract to fully and manually review tens of thousands of brief, incomplete and often inaccurate reports in the hope of identifying a few hundred possibly useful in development of blasting accident trends.

3.2 Accident/Injury Trends

For comparison purposes, the initial data presented are for accidents from all causes including explosives-related ones. The main body of data are for underground explosives-related accidents and they are presented in terms of frequency and severity rates for metal, non-metal and coal mines. These data were normalized on the basis of millions of man-hours worked as well as by millions of tons of material blasted and pounds of explosive used.

Several definitions, taken from HSAC injury report forms, that may be useful in the discussion are given below.

"Disabling work injury. -- Any injury suffered by a person that arises out of and in the course of his employment that results in death, permanent total disability, permanent partial disability, or temporary total disability.

"Fatality. -- Any death resulting from a work injury.

"Days lost. -- The number of full calendar days the injured employee was unable to work as a result of a temporary total disability.

"Days charged. -- All fatalities and permanent total disabilities have a standard time-loss charge of 6,000 days. Injuries resulting in permanent partial disability are assigned a time-loss charge depending upon the particular injury as specified in ANSI A16.1-1967 (R1973).

"Disabling injury-severity rate. -- The number of days lost or charged from disabling work injuries per million man-hours of exposure. The rate is calculated by multiplying the total number of days lost or charged by one million and dividing the product by the total man-hours of worktime.

"Principal cause classification. -- The cause classification used in this report has been developed through many years of analyzing descriptions of accidents resulting in injuries at mineral extracting and processing operations. It is designed to meet the need for a coding structure to classify injuries into standard accident categories to be

used in comparisons and determination of trends.

"Explosions of gas or dust. -- Explosions of gas or dust in the mine environment.

"Explosives and blasting devices. -- Cases in which the cause of injury was the detonation, fumes, flying fragments, or use of the explosive or breaking agent, or detonators."

Figures 3.3 - 3.5, as background data, portray the trends of all fatal and non-fatal disabling accident injuries in the metal, non-metal and coal industries from the early 1930's to the present. In all cases the general trend has been toward safer mining with fewer deaths and injuries per million man-hours. Most certainly this reflects the effort of responsible mining companies, union emphasis on safe working places and the legislative and enforcement efforts of state and federal governments. But less obvious and indirectly indicated by these graphs have been the tremendous changes in mining methods and increases in exposure to hazardous operations of technical and administrative personnel. The bulk of mine production has shifted from underground to surface operations in which the growth in equipment size and capacity has allowed substantial increases in production capacity with substantially reduced mining personnel. Finally, the controlled environments of maintenance shops and offices can be substantially safer than the active, on-line environment of the mining operations reducing injury rate.

Figure 3.6 illustrates some of the variables on safety statistics generally ignored by analysis based strictly on frequency per million man hours as follows:

- 1900 -Introduction of coal undercutting machines
- 1908 -USGS recommendation of use of permissible powder in underground coal mines
- 1920's -Introduction of mechanized loaders
- 1930's -Mercury Fulminate replaced in ignition and priming charges
- 1940's -Plastic replaces yarn/enamel insultation on leg wires
- Introduction of rubber-tired shuttle cars
- 1941 -Coal Mine Inspection Act
- 1948 -Advent of continuous underground mining

FIGURE 3.3
METAL MINES

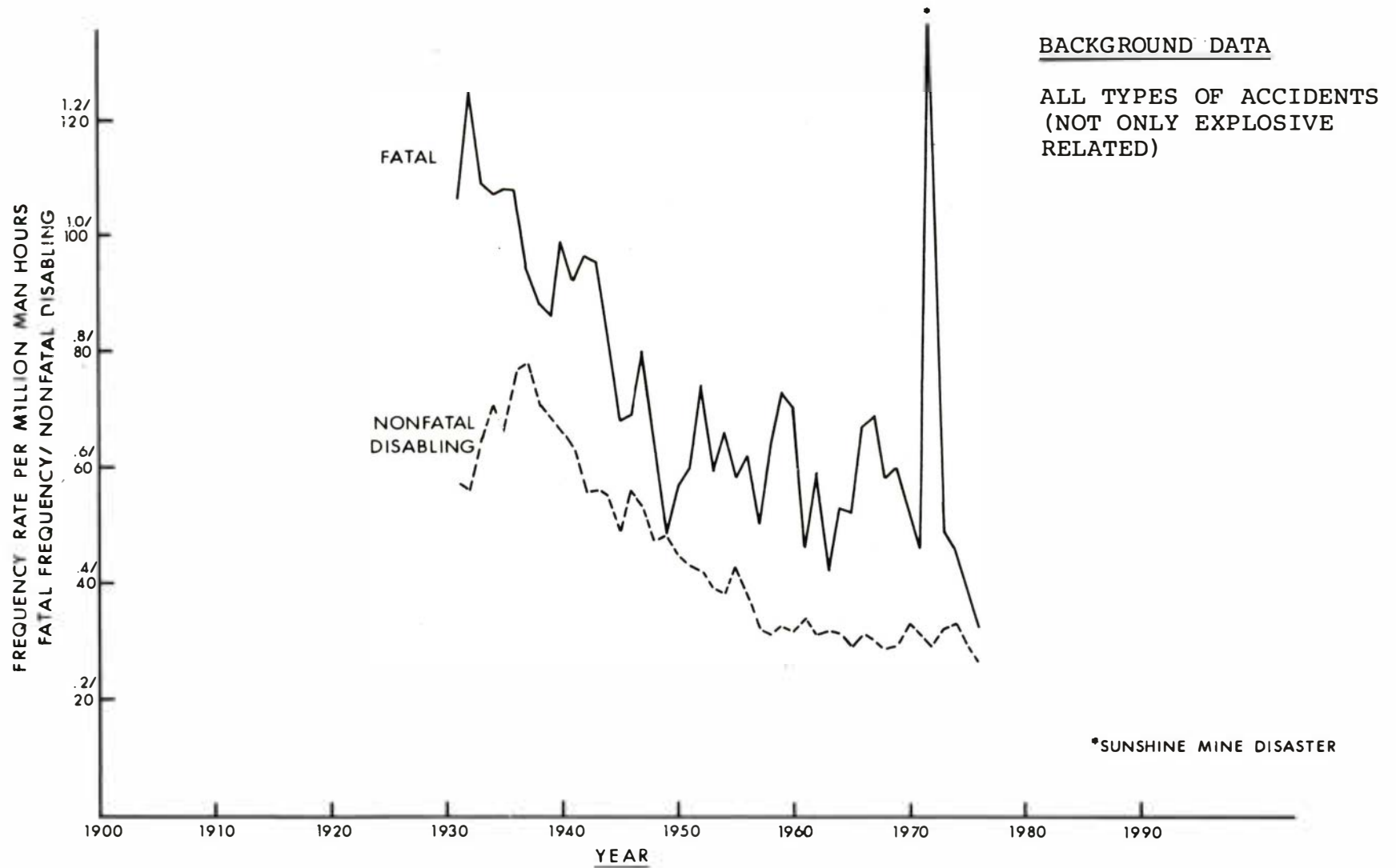
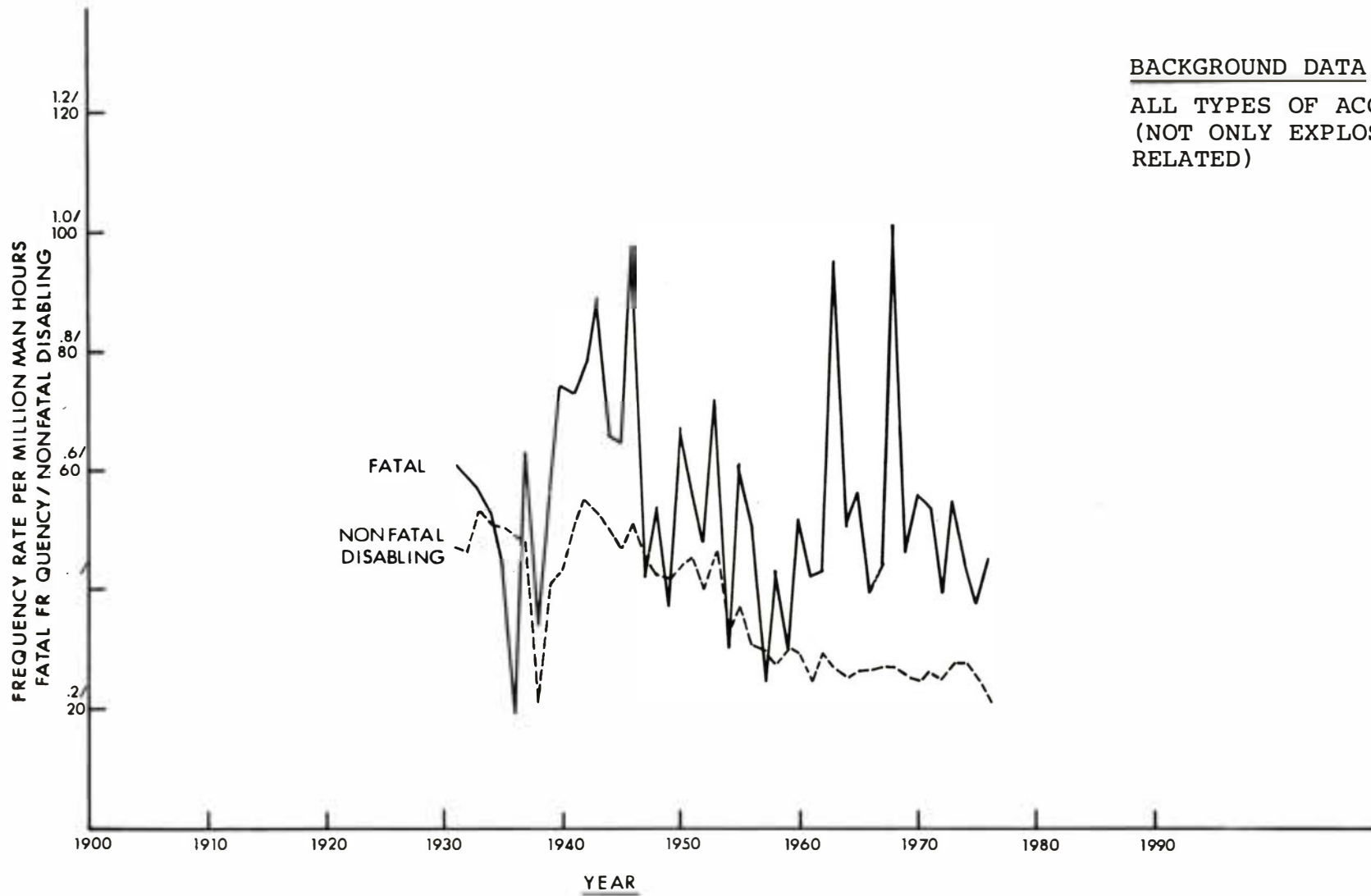
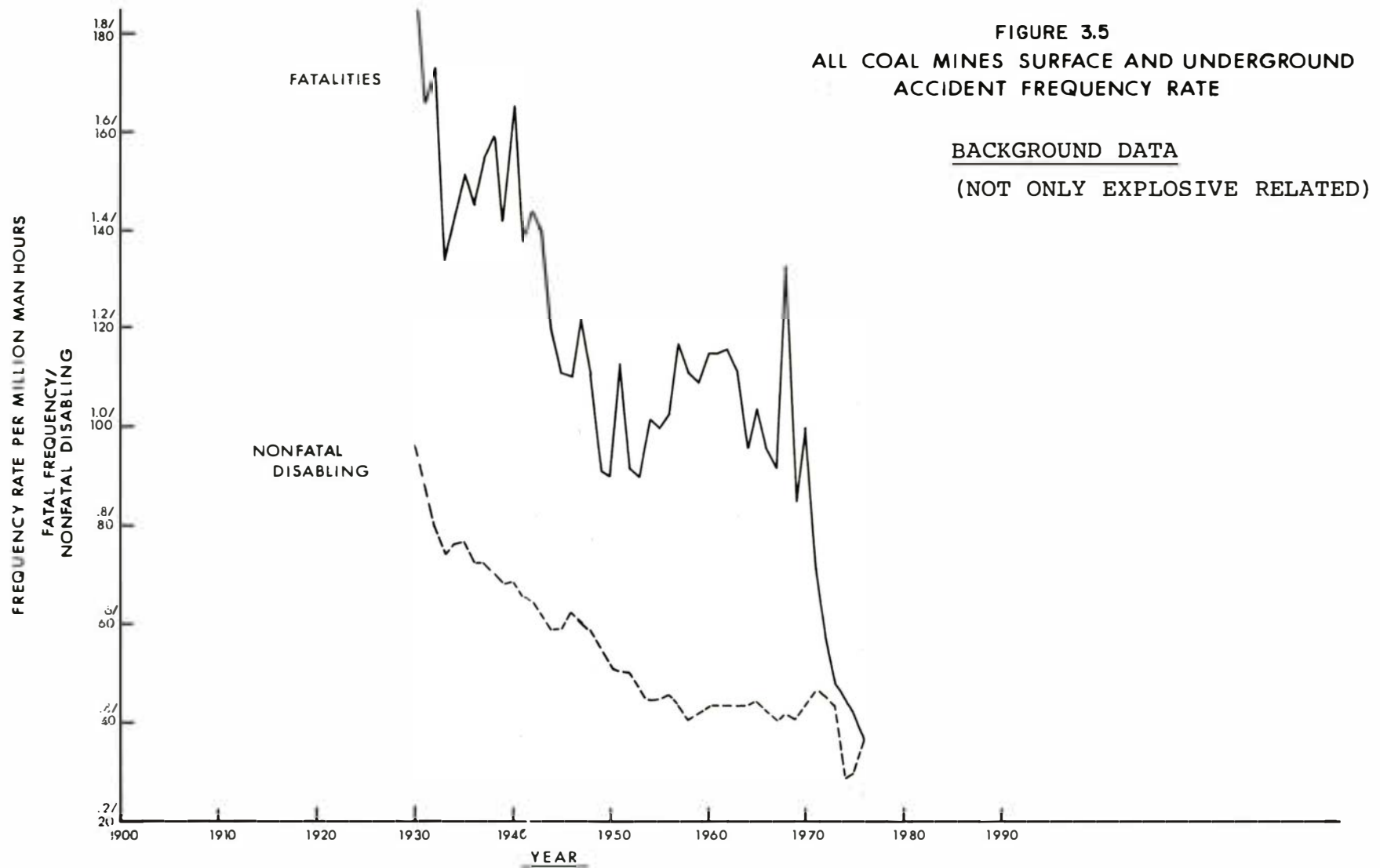


FIGURE 3.4
NONMETAL MINES

BACKGROUND DATA
ALL TYPES OF ACCIDENTS
(NOT ONLY EXPLOSIVE
RELATED)





1952 -Coal Mine Safety Act
1969 -Coal Mine Health and Safety Act

Figure 3.6 was prepared for coal mines only, but is typical of mining in general. It is important to note that blasting has never contributed more than 10% of the fatalities in underground coal mining in any given year and has historically declined to less than 1%. Figure 3.7 for explosives-related accidents in underground metal and non-metal mines shows a less dramatic but similar trend with the contributing percentages dropping from slightly more than 1% to less than .7%. During the period of 1970-1977, blasting accidents were .574% of all underground accidents in metal, non-metal, and coal mines based upon HSAC data listed in Table B3.4, in Appendix B. These figures simply illustrate that blasting has never been a major contributor to the accident experience of underground mines.

However, research into trends in blasting accidents for 1970-1978 has definitely established that when such accidents do occur, they are usually ten to fifteen times as severe as the average non-blasting accidents with a higher fatality rate.

3.2.1 Injury Experience Related Trends to Explosives 1970-1978.

Figures B3.1 - B3.16 are graphic presentations of fatal and non-fatal accident frequencies and severities of all underground accidents and explosives-related accidents normalized by millions of man-hours worked, millions of tons produced and millions of pounds of explosives consumed. These figures were drawn from Table B3.1 in Appendix B which was taken directly or adjusted from the government sources.

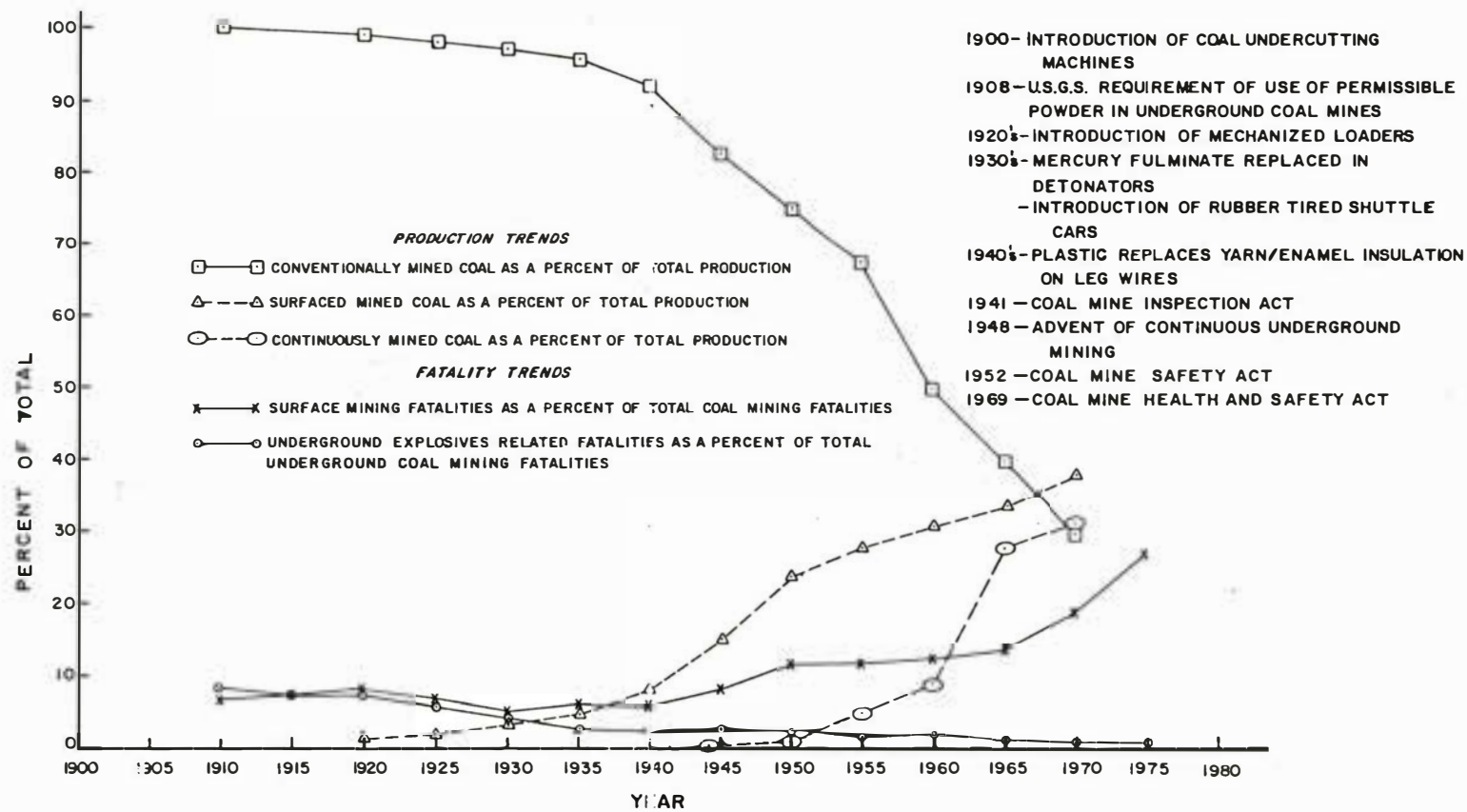
These are grouped into four sets. The Data Base is included in Appendix B.

- All Injuries Severity (Figures B3.-B3.04)
- All Injuries Frequency (Figure B3.05-B3.08)
- Fatal Accident Severity (Figures B3.09-B3.12)
- Fatal Accident Frequency (Figures B3.13-B3.16)

A substantial effort was made to seek significant trends from these data and graphs. This effort met with limited success. Several conclusions and/or remarks, general in nature, are given below:

(1) Though one serious explosive accident has a tremendous impact on the form of the graph, it does appear that the overall general trend in accidents and fatalities is downward.

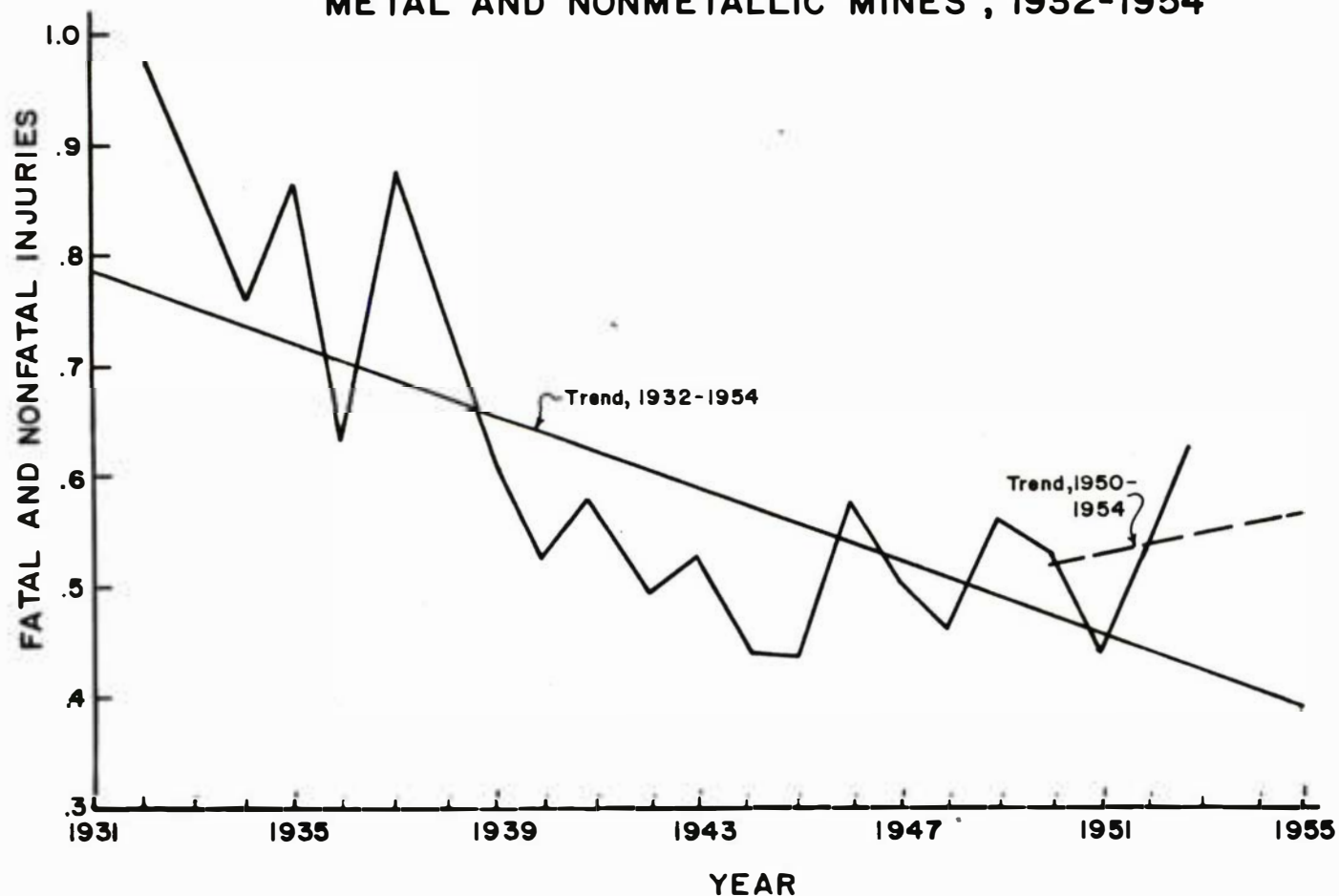
FIGURE 3.6
TRENDS IN U.S. COAL MINING



NOTE: ALL PLOTTED POINTS FIVE YEAR AVERAGES

FIGURE 3.7

INJURY-FREQUENCY TREND FROM EXPLOSIVES AT UNDERGROUND
METAL AND NONMETALLIC MINES, 1932-1954



NOTE: From ACCIDENTS FROM EXPLOSIVES AT METAL AND NONMETALLIC MINES, Metal- and Nonmetallic - Mine Accident-Prevention Course - Section 4 U.S.B.M. MINERS CIRCULAR 54-1956

(2) The data are such that no correlation, between explosives-related underground accidents (frequency or severity) and accidents from all causes, is indicated.

(3) No correlations were evident between accidents and (a) man-hours worked, (b) tons of material blasted, (c) pounds of explosives consumed; however, it should be pointed out that if a correlation did actually exist for, say between fatalities and man-hours worked, it may well be obscured because the man-hour value used is subject to a large uncertainty. The values used for pounds of explosive used and tons of material produced are also subject to large uncertainties.

Thus efforts to identify accident trends or hazard areas, in underground blasting operations using HSAC annual reports were severely handicapped despite the tremendous extra effort in collecting and scrutinizing a multitude of accident reports that contain insufficient information for expediting this effort.

3.2.2 Fatal and Non-fatal Blasting Accidents 1970-1978

The computer summaries for the HSAC computerized data base for underground explosions and explosives-related accidents were received through the USBM liaison officer. Those summaries were reviewed and the document number of all fatal accident reports identified. There were found to be thirty-eight incidents in which eighty fatalities occurred. Of these only twenty-seven of the fatalities are part of the computerized data base and the rest had to be manually extracted from the HSAC files. Tables B3.2 and B3.3 (Appendix B) summarize the fatal and non-fatal primary cause classification of the accidents listed in the computer summaries.

HSAC CLASSIFICATION

Explosive Related Accidents (frequency)		
	Coal 1972-1978, Metal/Non-Metal	1975-1978
	Coal	Metal/Non-Metal
Flyrock	60.6%	26.1%
Misfires & Undetonated Explosives	4.0%	20.3%
Premature Detonation	2.1%	12.3%
Shots Breaking through Pillars and Ribs	5.1%	1.4%
Insufficient Warning	3.8%	2.9%
Suffocation from Explosive Smoke	1.3%	18.8%

HSAC CLASSIFICATION (con't.)

Explosive Related Accidents (frequency)		
Coal	1972-1978, Metal/Non-Metal	
	Coal	Metal/Non-Metal
Airdox Related Accidents	9.0%	N/A
Blasting Caps and Detonators	1.9%	5.1%
Misc. Explosive Accidents	<u>12.1%</u>	<u>12.4%</u>
Total	99.9%	99.3%

By HSAC classification standards, (Tables B3.2 and B3.3) days lost (WDL) are results of "insufficient warning" in coal mines (23%) and "premature shots or blasts" in metal and non-metal mines (29.7%). Unfortunately, the last mechanism of injury is usually coded as the principal cause, making the HSAC breakdown of the actual cause very difficult in identifying the aspects of blasting procedures most hazardous.

Table B3.4, Appendix B, compares blasting accidents against all underground mining accidents for 1970-1978. Here again the infrequent occurrence of blasting injuries is highlighted by the drastic impact a single fatality can have on the percentage contribution to total annual fatalities.

PERCENTAGE OF EXPLOSIVES FATALITIES

	Percentage of Explosives Fatalities to All Underground Fatalities	Percentage of Explosive Injuries to All Underground Injuries
Metal	5.83%	.9 %
Non-Metal	9.84%	.94%
Coal	5.41%	.50%

Table B3.5, Appendix B, presents basic data (not normalized) that list the number of fatalities sustained each year in the three categories of mines. The corresponding non-fatal injuries incurred in these fatal accidents are also given. The tabulation is further broken down on the basis of single, double, and multiple injury per accident. Thirty-three out of eighty fatalities were single fatality accidents.

3.2.3 Summary of Fatal Explosive Accident Reports

The fatal explosive accident reports collected were reviewed and each incident abstracted and a data sheet prepared (Figure B.5, Appendix B). An abstract of each fatal incident also appears in Appendix B of this report.

Table 3.1 tabulates the data from the fatal explosive accident reports according to principal cause. Excluding the thirty-eight dust explosion fatalities, it appears that for coal mines about 50% were caused by poor personnel control during the blast; whereas, for metal and non-metal mines, failure to withdraw in time after lighting the fuse and poor personnel control accounted for 50% of all fatalities. It is also clear that single fatality accidents are much more frequent than multiple ones.

Table 3.2 shows these fatalities broken down according to worker activity and phases of blasting procedures. These data show that for all mine categories the principal victims were members of the blasting crew killed during the blast.

Table 3.3 distributes the fatalities by mining method. Conventional room and pillar mining was the principal method associated with blasting fatalities in coal. In metal and non-metal mines drifting, followed by room and pillar mining, were the principal methods associated with blasting fatalities. In either case the fatalities were associated with the primary blasting characteristic of the predominant mining method.

Table 3.4 distributes the fatalities by the commodity sought. Bituminous coal, silver and gold prospects, and molybdenum head the list. These also involve either large operations, as in bituminous coal and molybdenum mines, or very numerous small operations in gold and silver prospects.

Table 3.5 distributes the fatalities by explosives used, type of blasting, and planned method of detonation. Most coal mine fatalities occurred during primary blasting. In metal and non-metal mines the fatalities are fairly well distributed between ANFO and fixed explosives with primary blasting the major source of fatalities, and the planned method of detonation with the greatest number of fatalities being blasting cap and safety fuse, followed closely by electric detonators. These results are entirely consistent with the type of blasting and blasting systems normally employed in the respective types of mining.

Table 3.6 distributes the fatalities by state and region. Not surprisingly, blasting fatalities occurred most frequently where large concentrations of mining activity exist.

Figure 3.8 is a bar graph of the annual occurrence of blasting fatalities 1970-1978. It portrays that such accidents

TABLE 3.1

PRINCIPAL CAUSES OF UNDERGROUND EXPLOSIVES

RELATED FATALITIES 1970 - 1978

PRINCIPAL CAUSE OF FATALITY	COAL	METAL AND NONMETAL
1) Staying too long at the face while igniting safety fuses		9
2) Drilling into misfired holes or loaded bootleg		4
3) Poor personnel control		
a) Poor communication - guard at blast scene	2	1
b) Inadequate guarding or ignoring warnings	2	4
c) Insufficient warning and failure to withdraw men from blast area	2	
d) Failure to withdraw to a sufficiently distant and safe blast shelter		2
4) Shot breaking through rib or pillar*	2	1
5) Returning to blast area too soon		
a) Delayed blast		2
b) Improper disposal of misfire		2
6) Sympathetic detonation of improperly stored or spilled explosives		2
7) Premature Blast		
a) Secondary blasting igniting loaded round with returning too soon to blast scene		1
b) Stray electric current	1	
8) Tamping directly on primer		1
9) Loading explosive on "red hot" drill bit Failure to clean hole before loading	1	
10) Suffocation due to explosives fumes		1
11) Nonpermissible use of explosives		
a) Improper use of electric blasting cap wires as blasting cable	2	
b) Coal dust explosion from use of detonating cord and nonpermissible blasting practices	38	
	50	30

* Poor Mining Projections - Failure to follow projections

TABLE 3.2
DISTRIBUTION OF FATALITIES BY WORKER
ACTIVITY AND BY SEQUENCE OF BLASTING
1970-1980

	<u>COAL</u>	<u>METAL AND NONMETAL</u>
WORKER ACTIVITY		
DRILLER	0	4
BLASTER/SHOT FIRER	5 (+2)	20
GUARD	0	0
SUPERVISOR	3 (+1)	0
NON-BLASTING PERSONNEL	<u>4 (+35)</u>	<u>6</u>
	12 (+38)*	30
PHASE OF BLASTING PROCEDURE		
EXPLOSIVE HANDLING (Transportation & Primers)	0	0
BLASTING PREPARATION	3	7
BLASTING	9 (+38)	22
POST BLASTING	<u>0</u>	<u>1</u>
	12 (+38)*	30

* Includes victims of 1970 coal dust explosion mine disaster reported as caused by illegal use of explosives.

TABLE 3.3
DISTRIBUTION OF UNDERGROUND MINING FATALITIES
RELATED TO EXPLOSIVE BY MINING METHOD

COAL MINES

1)	Conventional room and pillar	8 (+38)*
2)	Conventional and continuous room & pillar	1
3)	Continuous room and pillar	1
4)	Breast and pillar - Anthracite	2

METAL AND NONMETAL MINES

5)	Room and pillar	8
6)	Modified room and pillar	1
7)	Drifting	12**
8)	Block caving - shooting hang ups	2
	- development	3
9)	Sublevel stoping development	2
10)	Open stoping/random pillars - stope	2
	- development	<u>1</u>

TOTAL FATALITIES	80
------------------	----

* 38 fatalities from a coal dust explosion initiated by the illegal use of nonpermissible explosive in a conventional room and pillar coal mine to shoot boom holes.

** Fatalities in prospect adits, drifts and raises during exploration or mine development prior to establishing ore mining method. Includes 6 fatalities of elderly "hobbyists" working cobalt, gold and silver prospects.

TABLE 3.4
DISTRIBUTION OF UNDERGROUND EXPLOSIVES -
RELATED FATALITIES 1970 - 1978 BY COMMODITY
SOUGHT OR MINED

<u>COMMODITY</u>	<u>NUMBER OF FATALITIES</u>
COAL	
Bituminous Coal	48*
Anthracite Coal	2
METAL AND NONMETAL	
Silver and Gold prospects	6**
Molybdenum	5
Potash	3
Copper	2
Lead/Zinc	2
Tungsten	2
Uranium	2
Asbestos	1
Crude Oil	1
Cobalt prospect	1
Iron	1
Gypsum	1
Limestone	1
Talc	1
Zinc	<u>1</u>
	80

* 1970 explosives-caused coal dust explosion mine disaster-
38 fatalities

** 1976 3 elderly brothers working a claim as a hobby

TABLE 3. 5

DISTRIBUTION OF UNDERGROUND EXPLOSIVE-RELATED FATALITIES
BY EXPLOSIVES . TYPE, PRIMARY OR SECONDARY BLASTING AND METHOD
OF DETONATION

	<u>COAL</u>	<u>METAL AND NONMETAL</u>
EXPLOSIVES		
ANFO		12
OTHERS	12 (+38) *	17
UNKNOWN		1
TYPE OF BLASTING		
PRIMARY	10	23
SECONDARY	2 (+38) *	7
PLANNED METHOD OF DETONATION		
ELECTRIC	11 (+38) *	10
BLASTING CAPS & SAFETY FUSE	1	17
UNKNOWN		3

* 1970 Coal Mine Disaster - dust explosion initiated by illegal use of explosives.

TABLE 3. 6
UNDERGROUND EXPLOSIVES-RELATED FATALITIES BY
STATE AND REGION 1970-1978

<u>REGION</u>	<u>STATE</u>	<u>COAL MINE FATALITIES</u>	<u>METAL & NONMETAL MINE FATALITIES</u>
Northeast	New York		1
Appalachia	Pennsylvania	2	
	West Virginia	2	
	Virginia	2	
	Kentucky	44*	1
	Tennessee		1
Midwest	Michigan		1
	Illinois		1
	Indiana		1
Rocky Mountain	Colorado		6**
	Wyoming		1
	Utah		1
Southwest	Arizona		2
	New Mexico		6**
	Nevada		1
West Coast	California		1
	Oregon		6***

*38 of the 44 fatalities in Kentucky were the result of a single coal dust ignition. This mine disaster was reported as being the direct result of the use of illegal explosives.

**Both New Mexico and Colorado have large concentration of underground mining activity.

***5 of the 6 fatalities in Oregon were elderly and/or totally inexperienced persons blasting in prospect mines which were essentially run as hobbies.

are rare and addresses the anomalies which occur by inclusion of disaster victims and hobbyists.

Figures 3.9-3.11 graphically portray the relationship of underground blasting fatalities and injuries to all underground mining fatalities and injuries for coal, metal and non-metal mines. The drastic fluctuation in the explosives fatalities as a percent of total fatalities highlights the relative infrequency of fatal accidents and the corresponding impact of a single fatality. However, the small number does not minimize the major hazard of working with explosives.

Figure 3.12 is a bar chart showing the distribution of fatalities by the annual production of the mines at which the accidents occurred. The obvious correlations exist in that more blasting accidents occur at relatively small coal mines because most small coal mines utilize conventional room and pillar mining practices while most larger mines use continuous miners and long-wall operations. In metal and non-metal operations the fatalities are fairly uniformly distributed with the hobbyist fatalities contributing to the anomaly in the 0-20,000 ton classification.

Figure 3.13 distributes the fatalities by age groups and includes non-~~blasting~~ personnel as well as the active participants in the blasting. The age group 31-35 years had the greatest number of fatalities and probably reflects the age group most active as blasters and supervisors.

Figure 3.14 distributes the fatalities by years of mining experience. The most fatalities occurred among inexperienced miners before the first year of employment was completed. They were non-blasting personnel rather than active participants in the preparation and guarding of blast, while the experienced groups having 15-19 years and 20-29 years were the next largest groups and were comprised mainly of blasters and supervisors.

Figure 3.15 distributes the fatalities by the amount of experience the victims had at that mine or on their job classification. Men new to their jobs or the mine are the predominant source of fatalities.

The objective of the previous tables, charts, and graphs was to identify blasting practices contributing most frequently to the injury accident experience so that the study Phase II, Mine Visitation, effort might proceed with maximum efficiency. The analysis of blasting accidents did not indicate that the normal blasting practices or any particular explosive or method of detonation contributed substantially to the injury experience but rather that the principal source of injury was human error on the part of blasters and blast guards.

FIGURE 3.8

FATALITIES PER YEAR UNDERGROUND EXPLOSIVES-RELATED
COAL AND METAL/NON-METAL MINES

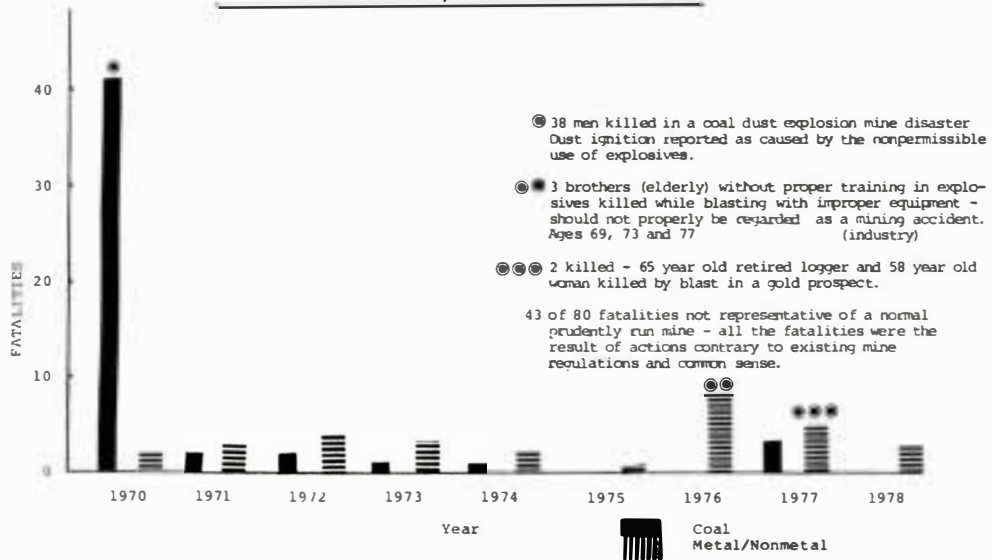


FIGURE 3.9

INJURIES AND FATALITIES AS A PERCENTAGE OF TOTAL
INJURIES AND FATALITIES IN UNDERGROUND COAL MINES

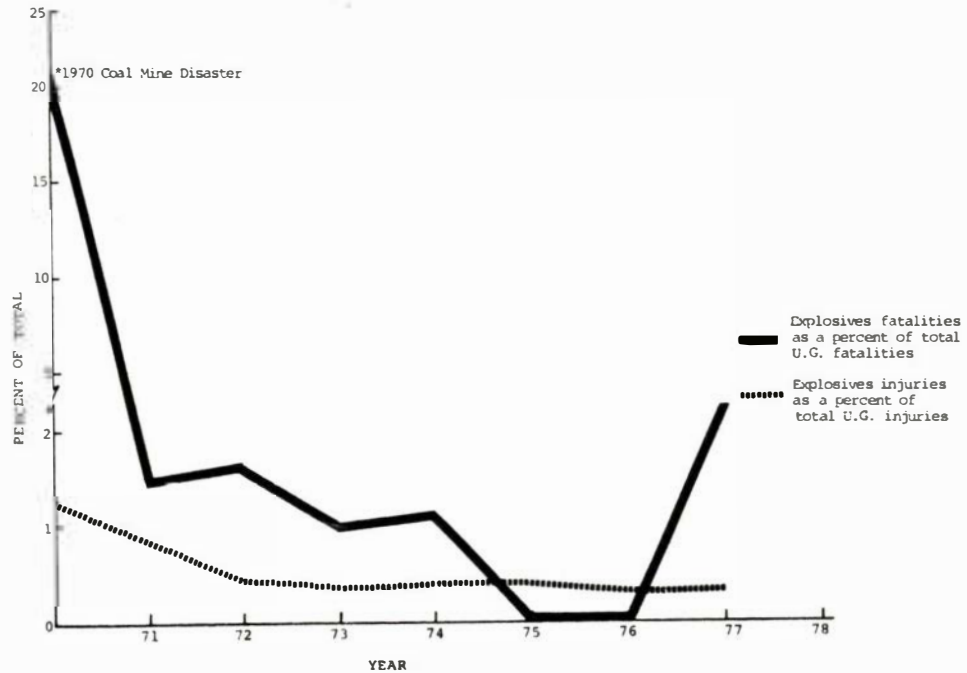


FIGURE 3.10

PERCENT EXPLOSIVE ACCIDENT VERSUS TOTAL ACCIDENTS
UNDERGROUND METAL MINES

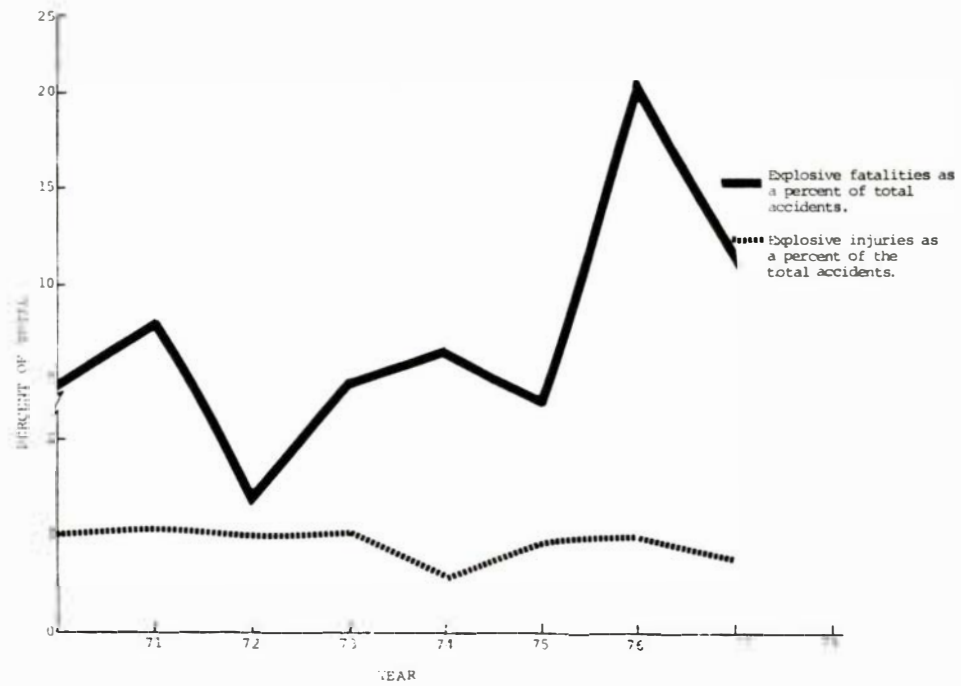


FIGURE 3.11

INJURIES AND FATALITIES AS A PERCENTAGE OF TOTAL
INJURIES AND FATALITIES IN UNDERGROUND NON-METAL MINES

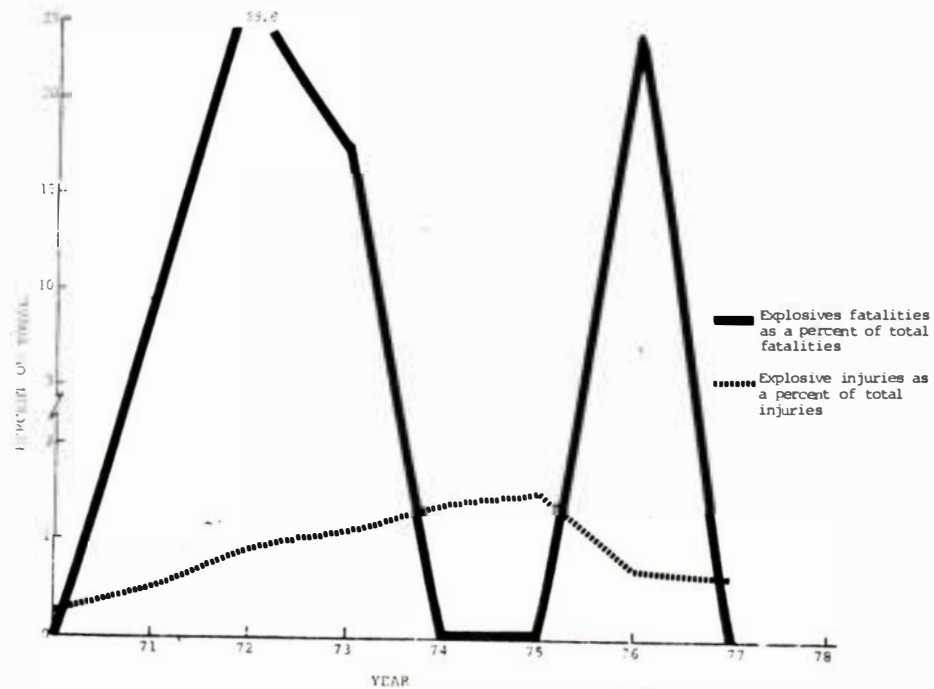


FIGURE 3.12

DISTRIBUTION OF UNDERGROUND EXPLOSIVES-RELATED FATALITIES BY ANNUAL PRODUCTION LEVEL 1970-1978

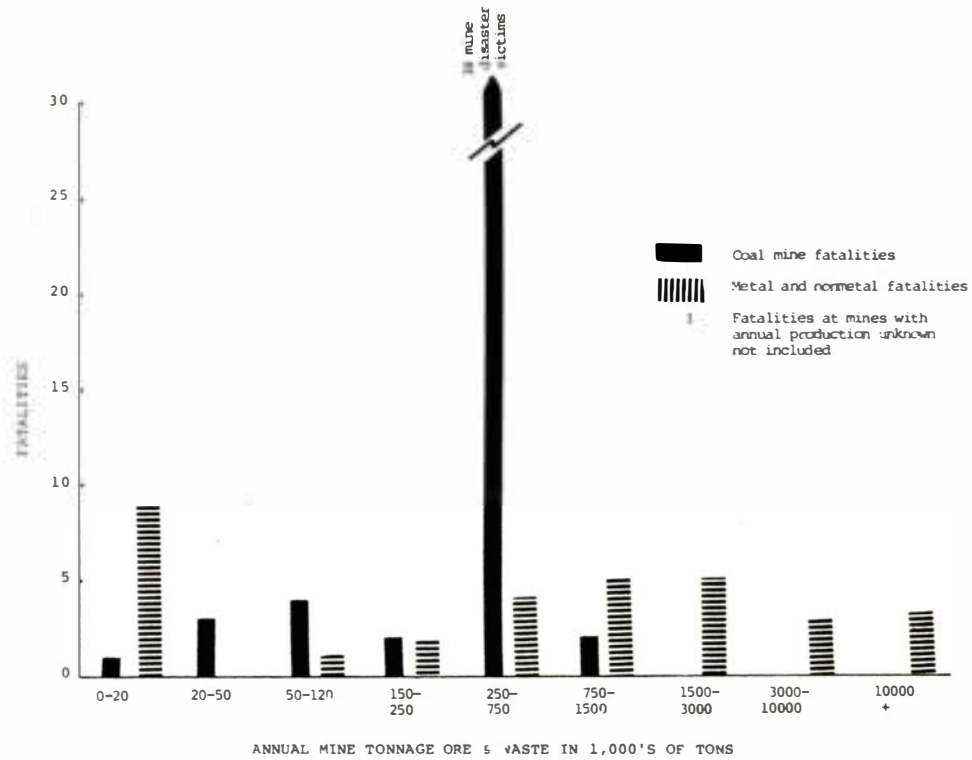


FIGURE 3.13

AGE DISTRIBUTION OF FATAL VICTIMS OF EXPLOSIVES-RELATED ACCIDENTS UNDERGROUND COAL, METAL AND NON-METAL MINES 1970-1978

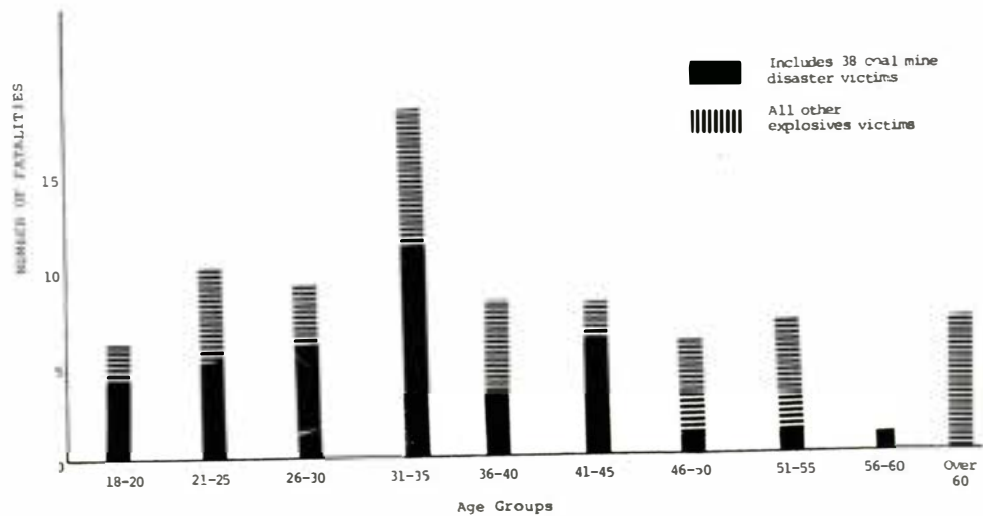


FIGURE 3.14

YEARS MINING EXPERIENCE DISTRIBUTION OF EXPLOSIVES-RELATED ACCIDENT
FATALITIES UNDERGROUND COAL, METAL AND NON-METAL MINES
 1970-1978

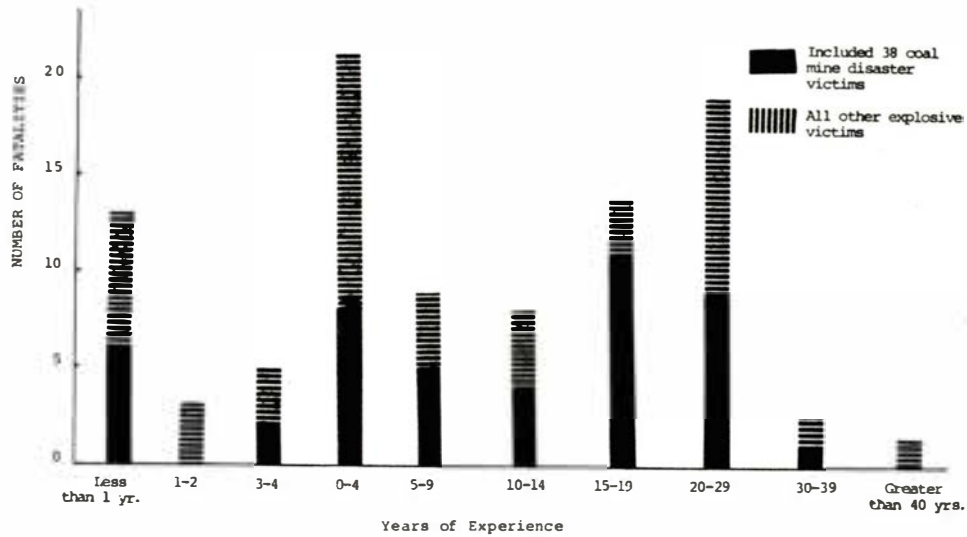
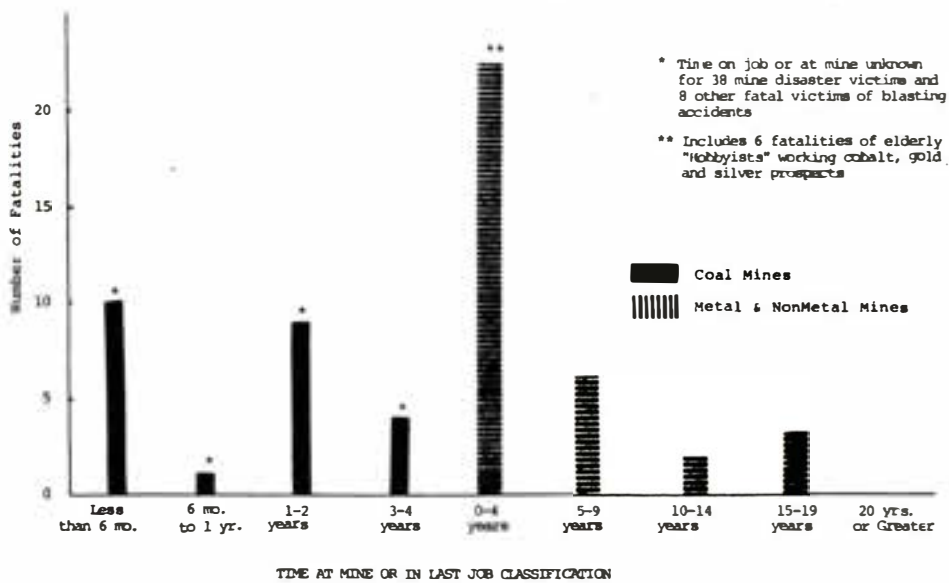


FIGURE 3.15

TIME AT MINE OR JOB CLASSIFICATION DISTRIBUTION OF EXPLOSIVES-RELATED
ACCIDENT FATALITIES UNDERGROUND COAL, METAL AND NON-METAL MINES
 1970-1978



3.3

Conclusions of HSAC Information Reports

- The trends for fatal and non-fatal frequencies for all surface and underground metal, non-metal and coal mines demonstrate that:
 - A. Coal is the most improved historically.
 - 1. There was a reduction in frequency rate with the Coal Mine Act of 1969.
 - 2. Also contributing to the reduction of explosive accidents:
 - a) increase in surface mined coal
 - b) decrease in conventionally mined coal
 - c) reduced crew sizes in face areas compared to support functions
 - d) introduction of longwall mining
 - e) increased underground man-hours for support services
 - B. Metal mine trends are similar to coal but less dramatic.
 - C. Non-metal mine safety has been relatively unimproved, with the Metal and Non-Metal Act of 1972 having a lesser impact than with coal.

3.4

Conclusions of Fatal Accident Reports 1970-1978

- The incidence of fatalities is highest in the Appalachian, Southwest and Rocky Mountain Regions, and corresponds to the major mining regions.
 - Appalachian Region - 52 fatalities (38 mine disaster victims)
 - Southwest Region - 9 fatalities
 - Rocky Mountain - 8 fatalities
- Conventional room and pillar mining has the highest incidence of fatalities - 58 fatalities (38 disaster victims) primarily due to:

- A. Difficulties of guarding blast areas within multiple access
 - B. Shooting through ribs and pillars
 - C. Failure to withdraw and seek adequate shelter after igniting safety fuse.
- Excluding coal dust explosions initiated by explosives, metal and non-metal mines have a higher number of explosives-related fatalities (30 vs. 12) than coal mines. This is reasonable due to the greater use and intensity of blasts in non-coal mines.
 - There is no identified trend or difference in accidents with regard to the use of ANFO vs. other blasting agents.
 - More fatalities occur during primary blasting than secondary blasting which is consistent with the fact that primary blasting occurs more frequently.
 - Secondary blasting fatality reports suggest that guarding blast sites is more difficult and less well-emphasized than at primary blasting sites.
 - Initiating explosives with blasting caps and safety fuse results in more fatalities in metal/non-metal mines than when electric detonators are used; this is due to:
 - A. Failure to withdraw or staying too long at the face, including
 - 1. igniting safety fuse alone
 - 2. too many safety fuses
 - 3. safety fuses too short
 - 4. lack of mobility because of injury or age
 - B. Use of blasting caps and safety fuses in difficult, isolated blast sites where the electrical systems are impractical
 - C. Returning to blast site too soon when there are possibilities of:
 - 1. delayed explosions

2. misfires

- The majority of fatal accidents involved blasters, shot firers and guards participating in the blasting procedure. There is a higher incidence of non-blasting personnel fatalities as opposed to active blasting participants in coal mines in particular and room and pillar mines in general. This is due to:

- A. Failure to withdraw workers from places adjacent to blast sites
- B. Inadequate guarding or warning
- C. Shots breaking through ribs or pillars

- There is no indication that explosives-related accidents or fatalities have increased in number, severity, or frequency in the underground mining industry. There have, however, occurred in the period 1975-1977, five fatal metal and non-metal blasting accidents among elderly and inexperienced non-professional miners which give the appearance of an increase. The fatalities involved:

- A. Sixty-five-year-old retired logger and fifty-three-year-old woman working a gold, silver prospect.
- B. Sixty-eight, seventy-three and seventy-seven-year-old brothers working a silver prospect

These people had neither sufficient training nor experience to justify calling them miners; also their prospects were not worked regularly or in sufficient volume to be regarded as a representative part of the mining industry.

- The thirty-eight fatalities in the 1970 coal mine disaster were victims of a coal dust explosion initiated by explosives. Only three, and at the most five, of the victims were actively participating in the blasting. The fatal accident report of the incident suggests criminal negligence and a total disregard for blasting regulations on the part of the mine's management. However, the responsible managers were all killed in the explosion. This disaster creates a large distortion in the explosives-related accident frequency and severity analysis, and, as such, was classified by HSAC under Coal Dust Explosions

in their 1970 Information Report. The reporting of this accident with Coal Dust Explosions was consistent with the established practice using the mechanism of injury as the primary cause of this accident.

The process of collecting, reading and analyzing the available accident injury statistics and fatal accident reports leads to a single important conclusion: The majority of blasting accidents and injuries occurred as a result of poor judgment, lack of common sense and disregard of established blasting procedures. However, the establishment of an awareness of the risks, and the insistence of safety first by mine management through training is essential if further reductions in the accident injury experience are to be achieved. As a result of the accident injury analysis, the mine visitation emphasis was placed on observations and inquiries into the formal blasting procedures employed at each mine, the qualifications necessary for blasters and blast guards, the authority of blasters, the initial and annual training for blasters and blast guards, and the attention and emphasis blasting is given in the management of mine operations and safety programs.

SECTION 4

REVIEW AND REAPPRAISAL OF FEDERAL REGULATIONS

4.0 INTRODUCTION

The contract scope of work dictated that, as a part of the Phase I effort and prior to any field work of mine visitation:

"The contractor shall review all Federal regulations and recommendations pertaining to underground blasting operations in order to become familiar with the scope and intent of the regulations and recommendations."

Following the Phase II mine visitations, and as a part of the Phase III - Hazard Analysis and Evaluation of Current Regulations:

"The contractor shall reappraise Federal regulations on blasting procedures with the aim of determining shortcomings in the regulations that are brought to light by the work of Phase I and Phase II."

This report section deals with the effort expended in complying with the above contract provisions and the findings resulting from that effort.

4.1 Review of Regulations

Reviews conducted in the performance of this contract were not limited to Federal regulations. Listed in this report bibliography (Appendix A) are texts on blasting design, explosives manufacturers' handbooks, U. S. Bureau of Mines Circulars and Information Reports, MSHA Information Reports, and periodicals. In addition to the pertinent sections of the Code of Federal Regulations (CFR)-30, eighteen state governments were contacted and the state statutes pertinent to blasting in underground mines were solicited for review. From CFR-30, Parts 15, 16, 17, 75.1300 to 75.1308, 57.6 to 57.6-200 (revised July 1, 1979) and 57.6 to 57.6-200 (revised January 1, 1980) were thoroughly reviewed and incorporated into this report, except for the January 1, 1980 revision Part 57.6, which came into effect well after the initiation of this research contract.

This review process served as a simple refresher to the contractor's mine visitation personnel, who were already familiar with the Federal minimum standards. The review of Federal regulations reemphasized the relatively broad nature of the definition of terms and acceptable practices, and the relatively narrow prohibitions therein included. CFR-30 is limited to providing a listing of minimum standards to be met and

any explanation about the particular hazard(s) a regulation is intended to mitigate must be found elsewhere.

4.2 Evaluation of Current Regulations

The contract research effort included the collection and analysis of blasting accident reports, the review of pertinent regulations and publications involving underground blasting and thirty mine visits to observe blasting procedures. Therefore the evaluation of current regulations involved an effort into determining the effectiveness of the regulations in preventing accidents and the promotion of safe blasting procedures and practices. The principal emphasis has been placed on a qualitative evaluation.

It was determined in the analysis of accident reports collected that all of the thirty-eight fatal accident incidents resulted from an action or practice which was at that time contrary to existing Federal standards. Some incidents could be best described as the result of incredible disregard for the most elementary safety precautions by persons who should have known better. In almost all cases the fatality was directly related to gross lapse in judgment or intentional risk taking on the part of individual miners or supervisors.

A careful review of the regulations found nothing that was not generally an accepted and recommended usage of explosives. While there are some aspects of the standards that are not easily explained, such as the minimum separation distances for the storage of detonators and explosives or where there is a "safe location" from which to detonate a blast, these regulations are generally consistent with current industry practices. Regardless, the practices are fairly uniformly observed and blasting is, as a result, a very minor contributor to the underground mining accident experience.

4.3 Standards Most Frequently Cited

The underlying philosophy of current safety and health regulations is the prevention of injury and fatal accidents and industrial diseases. However, the history of mine safety legislation has been that of responding to disasters with rules to prevent recurrences of situations that resulted in multiple deaths and/or chronic industrial health problems. This approach required accidents to justify the imposition of regulatory standards. Current justifications are at times subjective and not easily proven.

The investigation of accident reports discussed in Section 3 found no fatal injury which was not a violation of some safety standard. But the standards themselves were unsuccessful in preventing the fatalities or injuries. In other words, a regulation not observed, enforced, or unenforceable is of no value in preventing accidents.

The enforcement (or observance) of existing regulations as measured by the citations, notices or orders written is a direct measure of the efforts expended in prevention of accidental injury or industrial health problems. It is not, however, a measure of the success gained by the expenditure of these efforts.

The summaries of all citation/violation notices and orders issued by MESA/MSHA in its enforcement efforts from 1972 through 1979 were secured for underground coal, metal, and non-metal mines. These summaries were reviewed and the standards violated pertinent to the use of explosives in underground mines identified. Appendix C summarizes the citation or notices issued during the study period.

The number of violations issued pertinent to blasting in underground coal mines totaled 3,686 from January 1, 1972 to December 31, 1979. All explosives-related citations were from Part 75.1300, Subpart N - Blasting and Explosives. The violation of Subpart N ranks twenty-seventh in the number of violations issued and comprises about .5% of the total violations. Violation of CFR-30 Standards 75.1306, 75.1303, 75.1307, and 75.1304 comprised 93.4% of all underground coal mining blasting violations issued (Appendix C).

CFR-30 Standard	Undgr. Coal Mines Description	Explosives-Related Violations - %
75.1306	Storage of Explosives	52.3%
75.1303	Permissible explosives, blasting machines, and stemming	18.2%
75.1307	Separation of explo- sives & detonators, etc.	17.3%
75.1304	Transportation of explo- sives & detonators	<u>5.6%</u>
Total		93.4%

It would seem the enforcement effort has emphasized explosives materials to a greater extent than blasting practices. More probably, the conditions associated with physical locations, construction materials, and explosive materials are more readily available for inspection than the intermittent actions which make up blasting practices and procedures.

The examination of the history of citations, notices, and orders in underground metal and non-metal mines is less straightforward. In March, 1978 the standards were revised with the elimination of most advisory standards. These revisions are more a matter of recognition and clarification of the standards than the introduction of anything new; but in 1979 additional

standards were promulgated, and others are continually under review.

Non-compliance notices of blasting safety standards in underground metal and non-metal mines were 7.9% of all mandatory standards for the January 1972-March 1978 period and 5% for the March 1978-December 1979 period. In both cases the number of notices issued for the individual standards is more evenly distributed than it is in coal mine violations.

Under the old standards 80% of the notices are spread over the sixteen highest ranking standards, while under the revised standards 80% of the notices are spread over the twenty-one highest ranking standards. Four of the five highest ranking or most frequently cited standards are the same under both the old mandatory standards and the present standards. The most frequently cited standards include.

<u>CFR-30 Standard</u>	<u>Undgr. Metal & Non-Metal Mines Description</u>	<u>Percent Citations</u>
57.6-1	Storage of detonators and explosives in magazines	18.7
57.6-20	Location of magazines	8.1
57.6-112	Burning rate of safety fuse	6.1
56.6-5	Area maintenance around magazines	5.6
56.6-47	Transportation of Explosives	5.0

As in the case of violations of coal mine standards, those most frequently cited deal with fixed structures and materials and not practices or procedures.

4.4 Comparison of State and Federal Regulations

In the review and analysis of regulations pertaining to safe blasting practices, eighteen state governments were contacted to secure the state statutes and/or departmental regulations which apply to underground metal, non-metal, and coal mining. This was done for two reasons: first, was the fact that the Federal regulations represent the minimum standard which must be met by mine operators; and secondly, if a state regulation exists which is more stringent, the State enforcement personnel can apply the more stringent standard. Federal regulations also require "certified" or qualified personnel for several responsible jobs such as fire bosses, mine foremen, and shot firers, but leave the process for qualifying, testing, and certifying personnel with the state governments.

Table 4.1 lists the eighteen state governments contacted and the states whose regulations were reviewed. A series of comparisons were prepared which list safety regulations by

TABLE 4.1.

STATE REGULATIONS REQUESTED AND RECEIVED

Illinois	Virginia
Indiana	West Virginia
Kentucky	Wyoming
Maryland	Missouri
Montana	New York
New Mexico	Nevada
Ohio	Idaho
Pennsylvania	Colorado
Tennessee	Utah

miner activity and check off which states have that regulation and whether it is present in the code of Federal Regulations (CFR-30). These comparison tables are not included in this report.

The review of these comparison tables and the actual process of reviewing the statutes in preparation of the tables prompts several observations:

- Several states have regulations that are often broader in scope and are often more stringent than the minimum blasting safety federal standards. (West Virginia, Pennsylvania)
- No uniformity of format or content exists between state and Federal regulations and the only uniformity among states appeared to be where the similarity in regulations suggested a total adoption of a neighboring state's regulation.
- Federal regulations are devoid of standards which set explicit minimum training and experience levels for persons handling or using explosives.
- The recent revision (January 1, 1980) of Part 57.6 of CFR-30 eliminated advisory standard and reorganized and expanded upon select regulations and has produced a more serviceable and enforceable standard for safe blasting practices.

4.5 A Reappraisal of Federal Regulations

It is not the intent of this report to suggest that there exists a demonstrated need for new or more stringent regulations of explosives storage and use. The accident investigations and the historic trends in explosives-related accident frequencies and severities suggest that blasting is a minor frequency contributor but has a higher severity in the mining industry's safety problems.

However, the investigations undertaken both in reviewing accident reports and at mine visits dramatically demonstrate that the current regulations are often ignored. A possible cause for this appears to be a failure of mine operators and Federal agencies to train the blasters about the hazards the regulations are designed to mitigate. There seems to be little insistence that the time and effort required to comply with the regulations is a mandatory condition of their employment. Review of the history of citations issued by enforcement officers does not suggest an emphasis is being placed on unsafe acts but rather unsafe conditions. The appraisal of the regulations has resulted in the following recommendations:

- That the enforcement effort be directed at principal causes of blasting accidents with the emphasis on the adherence to safer acts in the handling of explosives.
- Future revisions of the coal mine explosive and blasting standards should address legal use and selection of detonators for multiple shot blasting circuits.
- The various "waits" required before returning to a misfired hole, 5-30 minutes depending on the classification of mining, is without explanation in the regulations*.

The standardization, or at least the expansion of the regulation, to specify the waiting period for the type of detonator used would be a positive revision; the term "misfire" should be eliminated entirely and a specific time period should be made mandatory after all blasts before reentry is permitted.

- The method of protection of detonators and explosives at the working face from roof falls and other sources of damage until the holes are loaded should be provided for in the regulations.
- Explicit requirements in the regulations to define minimum blasting hazard training to new employees.
- The improved dating of explosives/detonators containers to facilitate rotation and the use of the oldest first.
- Consideration should be given to clarifying regulations which are not explicit, such as requiring blasts to be initiated from a "safe location" (CFR-30-57.6-182), "persons shall be cleared and removed from areas endangered by the blast" (CFR-30-57.6-175), and "...that all persons are in the clear" (CFR-30-15.24, Section 5.16) without an explanation of what or where a "safe location or clear area is."

* 57.6-104 30 min. (Safety fuse) - Metal-Non-metal
 57.6-105 15 min. (Electric Blasting) Metal-Non-metal
 15.240Sec. 7 (a) 5 min. Bituminous Coal and Lignite Underground
 15.24-Sec. 6 30 min. Anthracite Underground

SECTION 5

OBSERVING AND EVALUATING SAFETY IN MINE BLASTING

5.0 INTRODUCTION

A major part of this project was to observe blasting procedures in mining operations. This phase was critical because it enabled InMinCo observers to compare actual practices with those recommended by various explosives manufacturers, with procedures developed by the mining industry and government regulations.

Mine management was informed that the intent of the study was to improve procedures involving blasting safety and that the results of this study could be used as a partial basis for revision of existing blasting standards. Most of the mine operators were willing to cooperate after they were given assurances of anonymity and confidentiality.

The types of mines visited were logically segregated by the nature of the commodity mined; i.e., metal, non-metal, and coal. Because coal mining is sufficiently different from metal/non-metal mining, an engineer with an extensive background in coal operations made all of the visits to the coal mines. Although metal and non-metal mines are frequently similar in nature, they were analyzed separately, and, whenever possible, were visited by an engineer with related or appropriate experience.

A total of thirty-one mines was visited, including eleven metal, ten non-metal, and ten coal mines. Four metal, four non-metal and twelve coal mines (of the original list proposed by InMinCo) refused to allow visitors for government-sponsored studies. Additional mines had to be substituted to obtain thirty-one mines for this study. Tables D5.1 through D5.3, in Appendix D, summarize mine data obtained during the visits. The following is a list of mines visited.

METAL MINES

<u>Mining Methods</u>	<u>Type of Ore</u>	<u>Tons Per Day Produced</u>
Room and Pillar	Uranium	600
Undercut and fill	Copper	3,000
Development	Uranium	-
Sublevel caving, sub-level stoping	Tungsten	-

METAL MINES
(con't.)

<u>Mining Methods</u>	<u>Types of Ore</u>	<u>Tons Per Day Produced</u>
Cut and fill stope, open stope	Silver Lead, Zinc	2,000
Cut and fill stope, VCR stope	Gold	5,500
Sublevel stoping	Copper	4,800
Block caving	Molybdenum	27,000
Room and pillar	Lead	5,000
Cut and fill	Lead, Zinc, Gold, Silver	800
Room and pillar	Copper	300

NON-METAL MINES

Room and pillar	Limestone	8,000
Room and pillar	Potash	1,250
Room and pillar	Talc	150
Slot and pillar	Colemanite	-
Room and pillar	Trona	11,000
Open stope	Tremolite	500
Room and pillar	Salt	8,000
Room and pillar with underhand bench	Limestone	900
Room and pillar with underhand bench	Salt	1,200
Room and pillar	Limestone	600

COAL MINES

<u>Mining Methods</u>	<u>Types of Ore</u>	<u>Tons Per Day Produced</u>
Room and Pillar (10 mines)	Bituminous	150 to 9,000
Breast and Pillar (1 mine)	Anthracite	500

5.1 Blasting Practices (Metal and Non-metal)

Blasting practices in both metal and non-metal mines are very similar and, therefore, will be covered under the same heading in the following sections. The sections will cover unique or hazardous procedures prominent in either metal or non-metal mines that were observed.

5.1.1 Blasthole Charging - Case Studies

Room and Pillar Metal Mine

Round loading is done by using Pettibone hydro-carriers custom fitted with a "cherry-picker" and a basket. The basket is fitted with a prill pot and all the regulators and controls needed. The carriers have self-contained compressors for charging ANFO. The air pressure is regulated from 130 psi input to 75 psi at the pot.

One of the drillers prepared all the primers for the holes he could reach from the floor. All holes not accessible from the ground were charged from the "cherry-picker." Holes above the water seepage line were loaded with ANFO and those below with cartridge powder. The water seepage line is delineated by blastholes "making water."

Improper, Hazardous and/or Illegal Actions

The driller tamped the holes charged with cartridge powder only once after the hole had been loaded with ten sticks of powder.

No system was used when tying in one blasthole to the next, i.e., red wire to red wire, or green to green, etc. The driller said, "I've been doing this for sixteen years so I should be able to do it by now." When loading was completed the driller walked away from the face to get a blasting galvanometer, leaving the lead wires unshunted.

The driller also disposed of two corroded caps that

exhibited continuity. He placed the caps into a loaded hole and placed a stick of powder on top of the caps and then tamped the powder.

Sub-level Stoping, Metal Mine

There are two types of stoping operations at this mine - standard ring drilling from a sub-level drift, or down hole rotary drilling with a Robbins MD-11 Tricone drill. The ring drill holes are drilled with a Gardner-Denver single boom drill. Blast holes are 2 inches diameter with eight feet of spacing at the bottom of the hole. Inclination, length of hole, and sequence of firing is designed for every round. Stopes are shot to a conventional or machine driven slot raise. The 6 3/4 inch diameter down holes are also shot to a slot raise from a pattern similar to a burn cut round to develop a free face and room for swelling. After the slot raise has opened, the holes on a 17-foot x 20-foot pattern are shot. Length, inclination, and loading parameters are designed for each round. These holes are typically loaded in 21-foot lengths separated by a 3-foot decking. Charge mass used is approximately seventeen pounds per foot of hole depth. Charges are primed with cast primers initiated with Primadet blasting caps on a string of Primuline Detonating cord. ANFO is poured from sacks into the holes. All blasting caps are short delay Primadets.

Ring drill holes can be as deep as ninety feet to 100 feet. These holes are frequently over open ground and require extra precautions when loading. This company uses a Ford diesel farm tractor with a custom-made lift basket. The basket will not rotate so the tractor must be maneuvered into place for each blasthole. Holes are bottom primed with a Tovex cartridge and a "ms" delay Primadet detonator. These detonators have either a twelve-inch or a thirty-inch length of shock tube attached and these are then attached to 7 gr./ft. Primuline (a detonating cord). The Primuline is then attached to a detonating cord trunkline. ANFO contained in a one-hundred pound capacity prill pot is pneumatically injected into the blastholes through a 120-foot long tube. This is a homemade unit with a single manually controlled valve. This setup requires at least two miners for safe operation.

Improper, Hazardous and/or Illegal Actions

During this operation the miners inadvertently used blocking prills, which consist of finer-size particles than stoping prills, and, as a consequence, tend to form lumps which lodge in the tube. During load-out, approximately one and one-half bags of ANFO spilled on the ground around the area being loaded. No attempt was made to dissolve or dispose of the spillage. When the blasting crew entered the stope the foreman found half a roll of A-Cord (detonating cord) which had been run over by a tractor. They then used the roll of A-Cord for initiating

the round rather than disposing of it.. The miners at the development drift heading had two cases of Tovex at the face where several holes were loaded. At the same time, the drillers were using the jumbo to re-drill several holes. Upon our arrival at the heading the foreman asked the miners to move the equipment out. The jumbo was moved about fifty feet down the drift and set up for drilling holes to slab down the roof rock. This was a violation of the company safety rules and Federal regulations.

Cut and Fill - Metal Mine

Vertical Crater Retreat (VCR) stoping is a relatively new method of mining and has been in use at this mine for approximately one year. It is a technique in which blastholes that have been drilled through from one level to the next are loaded with an explosive centered near the bottom of the blasthole. Loading is done from above. This technique allows rock to be broken without having miners working under disturbed ground, thus eliminating need for ground control.

Typical VCR rounds are twenty-eight, 6 inch-diameter holes on an 8 foot pattern; each hole is loaded with sixty pounds of Tovex.

In the borehole charging procedure, each hole is measured and a mine wedge, tied to a length of E Cord (detonating cord), is lowered to a point four feet above the open end of the blasthole. A second wedge is dropped into a hole to close the bottom of the hole. If necessary, small rocks are dropped into the hole to force the wedges against the walls of the blasthole. After all holes have been fitted with E Cord and wedges, the holes are charged with a thirty-pound cartridge of Tovex which has been cut into approximately six-inch lengths. The hole is then primed with an Atlas Deckmaster primer and delay insert. The primer has a tube on one edge for the E Cord. Another thirty pounds of Tovex is cut up and placed into the drill hole. Two 5 inch x 3½ foot water dummies are then dropped onto the Tovex for stemming. The round is initiated with E Cord which is primed with an electric blasting cap.

VCR blastholes are initially eighty feet to one-hundred and seventy feet long. A VCR round will pull eight to ten feet per shot with an approximate powder factor of 1.1 to 1.2 pounds per ton. At the VCR stope observed, there had been no damage resulting from the "shot gun" effect. In other stopes, however, there has been extensive damage on the charging level caused by blowout from the blasting. Miners seem to think that the direction of air flow is the governing factor. If the air flows down through the blasthole there is very little blowout damage; however, if the air flow is upward there will very likely be some damage on the charging level.

Cut and Fill - Non-Metallic Mine

This mine is in a well-established district and has been in operation for many years. The miners were experienced and competent but departed somewhat from recommended practices.

The round was designed for creating rooms in a room and pillar system. Blastholes were ten feet deep. One miner performed the drilling and charging operations while the other mucked out from previous rounds in other parts of the stope. The miner removed the drill and extraneous material from the area after completing drilling operations.

Improper, Hazardous and/or Illegal Actions

The detonators available had only ten-foot leg wire attached. Since the blastholes were also ten feet deep, three eight-inch cartridges were placed into the bottom of the blasthole to provide access to the legwires. After priming, each blasthole was completely filled with ANFO. The lead wires were still too short to reach from one hole to the next; hence, a piece of shot wire had to be spliced to each detonator.

After the "load out" was completed, there were twenty sticks of water gel and a bag of prill left over. The miner tied three sticks of powder together and placed them into a large crack in a rib. He then poured ANFO into the crack. The remaining water gel was used to make several "bombs" consisting of two or three sticks each which were then placed on boulders. The miner poured the remaining ANFO on the various "bombs" and then placed a rock on each bomb for "confinement".

Room and Pillar - Non-metallic Mine

This was a new mine and management had difficulty maintaining an experienced labor force. The most experienced miner on the job had less than four years' experience in underground mines.

Improper, Hazardous and/or Illegal Actions

The explosives truck was equipped with two loading hoses. The arrangement required two miners for loading each hose; another miner was needed to operate the controls at the pressure vessel and a fourth one to manipulate the loading hose. At one point one of the men in the blasting crew had to leave the face area thus leaving three men to perform the duties of four. During this man's absence the third man attempted to load his portion of the round by himself. He kinked the prill hose and turned the air on. He then went through the loading routine. All went well during load out of the first blasthole. As he withdrew the hose from the blasthole he lost control of the hose. The results were predictable: the hose whipped wildly about the

heading, spewing the prill. The miner received a fairly severe blow on the head while the observer was showered with ANFO.

Open Stope - Non-Metallic Mine

Drilling and blasting operations are performed by the same crew. Primary stope blasting is done at the end of the shift with all miners at the shaft station. The mine crew generally is comprised of one to two men actually involved with drilling and blasting.

Large boulders and slabs are pushed aside for secondary blasting which is done on shift. They are either drilled and shot with a half cartridge of Tovex 200 or are mud-capped with up to twenty-five pounds of Tovex Type P cartridges per boulder. Cartridges are split and packed onto the boulder. All blasting is initiated electrically. Access to the stopes is guarded and miners on the level above are notified that secondary blasting is in progress. If there is access to the stope from the level above, a guard is stationed there as well, and a blast warning whistle, located in the access manway, is sounded. There were no precautions taken, however, to verify that access manways were clear.

There are no grizzlies in the ore transfer system; and as a consequence, secondary blasting is required in the crushers several times each shift. On these occasions, the boulders are drilled and charged with a half stick of Tovex 200. The vibrating feeders to the crusher are turned off, but the crusher and other electric appliances are left energized. The electric blasting caps were plugged into a blasting circuit receptacle at the crusher. The hoist man was notified that blasting was under way at that level, guards were placed at accesses to the shaft station, and a blast whistle was sounded. Approximately one minute elapsed between the sounding of the blast warning whistle and the blast. The charge was initiated by plugging the secondary blast line into a blasting receptacle on the locomotive. The blasting circuit was shunted at all other times.

Primary and secondary blasts are initiated from separate circuits. There are separate secondary blast circuits for the stopes and for the crusher stations.

Primary blasting is done at the end of shift only. Blastholes are wired together and then wired to the main blasting circuit at the end of the shift. The blasting circuits have a 15 ft. distance between them at the shaft stations and are left open or shunted until the end of the shift. The blasting circuits are plugged into the mine service 220V. A.C., power source and the blasting switch is unlocked and the blast is initiated. No work is done underground until the shift goes down the next day.

5.1.2 Blast Area Clearing and Guarding - Case Studies

Each mine addresses the problem of clearing and guarding in a manner that is most compatible with the mine layout and production requirements. This phase of the blasting cycle required the most attention. All but two of the metal mines and two non-metal mines permitted on-shift blasting. Several of the mines which did not allow on-shift production blasting would permit on-shift blasting for breaking boulders or clearing ore passes. In every instance except one, permission or supervision by a shift boss, is required.

Each mine that did not allow on-shift blasting employs its own system of accounting for personnel. The systems have been developed to suit local policy and philosophy. It is sufficient to say that in each system all personnel are positively accounted for by brass check or are visually identified and counted. One metal and one non-metal mine, in development stages, did allow the use of explosives during the shift, but would remove all personnel from the mine and account for them prior to initiation.

Room and Pillar - Metal Mine

Each working area of the mine is isolated from the others and there is only one access to a working place. Prior to blasting all personnel are removed from the work place and counted by the lead miner. A guard is placed at the entrance to the section, well back from the blast area, and the lead miner fires the round.

Room and Pillar - Non-Metallic

Production requirements are such that it is necessary to blast continuously throughout the shift. During charging operations, access to the heading is posted with a warning sign. When ready to shoot, the shot firer sounds the horn on his powder truck. Personnel are cleared from the heading, but no guards are posted to prevent non-operating personnel from walking in on a blast. Adjacent areas are checked and cleared, but not guarded.

5.1.3 Transportation - Case Studies

All of the mines visited, except one metal mine and one non-metal mine, utilized specially made vehicles for transporting explosives. These vehicles, either commercially made or home-made, all complied with the standards set forth in Title 30 CFR.

The one metal mine not using a powder carrier, transported all explosive cases and blasting agent bags in the LHD Bucket. Detonators are also carried in the LHD bucket but in a separate closed wooden compartment. The LHD bucket was not lined with non-sparking material. In one non-metal mine the

day boxes are transported from the underground magazine in LHD buckets. Several examples of procedures for transporting explosives are given below.

Non-Metal Mine - Open Stope

The mine had a variety of working places and the amount of climbing required necessitated development of a blasting cap carrier. Several different systems including wooden boxes, carpenters' leather nail pouches, and plastic bags were tried and found to be impractical. The most satisfactory system was found to be a Nalgene liquid chemical sample bottle. These have screw-on lids and are fixed with a nylon rope sling so that the miners can carry them over the shoulder while climbing into stopes and raises. Each container is clearly marked "Danger Explosives" in 1-½ inch letters on a yellow background.

Explosives are transported on Granby cars which have been fitted with a 2 foot x 4 foot fiberglass carrier. The carrier is placed into the ore car so that it cannot dislodge if the car is inadvertently taken through the camelback dumping device. In addition, the carrier prevents the explosives from contacting metallic surfaces of the Granby car and provides the motorman with a view of the explosives.

Non-Metal Mine, Room and Pillar

This mine utilized underground rubber-tired magazines in its various sections. The magazines were made from ½-inch thick steel plates lined with 3-inch x 12-inch timber. Powder trucks were used to transport the explosives and blasting agents from magazines to the working places.

This company was charged with violating 30 CFR 57.6-44:

1. The powder trucks are equipped with air-starting motors and to alleviate the necessity of having to park the vehicle near an air header the miners park the truck at a convenient location, set the brake, block the wheels, leave the engine on, and leave the vehicle unattended. This is a clear violation of this regulation.
2. While the boreholes are being loaded the vehicle is in the same location except that the shot firer is in the area although his attention is directed toward loading out the round. The company contends that these situations are identical, and, if one is in compliance, the other should be as well.

This mine has "day-boxes" situated throughout the mine and the powdermen notify the motormen of their requirements at the start of a shift. The motorman spots powder cars at a

convenient place near the stope. The cars were prevented from rolling by driving the draw bars into the track ballast. The shift boss advised the mine crew to block the wheels of the powder cars with mine wedges, but this had not been done by the time the observer left the stope.

The powder cars have a drop side which is hinged at the bottom. The miner pushed the car into the stope and opened the car at which time approximately thirty five-inch diameter, thirty-pound cartridges of Tovex and two rolls of detonating cord dropped to the ground. Though it is unlikely that a drop of about two feet would initiate the explosives, the cord may have been damaged.

5.1.4 Storage - Case Studies

All but one metal and all non-metal mines have some underground storage capacity ranging from one shift day box to a complete and permanent storage magazine. All day boxes for explosive and blasting agent storage complied with the standards.

Metal Mine - Vein

The underground storage facility in a copper mine was particularly noteworthy.

This company takes proper care of its underground storage facilities for explosives. The magazines all have concrete floors and white-washed ribs and roofs. Explosives are kept on platforms which are sixteen inches above the floor. All explosives were neatly stacked and there was no trash in any magazine. Blasting caps are kept in separate magazines, well away from the explosives magazines. Development and stoping detonator caps are kept in the same magazines however they were not separated to prevent confusion in their use.

Good and poor condition detonators are kept in the same magazine. When a new explosive supplier is contacted the company ceases using the detonators of the previous supplies, and, as a result, collects thousands of "mixed breed" blasting caps. Many of the caps have no tags; the manufacturer and condition of the detonators are unknown. To date, the manufacturers have been reluctant to help in identifying or disposing of these items.

5.2 Blasting Accidents - Case Studies

InMinCo attempted to arrange visits to types of mines which have a high frequency of accidents and several of the mines had experienced explosives-related accidents.

- Metal mine - two fatalities, three lost-time accidents
- Metal mine - one fatality
- Metal mine-lost-time accident
- Non-metal mine - one fatality
- Non-metal mine - two lost-time accidents

The documentation of non-fatal accidents is so difficult that a general survey was quite impossible. During the mine visitations each mining company was asked whether there had been any recent accidents. Each non-fatal accident report is described briefly in Appendix B.

5.3 Training and Retraining of Blasters - Safety, Case Studies

All mines visited were in compliance with the training requirements set forth in CFR-30, Subchapter 48. Several examples of training programs are given below:

Non-Metal Mine - Room and Pillar

The company has one section of the mine set aside specifically for training. All new personnel spend three weeks in this section becoming familiarized with equipment and procedures while under the direct supervision of an experienced miner. All equipment and procedures are the same as in production headings. Task training for miners who bid on jobs is also done in this section. After training is completed the miners go to production sections and have thirty days to qualify or be removed from consideration. The selection of successful candidates is, however, based more upon seniority than competence.

Metal Mine - Cut and Fill

New personnel, regardless of experience, spend approximately fourteen weeks in training under the supervision of two experienced miners. Training includes all aspects of mining and operation of various pieces of equipment. After training has been completed the new candidate is sent to work as a third man on a mining crew. He is supervised by two miners and evaluated before being permitted to work alone.

This mine has an exemplary safety program that is endorsed and enforced by mine management. All personnel on the mine force are aware of the importance of safety. All are quite aware of the consequences of violating safety standards. The safety department is an integral and active part of mine management. Some of the company standards are:

- No explosives are allowed in working places until the second half of the shift.
- Normally, no on-shift blasting is permitted, however, missed holes and chute hangups can be shot with special permission of the supervisor.
- Blasting must be completed twenty minutes prior to the start of the next shift. Behind-schedule blasting is done at the end of the next shift.
- All personnel are evacuated from the mine during a blast.
- Safety fuse is initiated with electric squibs. Blasting caps are used to initiate Nonel Primadet detonators.
- All blasting is controlled from a single point. Initiation of various levels are sequenced via an automatic timing device.

Metal Mine - Room Pillar - Sand Fill

New employees are given eight weeks training - seven weeks of training in underground practices and one week in classroom instruction.

Ground conditions are very poor in this mine however the company has an awareness of this and is very safety conscious. Lost-time accidents have decreased from twenty-eight per year to five per year in the last four years.

Blasting patterns designed specifically for conditions are used. Any deviation from an established pattern must be approved. If the round does not pull, the miners are penalized as specified in a contract.

Any missed hole must be reported to the supervisors. The ground must be bolted or studded prior to shooting misfires.

Metal Mine - Sublevel Mining

Union Carbide Corporation's Pine Creek mine was found to have a thorough safety program supported by a conscientious and competent safety department. All levels of corporate management endeavor to promote safety. All employees are aware of the company position with respect to safety and everyone on the company payroll is encouraged to contribute.

The Pine Creek Mine has the most comprehensive blasters' training and certification program of any seen during this study.

They are to be commended for their effort in training employees in safe blasting procedures.

5.4 Standard Blasting Procedures Observed in Coal Mines

5.4.0 Introduction

Though blasting procedures in conventional coal mines are similar in many respects, they vary somewhat depending on the equipment used, manpower required and other conditions encountered. Entry dimensions of mines observed ranged from 3 x 25 to 12 x 16 ft., and inclinations ranging from 0 to 60° were encountered. Manpower requirements in various mines varied from 9 to 38 for the primary and secondary blasting observed. In each mine a systematic mining cycle had been established, employee responsibilities were well defined and a safety training program was in effect. Blasting procedures were suitably tailored to the equipment used and manpower required.

Very few unsafe acts or violations of Federal Regulations were observed. None of the mines visited had experienced a fatality or injury due to blasting. All of the personnel interviewed expressed their confidence that the safety procedures employed were adequate so long as the coordinate effort for safety continued. All personnel interviewed also had an acute awareness of the hazards in the handling and use of explosives. No changes in the procedures used were recommended by any personnel nor thought to be necessary by inspectors.

None of the coal mines visited were known to have had any fatalities or lost-time accidents caused by explosives. Abstracts of all explosives-related fatal accidents in underground mines from 1970-1978 are included in Appendix B.

5.4.1 Blasthole Charging

In all the mines visited the most commonly used drills were hydraulic auger drills which included brand names such as Long-Airdox, Shroeder, and Joy. In rare cases jacklegs were used for rock drilling.

The average size hole was 2 inches in diameter; a few mines were using 1-3/4 inch and 1-7/8 inch diameter holes. As for the number of holes per round, most mines complied with the regulation, i.e., less than twenty holes. The number of holes ranged from four holes to twenty holes per round with only one mine using twenty-one holes.

No misfires had been experienced in any of the mines visited. This is probably because all of the blasters were "Certified Shot Firers" with at least three years of practical experience before becoming shot firers and because the bulk of the blasting was less than ten holes wired in series and initiated by permissible blasting machines.

5.4.2 Clearing and Guarding Blast Areas

The number of blasts per shift varied from mine to mine. The blasting sequence was designed to fit each individual mine's mining cycle. However, almost all of the mines were on "on-shift" blasting. One mine had up to twenty blasts per shift.

All of the mines visited followed the standard method of guarding and clearing blast areas. The procedure included patrolling adjacent work areas, placing guards around blast areas and giving "fire-in-hole" signal three times before initiating a blast. In all cases it was the shot firer's responsibility to see to it that the above precautionary measures were carried out and followed.

As far as the blasting procedures under the direct control of the shot firer are concerned, the hazards are minimal as long as proper equipment and permissible explosives and practices are employed. However, the areas over which the shot firer can exert the least control pose the greatest risks of injury. In most of the mines visited the shot firer worked alone and blasting was his sole responsibility. As a result, it was difficult to be certain where the remainder of the crew was working or that adequate assistance would be available for guarding a blast site. The shot firer was not able to be certain that once an area had been cleared that it would remain clear, nor was he able to be absolutely certain that the round being fired would not break through into an active working place. Many instances were observed where the shot firers had to rely on other section crewmen's training and awareness to guard against injury since they were not aware of where blasting was in progress. It appeared that the only times that guarding hazards are particularly dangerous are 1) when new miners or visitors are in the section, 2) unusual conditions or disruptions of the normal mining cycle are encountered, or 3) intentional risks are taken such as not removing men from adjacent works because a breakthrough is not anticipated.

5.4.3 Transportation

Different transportation methods for explosives and detonators were observed in different mines. Each method was basically designed on the basis of available equipment and mine conditions. One observation was that however unique the systems were, they complied with regulations. Caps and powder were transported separately. One mine reserved the conveyer belt for transporting explosives and caps into the mine. Another mine transported powder and caps on different shifts always keeping a two-shift supply underground. Other methods included special rail cars, trailers, special boxes into scoops, etc.

5.4.4 Storage

The storage of explosives and detonators also differed

for each mine, depending on conditions. On the surface, caps and explosives were stored in different magazines, the majority of which were concrete. Underground, steel and woodlined boxes were used, but fiberglass units were observed. These boxes were either located in neutral headings or crosscuts in the intakes.

5.4.5 Training - Conventional and Continuous Coal Mining - Case Study

This mine employs one hundred and eighty-five underground miners, of whom approximately one-third are involved in conventional coal mining. Eight are full-time shot firers certified by the State and have at least two years of underground coal mining experience.

This company meets all of the state's requirements and has made extraordinary efforts in complying with the Federal training requirements as well. Of the forty-two salaried personnel at the mine, seven are members of the company safety inspection team or the training office. Each miner receives the mandatory hours of new or experienced miner training courses, or annual retraining or task training courses. This mine is several hundred miles from the nearest MSHA district office and has, therefore, undertaken to provide all of the necessary training using their own instructors and facilities. The training department has three full-time instructors and approximately \$200,000 worth of audio-visual equipment, including video tape machines. They have independently developed training programs approved by MSHA which satisfy the CFR-30, Subchapter 48 requirements, including task training programs for blasters. The majority of the task training is on-the-job instruction with a qualified instructor present.

SECTION 6

ABBREVIATED GUIDELINES FOR SAFER BLASTING

6.0 INTRODUCTION

The mining industry is faced with problems that directly affect the safety and productivity of the labor force. One of the most severe problems is a lack of skilled engineering personnel as many graduate engineers are diverted to fill supervisory positions, hence there is a lack of engineers available for research and development of safer and better mining techniques.

The mining industry which is small and closely knit, has also been reluctant to disseminate information among members of the mining community. It is then apparent that it needs assistance in solving technical problems. A possible, and welcomed, solution would be to have the Federal Government, through the coordinated efforts of USBM and/or MSHA, form a technical advisory group that the mining industry could call upon to aid in finding solutions to problems.

The abbreviated guidelines set forth in this section will further fulfill the needs for improved safety in the blasting sequence of mining in metallic, non-metallic and coal mines. These guidelines are offered for industry's as well as governmental agencies' benefit.

The guidelines are not intended to supplement the extensive descriptions in the many books on blasting, e.g., "Blasters' Handbook", published by E. I. duPont de Nemours and Company, in sixteen editions since 1942. The guidelines offered here are based upon InMinCo's observations obtained during its mine visits and from the blasting experience of its staff. The guidelines are highlights intended to improve safety.

6.1 Abbreviated Guidelines Metal/Non-Metal Blasting

6.1.1 Blast Design

Most regulations and guidelines for safer blasting procedures are generally concerned with personnel protections during loading, blasting, and explosives handling. However, many hazards are a result of bad or improper round design.

The following are recommendations or guidelines in some areas of blast design which if ignored could result in hazardous situations.

- Shot Design

Blasting results are sub-optimum whenever drilling accuracy is lacking. In order to compensate for bad drilling, the tendency is to overload the holes, i.e., using the "brute-force" method. This creates hazardous situations such as a "frozen" round or over-charged blast-holes resulting in flyrock and excessive damage to remaining rock contour.

Recommendations

1. Better techniques are needed for drilling accurate holes; this is especially important for "burn" cuts where parallel holes are a must for successful blasting.

2. In very restricted areas, i.e., small area drifts or blasting in very "hard" rock, one can improve blasting results by increasing the number and/or diameter of relief holes.

3. In areas where relief (unloaded) holes are used in conjunction with charged holes, it is recommended that deeper, and if possible, larger diameter holes be drilled. This increases the probability of pulling full depth, thus reducing the formation of bootlegs.

- Powder Factor

Powder factor is considered to be an important parameter in blasting. Many operators and blasting personnel consider "powder factor" the main criteria for efficient blasting. It is defined as the ratio of the weight of the explosive to that of the rock burden expressed as pounds per ton or as pounds per cubic yard.

Recommendations

1. The subject of optimum powder factors for given rock-explosive combinations should be thoroughly reviewed and information on this subject made available.

2. The blasting crew should not be provided with more explosives than that previously calculated as necessary for the blast.

- Predetonation Avoidance

For safety and efficiency all holes in a round are not fired at one time and different delay-period detonators are used to stagger firing of holes. If there is improper design, an adjacent hole may have sympathetic detonation before its expected time via shock waves propagating through the strata from the first round. The occurrence of this depends on the spacing between holes, the delay interval and shock sensitivity of the explosives.

Recommendations

Predetonation can be prevented by:

1. Increasing blasthole spacing for explosives that exhibit a relatively high shock sensitivity (e.g., dynamite).
2. Paying more attention to the shock propagation characteristics of various rock strata.
3. Closely monitoring the location of ground water, open channels and clay seams. These conditions increase the chance of sympathetic detonation.

6.1.2 Blasthole Charging

Charging is the phase of a blasting operation where explosives and blasting agents are placed in the blastholes. Explosives and blasting agents are either cartridge or in bulk form. Cartridge materials are generally manually loaded into the borehole; however, pneumatic cartridge loaders were recently introduced in hardrock mines for loading cartridge water gel explosives. Bulk ANFO is often loaded pneumatically using either an ejector (Venturi) system or a pressure pot system.

The ejector system utilizes high-velocity air moving through a Venturi to create a partial vacuum which sucks prills into the air stream, hence into the blasthole. There are two styles of loaders which differ greatly in appearance but function identically. In one system the prills are poured into a container; they are then drawn into the air stream by gravity and venturi action. The other system has a hose which is inserted into a container of prills whereupon they are drawn into the air stream by venturi action.

The principal difference between the pressure pot and ejector systems is that the former is closed; prills are forced into the air stream by compressed air. Air flow is controlled

by remotely-operated valves attached to the outlet of the prill pot. Pressure pot systems vary in size from small, portable units with limited capacity to truckmounted units having 600 to 800 lbs. capacity.

In either system prills are placed in the blastholes through a prill hose inserted to the bottom of the blasthole. As the blasthole fills, the hose is gradually withdrawn until the proper charge has been placed, at which time the system is turned off. Packing and charge density is a function of the velocity of prills moving through the prill hose.

Either system is easy to use, and miners can become proficient in a very short time. The mechanics of ANFO loading are relatively simple and straightforward; however, there are some difficulties encountered with pneumatic loading systems and there are potentially dangerous situations which can arise from the use of pneumatic ANFO loaders. The most notable hazard associated with pneumatic ANFO loaders is the generation of static electricity. Other problems are: clogging of prill hoses and valves; crushing of prills caused by too high an air velocity; spillage and rebounding prills; and, inconsistent charge density.

Both types of ANFO loading systems utilize compressed air as the transport media. In most instances pressure pot systems have air pressure regulators and the system can be controlled. Ejector systems, however, are nearly always connected to the mine compressed air supply; thus the air pressure cannot be controlled and higher than optimum pressures can result causing excessive prill velocities.

Excessive prill velocities can cause two problems, both of which are potentially hazardous. As prills impact the rock at the bottom of the blasthole they tend to crush, thereby increasing the charge density. Although increased charge density may be beneficial up to a point, it has been demonstrated that if the bulk density is too high the steady state detonation rate of ANFO is decreased, resulting in poor blast results.

The second problem caused by excessive air pressure is that it can cause prills to rebound and spill out of the drill hole. If there are significant amounts, the ANFO prills may be detonated with the blast and cause excessive concussion in nearby areas.

All tools and equipment designed for use with explosives must be of non-sparking material. The problem in using plastic materials is that they are dielectric materials capable of generating static electricity. Fortunately the static electricity generated by blowing prills through loading pipes is not large enough to directly initiate the charge. However, if the ANFO loader is insulated from the ground, it can effectively serve as a capacitor and accumulate a static charge which is suffi-

cient to initiate, in particular, electric detonators. This potential problem has been alleviated by using semi-conducting hose and providing loaders with grounding devices. Manufacturers now specify hose resistance (5000 ohms) per linear foot and a total hose resistance of 5 megohm.

Nitroglycerin (NG) sensitized cartridge explosives are manually loaded into blastholes. The cartridges are placed into the blasthole and pushed to the bottom with a loading pole. ~~The primer~~ at the bottom of the hole is never tamped, but the following cartridges are frequently split prior to insertion so that they will pack more tightly in the blasthole. Tamping is intended to serve three purposes: increase the charge density, to improve coupling between the explosive and the rock, and to deform the cartridge so that it will remain in the blasthole prior to detonation.

Modern cartridge explosives, though still generally referred to as "dynamite", are rarely "straight" dynamite. Herein "straight" dynamite is defined as dynamite consisting of nitroglycerin as the principal means of developing energy. Although other classes of dynamite (ammonia dynamite, gelatin dynamite, ammonia-gelatin dynamite, and semi-gelatin dynamite) are still available, ANFO and "water gels" are progressively replacing "dynamites".

Although there are pneumatic cartridge loaders available, they are only permitted for use with water-gel cartridges in underground mines in the United States. Basically these systems propel cartridges through a pipe inserted into the blasthole. These systems have been employed in loading blastholes up to 135 feet deep, and two men can load 1100 to 1300 lbs. per shift in holes up to 50 feet deep.

To avoid occurrence of post-blast flashes in blind vertical crater retreat (VCR) blastholes, the following procedures are recommended;

WHEN LOADING THE FIRST TIME

- Use only non-aluminized explosives
- Properly stem all VCR holes. This requires a minimum of seven feet of stemming in a 6½-inch diameter hole.
- Load and blast fan holes (after the breakthrough holes have been blasted) high enough to allow slabbing room.

BEFORE RELOADING BLASTED HOLES (DO NOT DROP ROCKS IN VCR HOLES)

- Check all holes for airflow through the hole. Airflow can be easily felt in a clean hole. Holes that are partially covered over can be checked with a smoke tube or aspirator bulb.
- Holes that are tightly covered over must be carefully cleaned off before the airflow can be checked. Avoid dropping rocks down the holes since sparks may detonate any combustible gases trapped in the hole. If possible, the holes should be uncovered remotely with a bar or long-handled shovel.
- Blind holes with no airflow should be purged by filling with water. The water hose should be placed near the top of the hole and turned on from a remote location.
- Do not stand directly over a blind hole at any time and DO NOT DROP ROCK IN VCR HOLES TO SEE IF THEY ARE BROKEN THROUGH!!

6.1.3 Priming

Priming the charge is basic procedure in blasting because it is the primer that detonates the main explosive. Primers are usually blasting caps (electric, non-electric) inserted into a cartridge of explosive. Other types of primers have been developed for use with ANFO. One type, "Detaprime" resembles a small red rubber tube about $\frac{1}{2}$ -inch in diameter. They are a mixture of PETN and an elastomeric rubber. Pentolite primers are also available. These are cast primers and they are often used for priming large diameter holes containing ANFO.

Primers are nearly always placed at the bottom of the blasthole with the detonator pointed toward the charge (indirect priming). The reasons for indirect priming are: (Blaster's Handbook - 16 ed.)

- To reduce the possibility of borehole cutoff.
- To reduce the possibility of unshot cartridges (bootlegs) in the bottom of the holes.
- To assure that an additional primer can be added if there is a powder separation from a blocked hole.
- To allow the retrieving of a primer cartridge from a blocked hole.

- To produce more heave and rock displacement in development rounds or other "tight" shooting conditions.

Direct priming (collar priming) should be restricted for use with short delay or instantaneous caps or in very large dynamite blastholes, where holes are more widely spaced, which reduces the danger of cutoffs. Direct priming should be used only when there is a compelling safety consideration that makes it inadvisable to use indirect priming.

There are instances when the use of multiple point priming should be considered. These instances do not occur frequently and will be mentioned briefly. Multiple point priming is recommended: (Blaster's Handbook, 16th ed.)

- In small-diameter, ANFO-loaded holes with detonating cord or uplines which might disrupt or deflagrate the explosive load and affect the blasting results.
- In water-filled holes where the sensitivity of the main charge may be affected by water seepage into the product.
- Where relatively insensitive packaged ANFO products that have poor cartridge-to-cartridge sensitivity are used.
- Where blocky or seamy rock may cause cutoffs, especially in deep boreholes.
- In ragged holes where column separation is suspected or probable.
- Where vibration levels must be controlled by using different delays in decks in each borehole.

The priming requirements for ANFO depend on various factors. The detonation velocity of ANFO depends on the diameter of the charge, and the steady state velocity of adequately-primed ANFO is reached within two or three borehole diameters. If the size of the primer is much smaller than the diameter of the ANFO, the ANFO will be initiated over a smaller area and the distance required to reach steady state velocity may increase. Therefore, for most efficient priming the primer diameter should be approximately the same as that of ANFO.

Detonating cords can cause incomplete detonation of ANFO in holes smaller than $3\frac{1}{2}$ inches in diameter. This causes excessive fumes and poor fragmentation. If it is necessary to use detonating cord in small diameter blastholes, multiple point

primers should be used as well. This may reduce the problem but not eliminate it.

6.1.4 Blasthole Sequencing

Explosives manufacturers have developed detonators having different delay periods that can be used to detonate explosives in holes sequentially, aiding greatly in the efficiency and safety in blasting. There are approximately forty delays or intervals of electric blasting caps varying from instantaneous to about $15\frac{1}{2}$ seconds. Nineteen of the intervals are within the first second after energizing. Nonel caps sequence from instantaneous through sixteen seconds in forty intervals. Fuse-type caps are sequenced by one of two means: (1) by controlling the time ignition is begun or (2) by controlling the duration of ignition. In the first case the most frequently used and preferred method is the igniter cord system (a trunkline cord used with safety fuse).

In the second system sequencing is controlled by the length of safety fuse to each detonator. Fuses are lighted simultaneously since the burning rate of the fuse is known and, within limits, relatively constant. The length of fuse controls the time of detonation. This system is not recommended.

Recommendations

Since the introduction of delay initiators about twenty-five years ago it has become common practice, if not an accepted state-of-the-art, to use delay initiators in both underground and surface operations. Significant improvements have been noticed in blast results (fragmentation and muckpile characteristics, reduced flyrock, low ground vibration, and controlled air blast noise). However, the success of the above-mentioned blast performance heavily depends on the reliability of currently available delay initiators in terms of their actual firing times and the dispersion about their mean firing times. Private investigations have been carried out to verify the above (Winzer 1978). The following recommendations are based on Winzer's results and on other investigations.

- Use of longer periods of MS series delay detonators decreases the probability of success in sequencing, i.e., the absolute or cumulative error on longer delay period detonators is greater. The chances of delays overlapping to the next period is greater. This can result in flyrock, cutoffs and high ground vibration levels.
- Avoid using large number of caps of the same period. This can reduce cutoffs and increased backbreak.

Thus, it is generally recommended that blasters should use modern recommended delay blasting designs by consulting manufacturers of detonators. Closer attention should be given to any literature on nominal firing times and scatter data (Winzer 1978).

Safety fuse and blasting cap initiation is still very important to the mining industry particularly for secondary blasting and for occasional "pop holes." This initiation system is also useful in locations where there may be static electric currents present. As with any explosive product, the miners or blasters should be thoroughly trained in all aspects of its use. Technical questions should be directed to the manufacturers.

6.1.5 Wire-In

Wire-in is the phase of blasting where the initiators (detonators) are tied together to any energy source either electric or thermal. In electric initiation, the energy can be directly applied to the blast round from a remote location. Nonel detonators are initiated by a "spit" from the Nonel core that is initiated by detonators, detonating cord or percussion devices. Igniter cord for safety fuses may be lit at the blast site or from a remote location with the use of electric-squibs.

Recommendations

The Dupont Blaster's Handbook gives an excellent coverage of Electric Firing Techniques. In summary, successful electric blasting depends on:

- Proper selection and layout of the blasting circuit - series or parallel.
- An adequate energy source compatible with the type of blasting circuit selected.
- Recognition and eliminating of all electrical hazards.
- Circuit balancing approximately the same number of caps per secondary circuit, good electrical connections and complete circuit testing.

In general, good "housekeeping" should be highly emphasized here, as in all other areas of explosive handling.

When using electric detonators, blasting personnel should make use of the manufacturers' recommended arrangements of detonators in the circuit. This information is readily available and can be obtained for various energizing sources including various blasting machines. Arrangements will vary depending on the source used.

It is a recommended blasting practice that each "element" of a blasting circuit be checked with a blaster's ohmmeter before connections are made to any other "element". An element includes single caps, series, series-parallel combinations, lead (firing lines and blasting trunks). The correct resistance of each "element" should closely match the calculated value prior to any blasting. Lead wires from the blast site to the trunkline are generally used only once then discarded.

6.1.6 Guarding

When charging and wire-in are completed, the round is ready to shoot. At this time all personnel should be cleared from the blast area and access to the blast area controlled. This may be accomplished in any of several ways: by stationing guards, by posting warning signs and lights, and by physically accounting for everyone on shift prior to shooting or removing all personnel from the mine at the end of the shift. The complexity of the mine, the mine layout, and the experience level of the labor force all influence the ease with which proper blast guarding is accomplished.

Recommendations

- Special attention should be given to non-blasting personnel such as visitors, geologists, surveyors, engineers, etc., who are not directly involved in blasting procedures.
- Clearly visible signs, barriers and/or audible signals should be erected or given prior to blasting and after blasting for checking work areas before beginning mucking and drilling operations.
- Check closely on "contract" miners who might not take ample time for checking work areas after the blast, before resuming mucking and drilling operations.
- The procedures given above are especially important when blasting during the shift (on-shift blasting).

6.1.7 Blasting Procedures

Pre-Blast Procedures

An important characteristic of commercial explosives is oxygen balance. An oxygen-balanced explosive is one which contains sufficient oxygen to convert all the carbon and hydrogen to water and CO₂. Unbalanced explosives have a tendency

to produce more toxic gasses - especially oxygen deficient ones. The toxic gasses of concern are NO, CO, NH₃ and possibly CH₄. Regulations do exist limiting the production of CO and NO_x toxic fumes for explosives used in underground coal mines. These regulations do not apply to other types of mines. Explosives are classified according to their fume production characteristics as Class 1 to Class 3, in order of increasing fume production.

Recommendations

- More attention should be given to toxic fume production from explosives used, in relationship to existing space and ventilation conditions.

Post-Blast Procedures

The post-blast period is a critical one in the mining process and the procedures must be followed very carefully to prevent accidents. The following is a partial list of procedures that should be adhered to:

- There should be a close check of toxic fumes and combustible gases.
- Ample time given for appropriate ventilation after the blast.
- Experienced personnel should check the roof and ribs for loose rock.
- Check for misfires:
 - though not always possible, make an attempt to count the delayed explosions; vibration meters are sometimes useful for this purpose as well.
 - Make a careful inspection of the muck pile before mucking operations begin.

6.1.8 Training

Explosives-related accidents appear to be caused by carelessness or misjudgments. The analysis of fatal explosives-related accidents occurring between 1970 and 1978 indicated that, in every case, there was a violation of an existing standard. It would appear that the underlying cause for this type of accident is either an inadequate appreciation of the potential consequences of unsafe acts or, more likely, an absence of training and a lack of motivation for safe work habits.

The trend of safety citations issued in the recent past is indicated by the following:

- Between January 1972 and March 1978 seven of the ten most frequently violated mandatory blasting standards pertained to the transportation and storage of explosives. The remaining three dealt with the disposal of deteriorated explosives, the condition of blasting lines, and the control of static electricity during pneumatic loading.
- The pattern of violations of blasting standards subsequent to March 1978 is similar. The difference being that violations dealing with control of static electricity exceeded those dealing with treatment of misfired holes.

InMinCo does not intend to suggest that the violations of standards intended to control transportation and storage of explosives does not create a potentially dangerous situation, but InMinCo recommends that more emphasis be placed on enforcement of standards designed to enhance the safety of blasting procedures.

It is apparent that human error is the prevalent cause of blasting accidents; carelessness cannot be legislated away. Each individual, as part of society, should be held accountable for his actions; this should apply to mining operations as well. The mine labor force must be trained in the proper use of explosives through a continuous training effort. No person who has been trained and certified as competent should be absolved of responsibility for his actions. The miners should share the liability along with mine management for infractions of safety standards. Furthermore, Federal and State mine safety inspectors should be highly trained and qualified to recognize hazards associated with blasting.

The Mine Health and Safety Act of 1977 establishes the standards for training and retraining programs which, within guidelines, delineates skills and hazards associated with specific tools.

Figures 3.14 and 3.15 in Section 3 illustrate graphically the importance of training and the fact that all of the fatalities between 1970-1978 were caused by violations of Federal regulations. This illustrates that miners must be trained better. The constant awareness of risk coupled with good communication and adherence to well-established procedures is the most effective means of improving safety.

6.2 Abbreviated Guidelines, Coal Blasting

6.2.1 Blasting in Coal Mines

The blasting of coal presents several unique problems.

One is due to the nature of the product (coal) while the other has to do with the mine environment. These have a bearing on the selection of the explosive. Problems associated with the nature of coal are:

- Bituminous coal dust generated by coal cutting, by blasting, and through the normal transit of men and machinery, is highly explosive.
- Bituminous and anthracite coals can be and have been ignited by burning explosives, spontaneous combustion, and faulty electrical circuitry.
- Conventional coal mining methods, which include the blasting cycle, are generally applied where a coarse coal product is desired. This coarse product may be desired either for the "house coal" market or to facilitate the removal of shale partings in preparation plants. In either case, the explosives employed in breakage need to be low brisance explosives whose shattering power is relatively reduced (and heaving power enhanced) so as not to reduce the coal into small-size particles. Black powder was used as the principal blasting material until the early 1900's and was the cause of many mine fires and blasting accidents because of its incendive properties.

Several aspects of the underground mining environment that create potentially dangerous situations are:

- Coal and its associated rock formations often contain trapped methane gas. Methane is highly combustible and explosive in a 5-15% mixture with air. Methane explosions igniting secondary and often more violent coal dust explosions have been among the principal causes of coal mine disasters. Methane can be ignited by such things as open flames, electrical sparks, hot electrical wiring, and the flash or flame from explosives. The same applies to concentrations of airborne coal dust. The tremendous emphasis placed on good ventilation, rock dusting, and the required use of permissible explosives and accessories is entirely justifiable.
- Room and pillar mining by conventional mining methods requires cycling of up to twenty working faces per shift on each producing section. Each face must be undercut, drilled, charged and shot, loaded, roof bolted, and rock dusted. Therefore each operation and its associated machinery must move in and out of each working place while

cycling through the sections. The charging and blasting of faces is continuous through the production shift with men and machinery of the other mining activities always in the general vicinity. The existence of multiple openings and the presence of a large work force make blast guarding a critical concern.

- Guarding is more difficult for multiple headings. A blast with a single access is relatively easy to guard. But, during a blast where a breakthrough is not anticipated, it is more difficult to clear and guard the area.
- The ventilation of multiple working places by a single air split carries fumes to downstream operations.

Because of the unusual nature of coal and coal mines, blasting materials, procedures and practices have been thoroughly standardized. Much of the research which has contributed to the development of permissible explosives, electric detonators, and permissible blasting units, as well as the tremendous advances in mine ventilation are directly attributable to the efforts of the U. S. Bureau of Mines.

The development of permissible explosives, accessories and associated regulations constitutes a joint effort among a concerned industry, state, and federal mining personnel. Regulatory implementation was well-established by the mid-1940's.

6.2.2 Coal Mine Blasting Analysis

Unlike metal and non-metal mining, the responsibility for preparing and initiating a blast round in coal mining does not reside with a single miner or small crew. Under normal operating conditions the procedures for a safe blast would involve:

- Section foreman - responsible for inspection of all working places to insure adequate ventilation, properly supported roof and rib, and the orderly and systematic progress of the mining cycle.
- Roof bolter crew - responsible for installation of temporary and permanent roof support prior to preparing the face for the next blast round. Also, responsible for maintaining adequate ventilation, methane accumulation, and rock dusting.
- Cutting machine crew - responsible for undercutting the coal face to provide a "free" face

for blasting. They are also responsible for checking methane and roof conditions prior to and during coal drilling activities.

- Shot firer - responsible for the handling of all explosive materials, preparation of primers, cleaning and loading of blast holes, selection of safe blasting refuge, wiring of the blasting circuit, sign placement, blast guarding, checks for methane, firing the shot and, after a reasonable delay, examination of the blast area for a safe roof, methane accumulation, misfires, and burning coal.
- Loader and shuttle car operators - responsible for the examination of the working place for roof condition and methane prior to and during coal loading. Also responsible for examining the coal during loadout for unexploded powder, primers and caps, and burning coal.

In the broad sense the entire crew of a conventional mining section participates in the blasting cycle. Each and every member of the crew has responsibility in ensuring that safe blasting procedures are adhered to in the conventional coal mining cycle.

6.2.3 Typical Coal Mine Blasting Procedures

In a typical coal mine blasting procedure, the following sequence and practices of the shot firer should be, and were, observed.

1. The shot firer enters and examines the working places adjacent to the face to be blasted. The presence of workmen is noted and the workmen are advised of the location of the upcoming blast(s).
2. The shot firer enters the working place(s) to be loaded and examines the roof by visual inspection for the appropriate temporary and permanent roof supports. The roof is sounded and the face checked for methane accumulation by an approved "spotter" eighteen inches from the face roof and rib.
3. The shot firer examines the face to verify that the undercut and auger holes are cut and drilled as planned.
4. The shot firer then obtains, from the section magazines, sufficient powder, caps and cables to

load the face(s).

5. The shot firer returns to the face(s), deposits the blasting materials and posts a blasting warning (danger board) at the entrance.
6. Upon returning to the face, each auger hole is loaded and stemmed by approved methods.
7. When all of the holes are charged the shot firer orders any men or equipment from the affected area and uses those available as blast guards.
8. After placement of the guards the shot firer returns to the loaded face and wires in the loaded holes. The blasting cable is then connected to the permissible blasting machine.

He then shouts "fire" three times and fires the round. Special care is taken during the wiring of the round and laying of cable to avoid all energized electrical cables; the circuit is shunted until the blasting machine is attached.

9. After the blast the shot firer enters the blast site (after adequate time has passed to permit fumes to dissipate). He visually checks the area and sounds the roof as he enters. The broken coal is examined for fires, and all leg wires are collected. The shot firer then releases the blast guards. The whole process is repeated as other faces become available for blasting.

The handling of misfires is a hazardous operation. A general procedure for handling misfires is given below:

1. When a misfire is suspected, reentry of the blast site should be delayed five (5) minutes for bituminous coal and underground lignite mines; a waiting period of at least thirty (30) minutes should be observed for underground anthracite mines.
2. The misfires should be reported to the proper supervisor and disposed of before any other work is performed in that blasting area.
3. First, the blasting cable should be disconnected from the power source and shunted before electrical connections are examined.
4. Next, the leg wires of detonators in the misfired holes should be shunted.

5. Then, a careful check of the leg wires of the misfired holes should be made. Never pull on the wires of electric blasting caps. Test the detonators with a blasting galvanometer and, if the bridgewire circuit is intact, attempt to fire it in the usual way.
6. If the detonator does not fire the hole, remove the stemming, insert a new primer and try to fire again.
7. If this fails, wash out the new stemming and charge with water.
8. If this is not possible, then drill a parallel hole at least two feet away from the misfired hole, load and fire this charge.
9. After neutralizing the misfires, inspect the muckpile and surrounding area, as well as the coal when it reaches the tibble, for possible undetonated explosives and detonators.

SECTION 7

RECOMMENDATIONS FOR FUTURE RESEARCH

7.0 INTRODUCTION

Several areas where future research appears desirable are discussed in this section. Some of these are projects currently being proposed by the U. S. Bureau of Mines and several are listed below:

- "Survey of Safety Procedures for Guarding Blast Affected Areas" - USBM. Contract No. JO205019

Objective. - The objective of this procurement is to provide the Bureau of Mines and the metal/non-metal mining industry with a survey of current blast area guarding procedures. The latest applicable technology for guarding blasting areas will also be evaluated.
- "Device for Unloading ANFO Charged Blastholes". USBM. Contract No. HO202012

Objective. - The objective of this procurement is to provide the surface mining industry with a reasonably priced, reliable, and safe system for removing bulk load ANFO and stemming from loaded blastholes.
- "Blasthole Support System" - USBM. Contract No. JO205055

Objective. - To develop a cost-effective blast-hole support system for fractured, gravelly, or incompetent rock in underground metal mines.

7.1 Recommendations for Future Research

The following recommendations for future research are offered with the counsel that they be reviewed and possibly adjusted in the light of a constantly changing technology and state-of-the-art.

- Handling of Deteriorated Explosives

The Institute of Makers of Explosives, IME, has established guidelines on destroying explosives (Safety Library, Publication 21). The publication has since been discontinued from public circulation because: 1) the Institute felt such a publication should not be available to

the public who might, because of inexperience, do injury to themselves and others. 2) it would be difficult for the institute to constantly update the book to keep abreast of the everchanging explosive technology.

Blasters' handbooks from explosive manufacturers also cover this subject. However, they, like the IME, require explosive handlers to consult with the manufacturers of explosives.

InMinCo feels and recommends that a research effort should be undertaken to develop simple guidelines and procedures in this area so that local mine managers can safely dispose of deteriorated explosives and detonators in cases where advice from manufacturers is not readily available.

- Pneumatic Loaders Using Mine Air

Different pneumatic loader systems were discussed in Section 6. In most instances pressure pot systems have air pressure regulators. Ejector systems, however, are nearly always connected to the mine compressed air supply, thus the air pressure cannot be controlled.

We recommend that more information be made available on the effects of air pressure on ANFO loading density and its effects on blasting. The U.S. Bureau of Mines started a research effort in this area which was cancelled due to budget problems. (RFP No. JO20504, "Pneumatic Loading of ANFO in Underground Mines" had the following objective:)

Objective

"The purpose of this proposed study was to evaluate the state-of-the-art of pneumatic loading of ANFO. This evaluation was to be directed toward enhancing the safety of equipment and procedures associated with pneumatic loading. Furthermore, recommendations for research in areas needing additional development and testing will be made."

- Bright Colored Explosive Cartridges

One of the serious hazards encountered occasionally in blasting is explosives and detonators

in the muck pile. The restricted visibility in underground mines makes it very difficult to see these items.

Though a novel idea, we recommend considering the use of brightly colored wrappers on explosive cartridges and the use of dyes within the explosive itself.

- Training (Explosive Training)

Statistically more explosives-related accidents occur to young miners with little mining experience. To help reduce this trend we recommend that a study be made by multi-disciplined professionals to determine the most effective method for training and retraining miners associated with explosives.

Recently a member of the InMinCo staff was involved in a forty-hour training course given to new employees at a metallic underground mine. Overall the training sessions were excellent and relevant to mining hazards encountered. However, very little information was available on the hazards associated with explosives.

- Effect of Air Annulus between the Explosive and Borehole-wall and the Resulting Effects on Proper Detonation

The self-quenching of a detonating explosive, shortly after initiation, is a problem that is frequently encountered in blasting when using various types of packaged explosives (Mining Annual Review 1980).

Ireco Chemical conducted a study in this area and concluded that the phenomenon is related to the air annulus between the explosive and the borehole-wall. Pneumatic cartridge loading is believed to have particular advantages over the normal manual method. However, since most tamping in U. S. mines is manually done, we recommend more research and information be generated on the quenching phenomena associated with explosives that are tamped manually.

- Modification of HSAC Data

As with any research program, the data base is extremely important: For this contract we used the HSAC data base. However, the biggest problem was retrieving data for particular or specific causes of accidents in blasting. The type of data we needed is shown in Table 3.1, Section 3. Such data cannot be retrieved readily. We, therefore, recommend a study be done to modify the HSAC statistical retrieval system so that specific data can be retrieved more easily.

- Industry Assistance

There is a strong need in the mining community to solve technical problems in the area of blasting. We believe that the Federal government could provide active technical advice by establishing an advisory group coordinated by both the Bureau of Mines and MSHA.

- Vertical Crater Retreat (VCR) "Shotgun Effect"

During our mine visits we received reports of extensive damage due to blowouts. Miners felt that the direction of air flow was a key factor. Trapped combustible gases constitute another problem in VCR holes when rocks were dropped into such holes (Section 5.2.1, Blasthole Charging Cut & Fill).

We recommend a thorough investigation of the effects of air flow in VCR blastholes on "shotgun" occurrence. Procedures should be established for dealing with post-blast or trapped gasses where the blastholes do not break out into an undercut or become plugged.

To date, approximately ten instances of flashes of post-blast blasthole gasses have been reported in Canada and other countries. All incidents have occurred due to the generation of combustible gases in blastholes which fail to "break out". The reports indicated that, while this phenomena can occur with other explosives, it is more prevalent for those containing aluminum. (Suggested procedures for dealing with problem were presented in Section 6.)

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APPENDIX B

TABLE B3.1	Data Base for Accident Frequency and Severity Estimates
TABLES B3.2/B3.3	Summary of HSAC Classification of Explosives Related Accidents for Underground Metal/Non-Metal and Coal
TABLE B3.4	Explosive Related Accidents Compared to All Underground Mine Accidents - Metal/Non-Metal and Coal
TABLE B3.5	1970-1978 Fatal Accident Report Incidents
FIGURES B3.1/B3.16	Injuries and Fatal Accidents Frequency and Severity Charts
FIGURE B5	Example Data Sheet/Fatal Accident Summary Sheet
ABSTRACTS	Fatal Underground Explosive Accidents 1970-1978
SUMMARIES	Nonfatal Metal and Non-Metal Underground Mine Accidents (Recent Reported Accidents)

TABLE B.3.1
 DATA BASE FOR ACCIDENT FREQUENCY AND SEVERITY ESTIMATES
 FATALITIES, ALL INJURIES, WORKING DAYS LOST TO EXPLOSIVES RELATED ACCIDENTS,
 TONS PRODUCED AND EXPLOSIVES CONSUMED

ITEM	1970	1971	1972	1973	1974	1975	1976	1977	1978
All Underground Metal Mines									
Man-hours Worked (U/G only)	44,874,014	41,020,215	37,270,551	35,551,614	39,762,407	40,218,161	38,094,571	38,808,515	N/A
* Tons Ore & Waste x 10 ⁶	94	86	91	91	91	87	87	87	
Explosives Related Fatalities	2	3	2	2	2	1	5	4	
Explosives Related All Injuries	28	28	21	33	19	29	24	24	
Total Work Days Lost To Explosives Related Accidents	16,184	18,788	20,160	17,864	13,464	13,689	30,620	30,022	
All Underground Nonmetal Mines									
Man-hours Worked (U/G only)	8,600,529	8,630,222	7,971,307	8,994,810	9,910,055	10,768,031	10,551,967	10,679,190	N/A
* Tons Ore & Waste x 10 ⁶	84	78	82	83	87	84	86	86	
Explosives Related Fatalities	0	1	2	1	0	0	2	0	
Explosives Related All Injuries	1	2	3	6	8	7	3	3	
Total Work Days Lost To Explosives Related Accidents	203	6,008	12,000	6,096	376	854	12,003	354	
All Underground Coal Mines									
Man-hours Worked (U/G only)	164,576,129	153,801,537	170,495,460	171,782,448	173,409,396	210,474,994	217,941,158	206,289,834	N/A
Tons Coal Produced									
* Total Underground x 10 ⁶	388.8	276.1	304.2	301.4	277.6	293.1	294.6	257.4	
Conventionally Mined x 10 ⁶	169.4	123.1	125.0	120.6	96.4	98.1	97.8	85.5 ***	
Explosives Related Fatalities	41**	2	3	1	1	0	0	3	
Explosives Related All Injuries	122	75	101	67	44	59	58	55	
Total Work Days Lost To Explosives Related Accidents	255,855	14,537	21,936	8,922	12,707	3,855	32,33	21,200 ***	

* All production methods including mechanical miners.

** 38 Fatalities dust explosion initiated by explosives.

*** Estimated

TABLE B.3.1 (CONT.)

ACCIDENT FREQUENCY AND SEVERITY - UNDERGROUND
METAL, NONMETAL AND COAL MINES BY MILLION MAN-HOURS

ITEM	1970	1971	1972	1973	1974	1975	1976	1977	1978
EXPLOSIVES RELATED PER 10⁶ MAN-HOURS									
Metal Mines									
A. Fatal Accident Frequency	.045	.073	.054	.056	.050	.025	.131	.103	N/A
B. All Injuries Frequency	.624	.683	.563	.928	.478	.721	.630	.618	
C. Fatal Accident Severity Rate	267.4	438.8	321.97	337.54	301.79	149.19	787.51	618.42	
D. All Injuries Severity Rate	360.7	458.0	540.91	502.48	338.61	340.37	803.79	773.59	
Nonmetal Mines									
A. Fatal Accident Frequency	0	.116	.251	.111	0	0	.190	0	
B. All Injuries Frequency	.116	.232	.376	.667	.807	.650	.284	.281	
C. Fatal Accident Severity Rate	0	659.2	1505.4	66.71	0	0	1137.2	0	
D. All Injuries Severity Rate	23.6	696.2	1505.4	677.72	37.94	79.31	1137.5	33.15	
Coal Mines									
A. Fatal Accident Frequency	.249	.013	.018	.006	.006	0	0	.015	
B. All Injuries Frequency	.681	.488	.592	.390	.254	.280	.266	.267	
C. Fatal Accident Severity Rate	1494.8	78.0	105.57	34.93	34.60	0	0	87.26	
D. All Injuries Severity Rate	1554.6	94.5	128.66	51.94	73.28	18.32	14.83	102.77	
ALL UNDERGROUND INJURIES PER 10⁶ MAN-HOUR									
Metal Mines									
A. Fatal Accident Frequency	.96	.90	3.35	1.04	.86	.62	.63	.9	
B. All Injuries Frequency	60.30	62.60	59.38	88.58	84.02	75.59	65.76	87.97	
C. Fatal Accident Severity Rate	5749	5412	20123	6244	5130	3730	3780	5411	
D. All Injuries Severity Rate	8107	7700	22683	9033	7300	6657	6378	8407	
Nonmetal Mines									
A. Fatal Accident Frequency	1.40	1.39	.88	.67	.91	.28	.85	.28	
B. All Injuries Frequency	44.53	45.54	39.64	60.37	58.53	42.90	38.95	40.45	
C. Fatal Accident Severity Rate	8372	8343	5269	4002	5449	1672	5118	1686	
D. All Injuries Severity Rate	10627	10844	6820	5064	2910	3611	6740	3618	
Coal Mines									
A. Fatal Accident Frequency	.67	.92	.72	.58	.52	.47	.37	.44	
B. All Injuries Frequency	26.83	59.22	125.71	109.81	64.70	69.89	68.13	82.78	
C. Fatal Accident Severity Rate	7510	5501	4293	3458	3114	2822	2863	2647	
D. All Injuries Severity Rate	10498	7042	6716	5867	5527	2351	5170	6697	

TABLE B.3.1 (CONT)

ACCIDENT FREQUENCY AND SEVERITY - UNDERGROUND METAL, NONMETAL AND
COAL MINES BY MILLIONS OF TONS PRODUCED AND THOUSANDS OF POUNDS OF EXPLOSIVES USED

ITEM	1970	1971	1972	1973	1974	1975	1976	1977	1978
EXPLOSIVES RELATED PER 10 ⁶ TON ORE & WASTE									
Metal Mines									
A. Fatal Accident Frequency	.021	.035	.022	.022	.022	.011	.057	.046	N/A
B. All Injuries Frequency	.298	.326	.231	.363	.209	.333	.276	.276	
C. Fatal Accident Severity Rate	127.66	209.30	131.87	131.87	131.87	68.97	344.83	275.9	
D. All Injuries Severity Rate	172.17	218.47	221.54	196.31	147.96	157.34	351.95	345.08	
Nonmetal Mines									
A. Fatal Accident Frequency	0	.013	.024	.012	0	0	.023	0	
B. All Injuries Frequency	.012	.026	.037	.072	.092	.083	.035	.035	
C. Fatal Accident Severity Rate	0	76.92	146.34	72.29	0	0	139.53	0	
D. All Injuries Severity Rate	2.42	77.03	146.34	73.45	4.32	10.17	139.57	4.12	
Coal Mines - All Coal									
A. Fatal Accident Frequency	.121	.007	.009	.003	.004	0	0	.012	
B. All Injuries Frequency	.331	.272	.332	.222	.159	.201	.197	.214	
C. Fatal Accident Severity Rate	726.09	43.46	59.17	19.91	21.61	0	0	69.91	
D. All Injuries Severity Rate	755.18	52.65	72.11	29.60	45.78	13.15	10.97	82.34	
Coal Mines - Conventional Coal									
A. Fatal Accident Frequency	.242	.016	.024	.008	.010	0	0	.035	
B. All Injuries Frequency	.661	.609	.808	.556	.456	.601	.59	.643	
C. Fatal Accident Severity Rate	1452.18	97.48	144	49.75	62.24	0	0	210.53	
D. All Injuries Severity Rate	1510.36	118.09	175.49	73.98	131.82	39.30	33.06	247.95	
EXPLOSIVES RELATED PER 10 ⁶ LBS EXPLOSIVES USED									
Metal Mines									
A. Fatal Accident Frequency	.023	.040	.028	.029	.029	.015	.074	.055	
B. All Injuries Frequency	.324	.378	.295	.471	.277	.438	.355	.331	
C. Fatal Accident Severity Rate	142.17	242.73	168.67	171.38	174.95	90.57	443.72	331.01	
D. All Injuries Severity Rate	191.74	253.35	283.36	255.13	196.29	206.63	452.89	414.06	
Nonmetal Mines									
A. Fatal Accident Frequency	0	.022	.040	.017	0	0	.038	0	
B. All Injuries Frequency	.022	.043	.060	.102	.148	.133	.057	.059	
C. Fatal Accident Severity Rate	0	130.05	241.68	102.10	0	0	227.23	0	
D. All Injuries Severity Rate	4.40	130.22	241.68	103.73	6.96	16.19	227.29	6.97	
Coal Mines									
A. Fatal Accident Frequency	.771	.049	.071	.025	.026	0	0	.064	
B. All Injuries Frequency	2.106	1.83	2.39	1.705	1.148	1.404	1.41	1.18	
C. Fatal Accident Severity Rate	4625.36	292.61	426.22	152.64	156.53	0	0	385.74	
D. All Injuries Severity Rate	4810.66	357.47	519.42	226.98	331.50	91.79	78.62	454.32	

TABLE B.3.1 (CONT.)

MINE PRODUCTION AND EXPLOSIVES CONSUMPTIONS

1970-1978 METAL, NONMETAL AND COAL MINES

ITEM PRODUCTION (In Millions of Short Tons)	1970	1971	1972	1973	1974	1975	1976	1977	1978
METAL MINES									
Surface Ore	499	480	491	574	547	535	573	490	N/A
Waste	968	1,020	1,080	1,280	1,210	1,170	1,250	1,030	
Total ¹	1,470	1,500	1,570	1,860	1,760	1,700	1,820	1,530	
Underground Ore	87	80	86	82	80	74	73	74	
Waste	7	6	5	9	11	13	15	12	
Total ¹	94	86	91	91	91	87	87	87	
Total Tons Ore & Waste ¹	1,560	1,580	1,660	1,950	1,850	1,790	1,910	1,610	N/A
U/G Tons as % of Total Tons	6.0%	5.4%	5.5%	4.7%	4.9%	4.9%	4.6%	5.4%	
Explosives (In Thousands of Pounds) Total # All Types for Metal Mines	479,508	457,286	430,686	495,879	465,490	449,271	488,653	446,406	574,213
Permissibles Only	47	91	99	115	192	241	204	225	208
Estimated U/G Usage ²	86,404	74,157	71,146	70,018	68,591	66,248	67,610	72,506	
NONMETAL MINES									
Surface Ore	2,010	1,980	2,020	2,240	2,222	1,910	2,000	2,120	N/A
Waste	431	442	415	418	418	372	393	472	
Total ¹	2,440	2,420	2,430	2,650	2,640	2,290	2,390	2,590	
Underground Ore	80	73	77	82	82	79	80	80	
Waste	4	5	5	1	5	6	6	6	
Total ¹	84	78	82	83	87	84	86	86	
Total Tons Ore & Waste ¹	2,530	2,500	2,520	2,740	2,720	2,370	2,480	2,680	N/A
U/G Tons as % of Total Tons	3.3%	3.1%	3.3%	3.0%	3.2%	3.5%	3.5%	3.2%	
Explosives Total # All Types for Nonmetal Mines & Quarries	455,424	489,572	493,677	643,292	551,380	493,125	493,656	522,678	604,955
Permissibles Only	1,122	668	865	957	1,237	1,083	1,090	694	618
Estimated U/G Usage ²	46,098	46,136	49,653	58,767	54,051	52,747	52,809	50,804	
COAL MINES									
Total Coal Produced in Millions of Short Tons	602.9	552.2	595.4	591.0	603.4	648.4	678.7	688.7	N/A
% Of Total Surface Mined	43.8%	50.0%	48.9%	49.0%	54.0%	54.8%	56.6%	N/A	
% Of Total Continuous U/G Mining ³	28.1%	27.7%	30.0%	30.6%	30.0%	30.0%	29.0%		
% Of Total Conventionally U/G Mined ⁴	28.1%	22.3%	21.0%	20.4%	16.0%	15.2%	14.4%		
% Of Total Mined U/G All Methods	56.2%	50.0%	51.1%	51.0%	46.0%	45.2%	43.4%		
Tons Conventionally U/G Mined in Millions of Short Tons	169.4	123.1	125.0	120.6	96.4	98.1	97.8		
Explosives in Thousands of Pounds Permissible Explosives Only ⁴	53,185	41,010	42,232	39,307	38,332	41,996	41,123	46,663	38,530

¹ Data may not add due to rounding errors

² 100% of permissibles used U/B + (Total-permissible) X % ton U/G x $\frac{3 \text{ U/G}}{105}$

³ Continuous underground mining includes longwall

⁴ Conventional Mining includes mechanical and hand loading, machine undercutting and shooting from solid

N/A Information not yet compiled or available to public

TABLE B3.2

SUMMARY OF HSAC CLASSIFICATION OF EXPLOSIVES RELATED ACCIDENTS 1975 - 1978 IN METAL
AND NONMETAL UNDERGROUND MINES IN THE UNITED STATES

PRIMARY CAUSE OF INJURY	1975			1976			1977			1978			TOTAL			% of Total W D L*	% Total Acci.
	Fatal	Total Acci.	Total W D L*	Fatal	Total Acci.	Total W D L*	Fatal	Total Acci.	Total W D L*	Fatal	Total Acci.	Total W D L*	Fatal	Total Acci.	Total W D L*		
Flying fragments or chunks set in motion by explosives or detonators	1	13	7233	1	9	6603	2	11	12985	-	3	1	4	36	26822	21.8	26.1
Misfires or digging into undetonated explosives	-	5	792	-	5	38	1	8	10879	2	10	14520	3	28	26229	21.4	20.3
Suffocation from explosives smoke	-	8	50	1	3	6008	-	4	20	1	11	6017	2	26	12095	9.8	18.8
Premature shot or blast	-	3	392	4	8	24053	1	1	6000	1	5	6000	6	17	36445	29.7	12.3
Caps and Detonators	-	1	361	-	-	-	-	2	486	-	4	1576	-	7	2423	2.0	5.1
Insufficient Warning	1	1	6000	-	2	43	-	1	11	-	-	-	1	4	6054	4.9	2.9
Transporting or handling explosives	-	3	477	-	-	-	-	-	-	-	-	-	-	3	477	.4	2.2
Shot breaking through rib or pillar	-	1	260	1	1	6000	-	-	-	-	-	-	1	2	6260	5.1	1.4
Charging or tamping	-	1	4	-	1	4	-	-	-	-	-	-	-	2	8	0	1.4
Blowout or shotgun blast	-	-	-	-	-	-	-	-	-	-	1	0	-	1	0	0	.1
All other explosives related accidents	-	2	15	-	2	5	-	1	0	1	7	6012	1	12	6032	4.9	8.7
Total explosives related accidents	2	38	15584	7	31	42754	4	28	30381	5	41	34126	18	138	122845	100.0%	99.3
Average work days lost per accident	410.1			1379.2			1085.0			832.3			890.2				
Average work days lost to nonfatal accidents	99.6			31.4			265.9			114.6			123.7				

*Work Days Lost

TABLE B3.3

SUMMARY OF HSAC CLASSIFICATION OF EXPLOSIVES RELATED ACCIDENTS 1972-1978
IN BITUMINOUS AND ANTHRACITE UNDERGROUND COAL MINES OF THE UNITED STATES

PRIMARY CAUSE OF INJURY	1972			1973			1974			1975			1976			1977			1978			TOTAL				
	Fatal	Total Acc.	Total WDL*	Fatal	Total Acc.	Total WDL*	Fatal	Total Acc.	Total WDL*	Fatal	Total Acc.	Total WDL*	Fatal	Total Acc.	Total WDL*	Fatal	Total Acc.	Total WDL*	Fatal	Total Acc.	Total WDL*	Fatal	Total Acc.	Total WDL*	% of WDL*	% of Acci.
Flying fragments of chunks set in motion by explosives or detonators	-	70	3380	-	59	1148	-	26	1067	-	33	1416	-	41	1306	-	32	964	1	23	6317	1	284	15598	20.0	60.6
Airdox Blasting Related	-	10	467	-	8	73	-	3	13	-	5	383	-	5	79	-	6	682	-	5	73	-	42	1770	2.3	9.0
Shots breaking through rib or pillar	1	8	6060	-	3	43	-	4	17	-	1	4	-	3	139	-	-	-	-	5	4	1	24	6267	8.0	5.1
Misfire or digging into undetonated explosives	-	1	129	-	2	1800	-	1	52	-	6	1878	-	2	0	-	3	630	0	4	5	-	19	4494	5.7	4.0
Insufficient warning	-	5	106	-	2	58	-	1	5400	-	2	0	-	-	-	2	8	12421	-	-	-	2	18	17985	23.0	3.8
Premature shot or blast	1	2	6000	-	3	43	1	1	6000	-	1	21	-	-	-	-	3	849	-	-	-	2	10	12913	16.5	2.1
Caps and detonators	-	1	1	-	1	0	-	2	17	-	2	16	-	1	1000	-	1	0	-	1	14	-	9	1048	1.3	1.9
Suffocation from explosives accidents	-	-	-	-	-	-	-	2	26	-	4	0	-	-	-	-	-	-	-	-	-	-	6	26	0	1.3
Charging to Tamping	-	3	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	44	-	5	44	0	1.0
All other explosives related accidents	1	12	6044	1	7	6127	-	5	132	-	9	137	-	5	62	1	7	6299	0	7	159	3	52	18960	24.2	11.1
Total explosives related accidents	3	112	22187	1	45	9292	1	45	12724	-	63	3855	-	57	2586	3	60	21845	1	47	6616	9	469	79105	101.2	99.9
Average work days lost per explosive accident	198.1			109.3			282.8			61.2			45.4			364.1			140.8			168.7				
Average work days lost per nonfatal explosive accident	38.4			39.2			152.8			61.2			45.4			67.5			13.4			54.6				

* Work Days Lost

TABLE B3.4

EXPLOSIVES RELATED ACCIDENTS COMPARED TO ALL UNDERGROUND
MINE ACCIDENTS 1970-1977 METAL, NON-METAL AND COAL UNDERGROUND MINES

	EXPLOSIVE					ALL UNDERGROUND MINE ACCIDENTS					% Explosives Fatal To All Underground Fatalts	% Explosives All Injuries To All Underground Injuries
	Fatal	Disabling	All Injuries	Ratio		Fatal	Disabling	All Injuries	Ratio			
				Fatal to Disabling	Fatal To All Injuries				Fatal to Disabling	Fatal to All Injuries		
1970												
Metal*	2	28	28	1 : 14	1 : 14	43	2706	2706	1 : 62.9	1 : 62.9	4.7%	1.0%
Nonmetal*	-	1	1			12	383	383	1 : 31.9	1 : 31.9	0%	2.0%
Coal	41**	43	112	1 : 1.0	1 : 2.7	204	386	8958	1 : 1.9	1 : 43.9	20.1%	1.25%
1971												
Metal*	3	28	28	1 : 9.3	1 : 9.3	37	2568	2568	1 : 69.4	1 : 69.4	8.1%	1.1%
Nonmetal*	1	2	2	1 : 2	1 : 2	12	393	393	1 : 32.8	1 : 32.8	8.3%	.51%
Coal	2	3	75	1 : 1.5	1 : 37.5	133	259	8970	1 : 1.95	1 : 67.4	1.5%	.84%
1972												
Metal*	2	21	21	1 : 10.5	1 : 10.5	127	2213	2213	1 : 17.4	1 : 17.4	1.6%	.95%
Nonmetal*	2	3	3	1 : 1.5	1 : 1.5	7	316	316	1 : 45.1	1 : 45.1	28.6%	.95%
Coal	3	57	101	1 : 19	1 : 33.7	122	9945	21433	1 : 81.5	1 : 175.7	2.5%	.47%
1973												
Metal	2	29	33	1 : 14.5	1 : 16.5	37	2255	3149	1 : 6.08	1 : 85.1	5.4%	1.0%
Nonmetal	1	4	6	1 : 4	1 : 6	6	302	543	1 : 50.3	1 : 90.5	16.7%	1.10%
Coal	1	41	67	1 : 41	1 : 67	99	8917	18864	1 : 90.1	1 : 190.5	1.0%	.36%
1974												
Metal	2	18	19	1 : 9	1 : 9.5	34	2480	3341	1 : 72.9	1 : 98.3	5.9%	.57%
Nonmetal	-	8	8			9	367	580	1 : 40.8	1 : 64.4	0%	1.38%
Coal	1	27	44	1 : 27	1 : 44	90	6399	11219	1 : 71.1	1 : 124.7	1.1%	.39%
1975												
Metal	1	27	29	1 : 27	1 : 29	25	2240	3040	1 : 89.6	1 : 121.6	4.0%	.95%
Nonmetal	-	7	7			3	361	462	1 : 120.3	1 : 154	0%	1.52%
Coal	-	42	59			99	8269	14710	1 : 83.5	1 : 148.6	0%	.40%
1976												
Metal	5	20	24	1 : 4	1 : 4.8	24	1954	2505	1 : 81.4	1 : 104.4	20.8%	.96%
Nonmetal	2	3	3	1 : 1.5	1 : 1.5	9	328	411	1 : 36.4	1 : 45.7	22.2%	.73%
Coal	-	39	58			104	10762	19147	1 : 103.5	1 : 184.1	0%	.30%
1977												
Metal	4	17	24	1 : 4.3	1 : 6	35	1818	3412	1 : 51.9	1 : 97.5	11.4%	.70%
Nonmetal	-	3	3			3	303	432	1 : 101	1 : 144	0%	.69%
Coal	3	41	55	1 : 13.7	1 : 18.3	91	11082	17076	1 : 121.8	1 : 187.6	3.3%	.32%
TOTAL												
Metal	21	188	206	1 : 9	1 : 9.8	360	18234	22934	1 : 50.7	1 : 63.7	5.83%	.90%
Nonmetal	6	31	33	1 : 5.2	1 : 5.5	61	2753	3520	1 : 45.1	1 : 57.7	9.84%	.94%
Coal**	51	293	604	1 : 5.7	1 : 11.8	942	56019	120377	1 : 59.5	1 : 127.8	5.41%	.50%

* Only Lost Time Accidents Reported

** Coal Mine Disaster (38 fatalities)

TABLE B3.5

EXPLOSIVES RELATED FATALITIES
1970-1978 FATAL ACCIDENT REPORT INCIDENTS
UNDERGROUND METAL, NONMETAL AND COAL MINES (Part I)

YEAR AND TYPE OF MINE	SINGLE FATALITY INCIDENTS		DOUBLE FATALITY INCIDENTS		TRIPLE FATALITY INCIDENTS		MINE DISASTERS 5 FATALITIES OR MORE FOR A SINGLE INC.		TOTAL FATAL INCIDENTS	TOTAL FATALITIES	TOTAL NONFATAL INJURIES
	NONFATAL DEATHS	NONFATAL INJURIES	NONFATAL DEATHS	NONFATAL INJURIES	NONFATAL DEATHS	NONFATAL INJURIES	NONFATAL DEATHS	NONFATAL INJURIES			
1970 Metal & Nonmetal	1	0	- -	NONE	- -	NONE	- -	NONE	2	2	0
Coal	1*	0	- -	- -	- -	- -	- -	- -			
	1	0	- -	- -	- -	- -	- -	- -			
	1	1	- -	- -	- -	- -	- -	- -			
	1	0	- -	- -	- -	- -	- -	- -			
	-	-	- -	- -	- -	- -	38	1	4	41	2
1971 Metal & Nonmetal	1	0	- -	- -	- -	- -	- -	- -			
	1	0	- -	- -	- -	- -	- -	- -			
	1	0	- -	- -	- -	- -	- -	- -	3	3	0
Coal	-	-	2	0	- -	- -	- -	- -	1	2	0
1972 Metal & Nonmetal	1	0	- -	- -	- -	- -	- -	- -			
	-	-	2	1	- -	- -	- -	- -			
	1	0	- -	- -	- -	- -	- -	- -	3	4	1
Coal	1	0	- -	- -	- -	- -	- -	- -			
	1	0	- -	- -	- -	- -	- -	- -	2	2	0
1973 Metal & Nonmetal	1	0	- -	- -	- -	- -	- -	- -			
	1	0	- -	- -	- -	- -	- -	- -			
	1	1	- -	- -	- -	- -	- -	- -	3	3	1
Coal	1	0	- -	- -	- -	- -	- -	- -	1	1	0
1974 Metal & Nonmetal	1	0	- -	- -	- -	- -	- -	- -			
	1	0	- -	- -	- -	- -	- -	- -	2	2	0
Coal	1	0	- -	- -	- -	- -	- -	- -	1	1	0

TABLE B3.5 (cont'd)

EXPLOSIVES RELATED FATALITIES
1970-1978 FATAL ACCIDENT REPORT INCIDENTS
UNDERGROUND METAL, NONMETAL AND COAL MINES (Part II)

YEAR AND TYPE OF MINE	SINGLE FATALITY INCIDENTS		DOUBLE FATALITY INCIDENTS		TRIPLE FATALITY INCIDENTS		MINE DISASTERS 5 FATALITIES OR MORE FOR A SINGLE INC.		TOTAL FATAL INCIDENTS	TOTAL FATALITIES	TOTAL NONFATAL INJURIES
	NONFATAL DEATHS	NONFATAL INJURIES	NONFATAL DEATHS	NONFATAL INJURIES	NONFATAL DEATHS	NONFATAL INJURIES	NONFATAL DEATHS	NONFATAL INJURIES			
1975 Metal & Nonmetal	1	0	-- --NONE --		-- --NONE--		-- --NONE --		1	1	0
Coal	0	0	--	--	--	--	--	--	0	0	0
1976 Metal & Nonmetal	-	-	--	--	3*	0	--	--	5	7	2
	1	0	--	--	--	--	--	--			
	1	2	--	--	--	--	--	--			
	1	0	--	--	--	--	--	--			
	1	0	--	--	--	--	--	--			
Coal	0	0	--	--	--	--	--	--	0	0	0
1977 Metal & Nonmetal	1	2	--	--	--	--	--	--	4	5	3
	1	0	--	--	--	--	--	--			
	1	1	--	--	--	--	--	--			
	-	-	2*	0	--	--	--	--			
Coal	1	1	--	--	--	--	--	--	3	3	2
	1	0	--	--	--	--	--	--			
	1	1	--	--	--	--	--	--			
1978 Metal & Nonmetal	1	0	--	--	--	--	--	--	3	3	2
	1	2	--	--	--	--	--	--			
	1	0	--	--	--	--	--	--			
Coal	-	-	--	--	--	--	--	--	0	0	0
TOTAL Metal& Nonmetal	23		2		1		0		26	30	9
Coal	10		1		0		38		12	50	4
GRAND TOTAL	33		3		1		38		38	80	13

*Hobbiest Miners

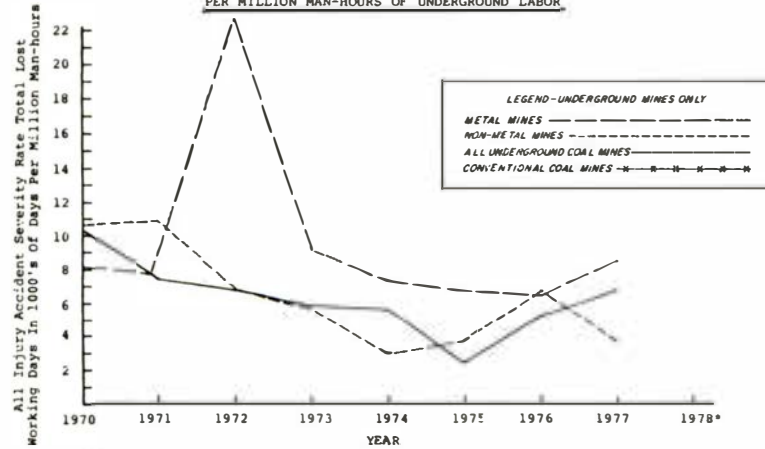
FIGURE B 5
EXAMPLE DATA SHEET

FATAL ACCIDENT SUMMARY SHEET

1. Number of injuries:
2. Commodity mined:
3. Mining method:
4. Annual tonnage: tons daily - ton/yr.
5. Number of employees: total - underground
6. Victim statistics: Age:
 Years mining experience:
 Time in job classification:
 Accident:
7. State and/or region/mine location:
8. Primary cause of fatal accident:
9. Victim participation: Driller
 Blaster - (shot firer)
 Guard
 Misc.
10. Activity: Explosives handling
 Handling preparation
 Blast
 Post blast
11. Explosive involved:
12. Type blasting: Primary
 Secondary
 Electric
 Safety Fuse &
 Blasting Cap

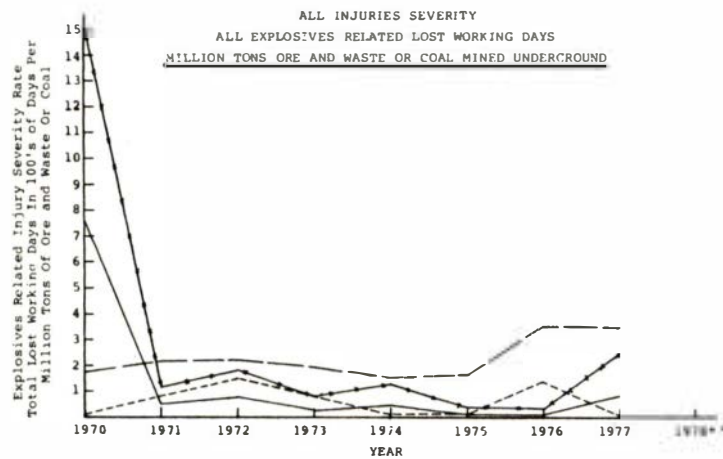
FIGURE B.3.1

ALL INJURIES SEVERITY

ALL UNDERGROUND MINE INJURIES LOST WORKING DAYS
PER MILLION MAN-HOURS OF UNDERGROUND LABOR

* Severity is total number of lost working days recorded or charged. Each fatality is a 6000 lost working days charge.

** 1978 Data not yet available



** Explosives related injury severity is the total lost working days recorded or charged to explosives related accidents. Each fatality is an automatic 6000 lost working days charge.

* 1978 Data not yet available

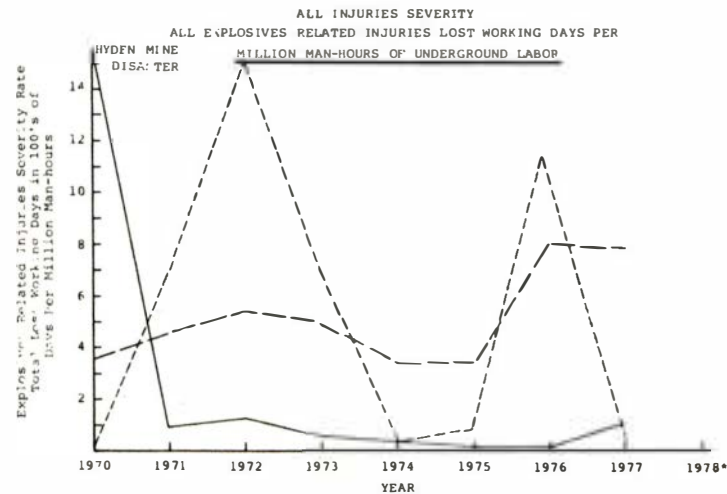
FIGURE B.3.3**FIGURE B.3.2**

ALL INJURIES SEVERITY

ALL EXPLOSIVES RELATED LOST WORKING DAYS PER
MILLION POUNDS OF EXPLOSIVES CONSUMED UNDERGROUND

** Explosives related injury severity is the total lost working days recorded or charged to explosives related accidents. Each fatality is an automatic 6000 days charge.

* 1978 Data not yet available



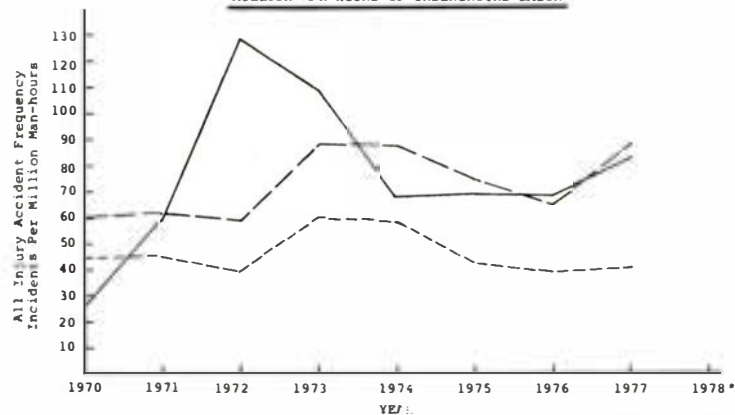
** Explosives related injury severity is the total lost working days recorded or charged to explosives related accidents. Each fatality is an automatic 6000 lost working day charge.

* 1978 Data not yet available

FIGURE B.3.4

FIGURE B.3.5

ALL INJURIES FREQUENCY
ALL UNDERGROUND MINE INJURIES PER
MILLION MAN-HOURS OF UNDERGROUND LABOR



* 1978 Data not yet available

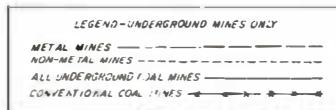


FIGURE B.3.6

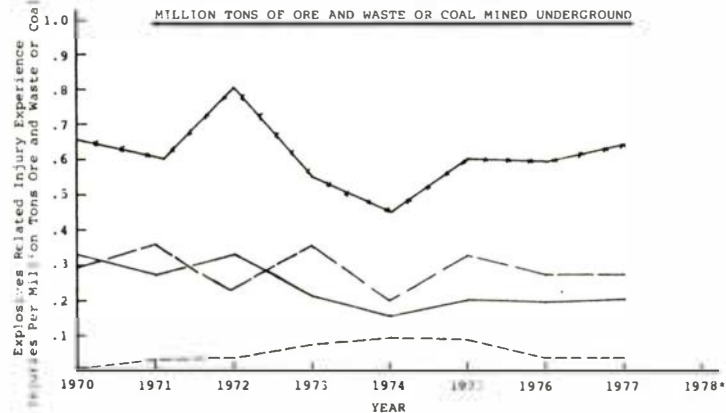
ALL INJURIES FREQUENCY
ALL EXPLOSIVES RELATED UNDERGROUND MINE INJURIES
PER MILLION POUNDS OF EXPLOSIVES CONSUMED UNDERGROUND



* 1978 Data not yet available

ALL INJURIES FREQUENCY

ALL EXPLOSIVES RELATED UNDERGROUND MINE INJURIES PER
MILLION TONS OF ORE AND WASTE OR COAL MINED UNDERGROUND

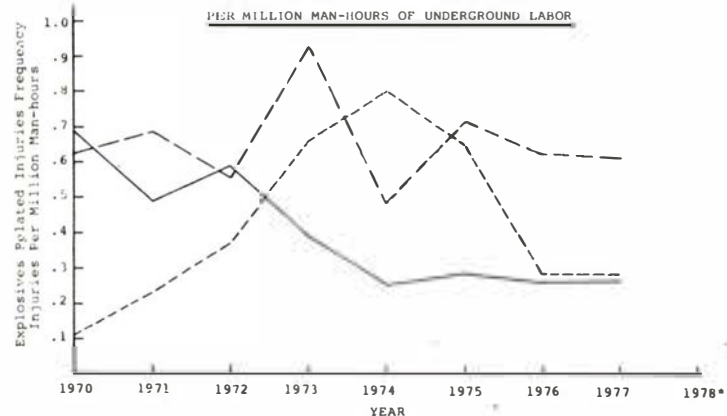


* 1978 Data not yet available

FIGURE B.3.7

ALL INJURIES FREQUENCY

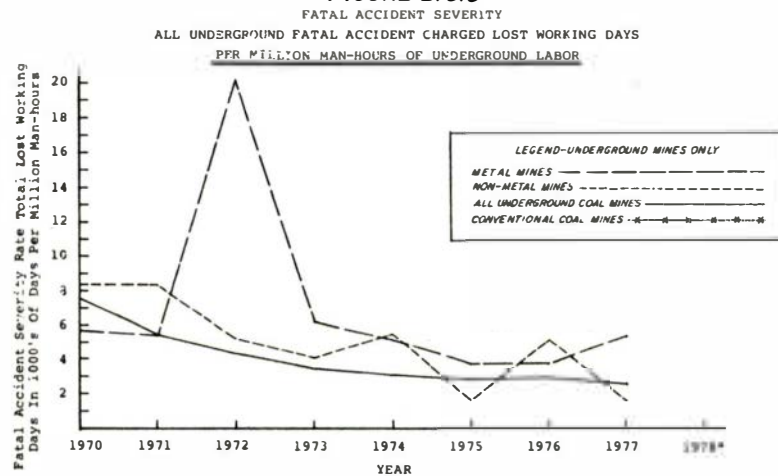
ALL EXPLOSIVES RELATED UNDERGROUND MINE INJURIES
PER MILLION MAN-HOURS OF UNDERGROUND LABOR



* 1978 Data not yet available

FIGURE B.3.8

FIGURE B.3.9



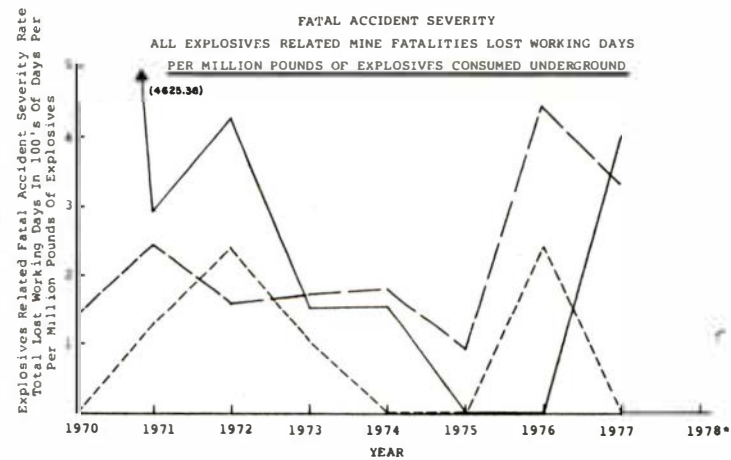
* Fatal accident severity represents an automatic charge of 6000 lost working days per fatality
 ** 1978 Data not yet available



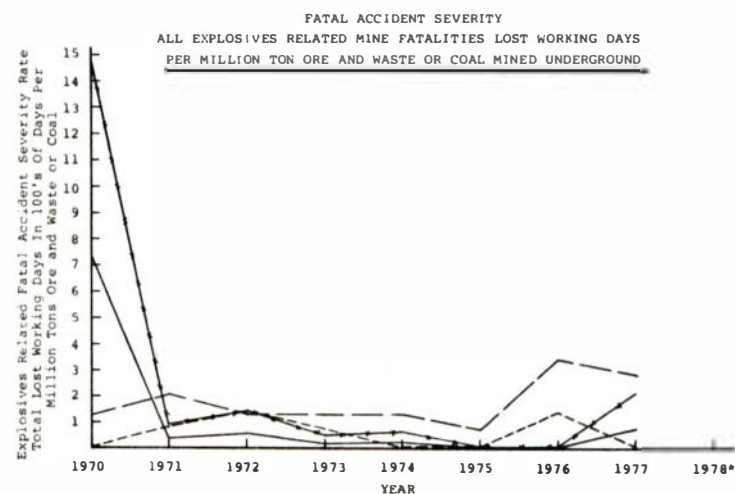
** Explosives related fatal accident severity represents an automatic charge of 6000 lost working days per fatality caused or related to an explosives accident
 * 1978 Data not yet available

FIGURE B.3.11

FIGURE B.3.10



** Explosives related fatal accident severity represents an automatic charge of 6000 lost working days per fatality caused or related to an explosives accident.
 * 1978 Data not yet available

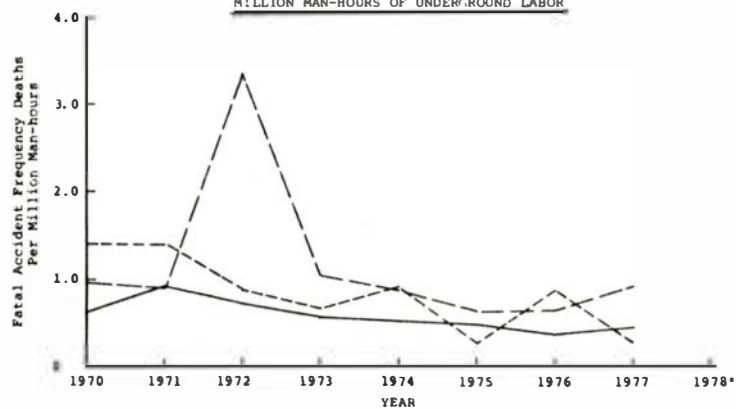


** Explosives related fatal accident represents an automatic charge of 6000 lost working days per fatality caused or related to an explosives accident
 * 1978 Data not yet available

FIGURE B.3.12

FIGURE B.3.13

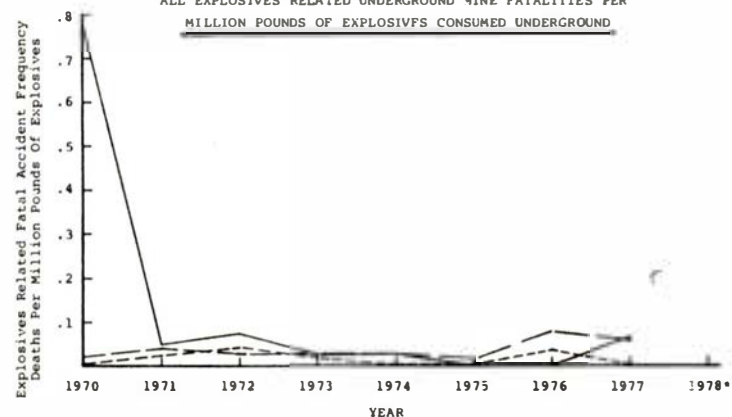
FATAL ACCIDENT FREQUENCY
ALL UNDERGROUND MINE FATALITIES PER
MILLION MAN-HOURS OF UNDERGROUND LABOR



* 1978 Data not yet available

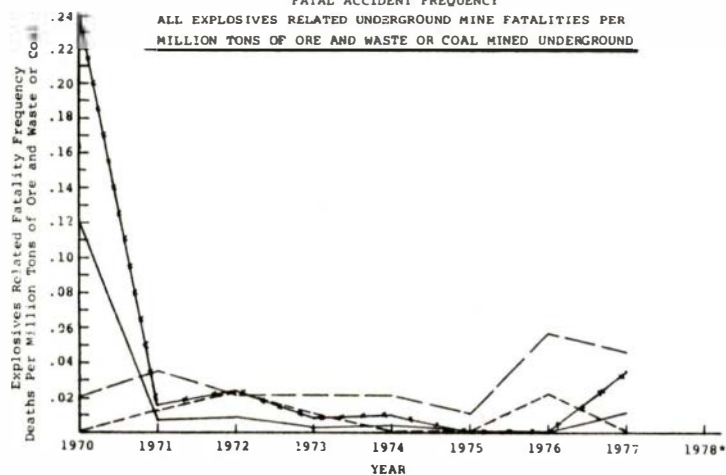
FIGURE B.3.14

FATAL ACCIDENT FREQUENCY
ALL EXPLOSIVES RELATED UNDERGROUND MINE FATALITIES PER
MILLION POUNDS OF EXPLOSIVES CONSUMED UNDERGROUND



* 1978 Data not yet available

FATAL ACCIDENT FREQUENCY
ALL EXPLOSIVES RELATED UNDERGROUND MINE FATALITIES PER
MILLION TONS OF ORE AND WASTE OR COAL MINED UNDERGROUND



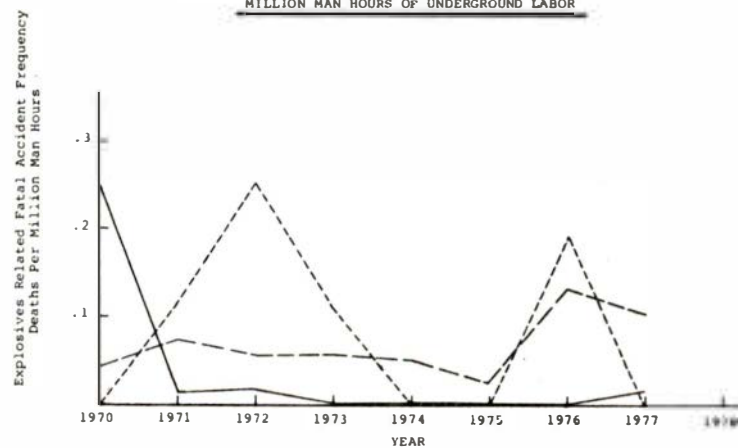
* 1978 Data not yet available

FIGURE B.3.15

LEGEND- UNDERGROUND MINES ONLY

METAL MINES —————
NON-METAL MINES - - - - -
ALL UNDERGROUND COAL MINES
CONVENTIONAL COAL MINES —*—*—*—*

FATAL ACCIDENT FREQUENCY
ALL EXPLOSIVES RELATED UNDERGROUND MINE FATALITIES PER
MILLION MAN HOURS OF UNDERGROUND LABOR



* 1978 Data not yet available

FIGURE B.3.16

APPENDIX B
FATAL UNDERGROUND COAL
MINE ACCIDENTS 1970 - 1971

ABSTRACTS

1. March 9, 1970 - Single fatality resulting from victim being struck by flying coal fragments. Principal causes were shot breaking through pillar, the use of explosives in a non-permissible manner, igniting fuses in separate entries in an unsafe sequence, and igniting multiple fuses (23) by a single blaster. Actions leading to fatal accident contrary to then existing health and safety regulations.
2. April 22, 1970 - Single fatality and single injury resulting from the premature blast of an explosives charged drill hole during the loading and tamping of an adjacent hole. Probable cause of blast was loading explosives on a red-hot drill bit inadvertently left in drill hole. Blasting procedures enforced at time of accident appropriate to the electric blasting of roof fall rock. Victims failed to clean drill hole or allow to cool before loading. Accident circumstances not directly covered by then existing health and safety regulations.
3. June 7, 1970 - Single fatality resulting from victim being struck by flying coal fragments. Principal cause of accident was inadequate guarding of blast area allowing motor man to be opposite blast site when round shot through pillar. Secondary cause was failure of blasters to recognize probability of shooting through pillar due to inaccurate measurements. Victim died five days after injuries sustained. Actions leading to fatal accident contrary to then existing health and safety regulations.
4. December 30, 1970 - Thirty eight (38) fatalities resulting from coal dust explosion and/or asphyxiation initiated by improper, nonpermissible, and illegal use of nonpermissible explosives. Actions leading to fatal accidents contrary to then existing health and safety regulations.
5. August 16, 1971 - Double fatality resulting from victim being struck by flying fragments of exploded powder wagon and coal; and, being struck against unknown objects by air blast. Principal cause of the accident was the secondary ignition of powder and caps on powder wagon by a string of blasting caps used in place of an approved blasting cable. Actions leading to fatal accident contrary to then existing health and safety regulations.

APPENDIX B

FATAL ACCIDENT REPORT ABSTRACTS

UNDERGROUND COAL MINES

1972 - 1978 EXPLOSIVES RELATED INJURIES

1. July 19, 1972 - Single fatality resulting from insufficient warning of impending blast, poor communications between blaster and victim and the nonpermissible use of explosives. The victim was in the immediate vicinity of the blast due to poor blasting procedures. Actions leading to the fatal accident contrary to existing Health and Safety Regulations.
2. September 27, 1972 - Single fatality due to failure of victim to withdraw to a safe location, due to erroneous measurements, failure to follow shot firers directives and failure to maintain survey control over mining. Victim placed self in the immediate vicinity of the blast and was fatally injured by shooting through rib. Actions leading to fatality contrary to existing health and safety regulations.
3. February 23, 1973 - Single fatality due to victim entering and performing work in the close proximity of blasting operations, failure of shot firer to clear affected area before blasting and shooting through rib due to erroneous measurements. Actions leading to fatal injury contrary to existing health and safety regulations.
4. March 22, 1974 - Single fatality due to the premature detonation of a blast round caused by stray electric current. Actions leading to fatal accidents contrary to existing health and safety regulations.
5. February 7, 1977 - Single fatality due to the failure to withdraw men from affected blasting area. Victim fatally injured by blast through pillar from adjoining working place. Actions leading to fatal injury contrary to existing health and safety regulations.
6. June 6, 1977 - Single fatality resulting from the failure of the victim to withdraw to a safe location before blasting, failure of blaster to clear blast area and blasting by inadequately trained and uncertified personnel. Fatal injuries due to victim placing self in immediate vicinity of blast. Actions leading to fatality contrary to existing health and safety regulations.
7. November 7, 1977 - Single fatality due to failure to withdraw men from affected blasting area. Victim fatally injured by blast through pillar from adjoining working place. Failure to follow mine projections contributing factor. Actions leading to fatal accident contrary to existing health and safety regulations.

APPENDIX B
FATAL METAL AND NONMETAL UNDERGROUND
MINE ACCIDENTS
1970 - 1974

ABSTRACTS

1. April 4, 1970 - Single fatality resulting from tamping directly on primer while setting a scaling blast. Excessive tamping and improper use of explosives and loading tools and inexperience contributing factors to accident. Victim not a trained blaster and actions leading to fatal accident contrary to then existing safety regulations.
2. November 4, 1970 - Single fatality as a result of flying rock fragments. Principal causes were victim staying too long at the face, short fuses, working alone and possible failure to properly bar down work place. Actions leading to fatal accident contrary to then existing safety regulations.
3. April 5, 1971 - Single fatal accident resulting from the sympathetic detonation of unused explosives left near blast site and initiating blast of an unsafe location. Actions leading to accident contrary to then existing safety regulations.
4. August 30, 1971 - Single fatality resulting from flying rock fragments from a premature blast, loading a round too far in advance of planned ignition, secondary blasting in the vicinity of a loaded round and returning to an area before cleared of smoke and fumes. Actions leading to fatality contrary to established company blasting procedures and then existing safety regulations.
5. September 21, 1971 - Single fatality resulting from victim being struck in the chest by flying rock fragments. Explosion occurred as a result of victim drilling into a misfired hole. Actions leading to fatal accident contrary to then existing safety regulations.
6. April 8, 1972 - Single fatality resulting from victim being struck by flying rock fragments when returning to face after igniting round. Actions leading to fatal accident contrary to then existing safety regulations.
7. November 1, 1972 - Double fatality and single nonfatal injury from flying rock fragments. Victims ignored warning signs and proceeded on foot to blast site where floor heave was being blasted. Primary causes of accident were insufficient warning, inadequate blast site guarding and failure to remove blasting cable and leg wires from a previous blast. Actions leading to fatal accidents contrary to then existing safety regulations.

8. December 18, 1972 - Single fatality resulting from victim being struck by flying rock fragments from an explosion caused by drilling in a loaded bootleg hole and falling down an adjacent raise. Victim was working contrary to supervisor's instructions. Actions leading to fatal accident were contrary to then existing safety regulations.
9. June 9, 1973 - Single fatality resulting from blast and flying rock fragments. Victim drilled into misfired hole while drilling next raise round. Principal cause of accident not cleaning out known misfired hole prior to drilling next raise round. Actions leading to the fatal accident contrary to then existing safety regulations.
10. July 24, 1973 - Single fatality resulting from victim being struck by ventilation door which was opened by air blast and concussion of planned hangup blast. Victim set and ignited explosives but failed to withdraw to an adequately safe place before blast. Contributing causes possibly short fuses, poor blasting procedures and ventilation control plans for clearing blast smoke and fumes. Actions leading to fatal accident contrary to then existing safety regulations.
11. December 26, 1973 - Single fatality and nonfatal injury resulting from flying rock fragments. Victims struck by material from blast while igniting fuse at another blast location. Principal cause of accident returning to the vicinity of an ignited blast round, failure to observe proper sequence of blasting rounds and failure to withdraw to a safe place. Actions leading to fatal accident contrary to then existing safety regulations.
12. March 6, 1974 - Single fatality resulting from head injuries to victim from being struck against unknown object by force of explosives concussion. Victim ignored blasting warning signs and guards and proceeded to unsafe location where he was injured by blast concussion or air blast. Actions leading to fatal accident contrary to then existing safety regulations.
13. August 16, 1974 - Single fatality resulting from victim being struck by flying rock fragments of a premature blast. Victim failed to withdraw to a safe location before blast occurred, not all fuses in round successfully spilled. Action leading to fatal accident contrary to then existing safety regulations and company blasting practices.

APPENDIX B
FATAL METAL AND NONMETAL
UNDERGROUND MINE ACCIDENTS
1975-1978

ABSTRACTS

1. June 6, 1975 - Single fatality resulting from being at the site of a benching blast as a result of poor procedures for clearing blasting areas and poor communications between blaster and guards. Victim was inexperienced and unsuitable to assist in blasting. Actions leading to fatal accident contrary to existing health and safety regulations.
2. July 12, 1976 - Three fatalities due to inexperience, improper equipment and bad judgment in the use of explosives. Accident a result of lighting blast hole fuses in an unsafe manner. Actions leading to fatal accident contrary to existing health and safety regulations.
3. August 4, 1976 - Single fatality due to inexperience, improper equipment, and bad judgment in the use of explosives. Accident a result of lighting blast hole fuses in an unsafe manner. Actions leading to fatal accident contrary to existing health and safety regulations.
4. August 12, 1976 - A single fatality and two nonfatal injuries resulting from inadvertent overloading of a blast round with ANFO and the subsequent failure to withdraw to a sufficiently distant and safe location before blasting. The sympathetic detonation of spilled ANFO prill resulting from loading equipment malfunction and mine personnel inexperience was probably a contributing factor. Actions leading to fatal accident contrary to existing health and safety regulations.
5. December 2, 1976 - Single fatality by suffocation due to entry of improperly ventilated area in which a round had been recently blasted. Actions leading to fatal accident contrary to existing health and safety regulations.
6. December 7, 1976 - Single fatality by flying rock fragments due to failure to withdraw to a safe location prior to blasting. Victim shot through fender pillar onto self. Inexperience, insufficient training and bad judgment contributing factors. Actions leading to fatal accident contrary to existing health and safety regulations.
7. April 1, 1977 - Single fatality and two injuries as a result of walking into blast of a reprimed misfire. Secondary blast (hang-fire) resulted from improper repriming preventing propagation with original fuse and primer acting as a time delay fused explosive. Actions leading to fatal accident contrary to existing health and safety regulations.

8. June 2, 1977 - Single fatality resulting from victim being present at the blast site. Cause of accident unknown but possibly due to delays in completion of fuse lighting placing victim at face when blast occurred. Actions leading to fatal accident contrary to existing health and safety regulations.
9. June 20, 1977 - Single fatality and single injury resulting from walking in on blast due to failure of "guards" to warn of impending blast. Actions leading to fatal accident contrary to existing health and safety regulations.
10. June 28, 1977 - Double fatality resulting from unsafe method of igniting fuse, insufficient training in the use of explosives and failure to withdraw from blast area. Cause of accident unsafe method of igniting fuse. Actions leading to fatal accident contrary to existing health and safety regulations.
11. January 25, 1978 - Single fatality resulting from failure of the victim to withdraw to a safe location before initiating blast. Actions leading to fatal accident contrary to existing health and safety regulations.
12. April 18, 1978 - Single fatality and two injuries while hand mucking at a working face when a misfire exploded. Cause of accident was improper disposal of misfire and returning to area too soon. Actions leading to fatal accident contrary to existing health and safety regulations.
13. October 13, 1978 - Single fatality resulting from being struck in the head by flying rock from an explosion which occurred when the driller drilled into a misfired hole. Action leading to fatal accident contrary to existing health and safety regulations.

APPENDIX B

NONFATAL METAL AND NON-METAL

UNDERGROUND MINE ACCIDENTS

(Recent Reported Accidents)

SUMMARIES

Metal Mine - Lost-time accident occurred during development blast round when spilled prill was detonated. Two injured men were too close to blast area. A lost-time accident occurred when a miner stood at the entrance of a drift, too close to a heading being shot, in order to see the flash of the round. Also a non-lost-time accident occurred when a blasting cap prematurely detonated. The miner received minor burns.

This mine has had no blasting accidents since they eliminated on-shift blasting.

Metal Mine - Lost-time accident occurred when a shift boss and Federal Mine Inspector walked into an unguarded place just as the round was detonated.

Metal Mine - A near miss occurred when the blasting crew lit the safety fuse without permission prior to clearing the mine. No one was informed of the pending blast nor was a warning sign posted. A foreman walked into the section and saw the burning fuse. The miners responsible were terminated.

Non-metal Mine - A lost-time accident occurred when two miners were hiding in a crosscut adjacent to a place being shot. The men had turned out their lamps and were lying down when the section boss checked the area. Both men were injured when the round broke through. The section foreman was relieved of his duties and the miners were returned to work.

Non-metal Mine - Near Miss - A maintenance crew was blasting "pop" holes to make room for equipment in a stope. When the maintenance crew was ready to tie the round in they stripped the insulation from the secondary blasting circuit and wired in the blasting line. At the same time a mine crew on the same level, but in a different area, was preparing a mud cap shot using the same blasting circuit. The mine crew shouted down the drift to see if the maintenance crew was clear and then posted a guard. The maintenance crew shouted back that they were clear and the mine crew fired their blast. The maintenance crew had just climbed out of the stope when their round detonated, so no one was injured. An investigation revealed that neither crew was aware of what the other was doing. The mine crew would not have had any reason to visually inspect the other area as it was about

two-hundred feet from the stope in which the maintenance crew was working. The maintenance crew was not supposed to tie into the secondary blasting circuit; a separate circuit is required.

APPENDIX C

Underground Coal Mines - Blasting Violations Issued During the
Period of 1-1-72 to 12-31-79

Underground Metal and Non-Metal Mines - Violations Issued During
the Period Jan. 1972 - March 1978

Underground Metal and Non-Metal Mines - Citations Issued During
the Period March 1978 - Dec. 1979
Mandatory Standards

Underground Metal and Non-Metal Mines - Notices Issued During the
Period Jan. 1972 - March 1978
Mandatory Standards

APPENDIX C

UNDERGROUND COAL MINES

BLASTING VIOLATIONS ISSUED DURING THE PERIOD OF 1-1-72 to 12-31-79

Rank	CFR-Part 75 Subpart N Standard	No. of Citations	No. of Orders	Total Violations	% of All Violations
83	75.1306	2,016	148	2,164	.3
180	75.1303	607	146	753	.1
188	75.1307	638	80	718	.1
349	75.1304	211	22	233	.0
531	75.1301	74	21	95	.0
532	75.1305	77	18	95	.0
793	75.1300	21	16	37	.0
973	75.1308	19	0	19	.0
1183	75.1305d	9	1	10	.0
1204	75.1303-1	6	3	9	.0
1563	75.1302	3	0	3	.0
1693	75.1302c	1	1	2	.0
1895	75.1305a	1	0	1	.0
1896	75.1305b	1	0	1	.0
1897	75.1305f	<u>1</u>	<u>0</u>	<u>1</u>	<u>.0</u>
TOTALS:		3,686	456	4,142	.7%
Total Underground Coal Violations:			619,003		

APPENDIX C

page 1 of 2

UNDERGROUND METAL AND NONMETAL MINES

VIOLATIONS ISSUED DURING THE PERIOD JAN. 1972 - MARCH 1978

ADVISORY STANDARDS

Rank by No. of Violations	CFR-Part 57 Standard	Observation (Warnings)	Abated during Inspection	% of all Violations	% of Blasting Violations
56	* 06-	52	22	.4	14.2
65	06-028	42	3	.3	11.4
72	06-000	34	6	.2	9.3
80	06-007	25	11	.2	6.8
80	06-010	25	11	.2	6.8
83	06-106	22	7	.2	6.0
87	06-049	8	1	.1	4.9
90	06-009	15	7	.1	4.1
90	06-180	15	5	.1	4.1
94	06-004	11	9	.1	3.0
96	06-005	9	5	.1	2.5
96	06-121	9	3	.1	2.5
96	05-130	9	1	.1	2.5
96	06-181	9	3	.1	2.5
97	06-098	8	2	.1	2.2
98	06-122	7	5	.0	2.0
98	06-005	7	1	.0	2.0
99	06-092	6	4	.0	1.6
100	06-055	5	0	.0	1.4
100	06-176	5	0	.0	1.4

* Further information was not provided on the computer readout

UNDERGROUND METAL AND NONMETAL MINES
VIOLATIONS ISSUED DURING THE PERIOD JAN. 1972 - MARCH 1978

ADVISORY STANDARDS

Rank by No. of Violations	CFR-Part 57 Standard	Observation (Warnings)	Abated during Inspection	% of all Violations	% of Blasting Violations
101	06-001	4	4	.0	1.1
101	06-020	4	3	.0	1.1
102	06-008	3	3	.0	.8
102	06-109	3	1	.0	.8
102	06-178	3	0	.0	.8
102	06-190	3	1	.0	.8
103	06-027	2	2	.0	.5
103	06-078	2	1	.0	.5
104	06-002	1	1	.0	.3
104	06-029	1	1	.0	.3
104	06-047	1	1	.0	.3
104	06-048	1	0	.0	.3
104	06-057	1	1	.0	.3
104	06-096	1	1	.0	.3
104	06-102	1	1	.0	.3
104	06-112	1	1	.0	.3
104	06-123	1	0	.0	.3
104	06-177	1	1	.0	.3
105	06-125	0	0	.0	.0
		367	129	*98.1	

*Doesn't add to 100% due to rounding to nearest .1%

06 Rank 12th in Summary Total Warnings 14,321

APPENDIX C
 UNDERGROUND METAL AND NONMETAL MINES
CITATIONS ISSUED DURING THE PERIOD MARCH 1978 - DEC 1979
 MANDATORY STANDARDS

Rank by Number of Citations	CFR-Part 57 Standard	Citations Issued	% of Total Citations	% of Citations Blasting Only
21	0006-0001	120	1.	18.7
41	0006-0020	52	.4	8.1
47	0006-0122	39	.3	6.1
50	0006-0005	36	.3	5.6
53	0006-0177	32	.3	5.0
59	0006-0047	25	.2	3.9
59	0006-0092	25	.2	3.9
59	0006-0102	25	.2	3.9
62	0006-0027	22	.2	3.4
64	0006-0002	19	.2	3.0
65	0006-0103	18	.2	2.8
68	0006-0103	15	.1	2.3
69	0006-0043	14	.1	2.2
71	0006-0029	12	.1	1.9
71	0006-0168	12	.1	1.9
72	0006-0042	11	.1	1.7
73	0006-0008	10	.1	1.6
74	0006-0057	9	.1	1.4
75	0006-0040	8	.1	1.2

UNDERGROUND METAL AND NONMETAL MINES
CITATIONS ISSUED DURING THE PERIOD MARCH 1978 - DEC 1979
 MANDATORY STANDARDS

Rank by Number of Citations	CFR-Part 57 Standard	Citations Issued	% of Total Citations	% of Citations Blasting Only
76	0006-0045	7	.1	1.1
76	0006-0112	6	.1	.9
77	0006-0003	6	.1	.9
77	0006-0030	6	.1	.9
77	0006-0046	6	.1	.9
77	0006-0016	6	.1	.9
77	0006-0120	6	.1	.9
78	0006-0004	5	.0	.8
78	0006-0107	5	.0	.8
78	0006-0120A	5	.0	.8
78	0006-0127	5	.0	.8
79	0006-0044	4	.0	.6
79	0006-0077	4	.0	.6
79	0006-0097	4	.0	.6
79	0006-0099	4	.0	.6
79	0006-0128	4	.0	.6
79	0006-0159	4	.0	.6

UNDERGROUND METAL AND NONMETAL MINES
CITATIONS ISSUED DURING THE PERIOD MARCH 1978 - DEC 1979
 MANDATORY STANDARDS

Rank by Number of Citations	CFR-Part 57 Standard	Citations Issued	% of Total Citations	% of Citations Blasting Only
80	0006-0009	3	.0	.5
80	0006-0012	3	.0	.5
80	0006-0050	3	.0	.5
80	0006-0065	3	.0	.5
80	0006-0177A	3	.0	.5
81	0006-0006	2	.0	.3
81	0006-0020B	2	.0	.3
81	0006-0056	2	.0	.3
81	0006-0101	2	.0	.3
81	0006-0114	2	.0	.3
81	0006-0162	2	.0	.3
81	0006-0175	2	.0	.3
81	0006-0195	2	.0	.3
81	0006-0200	2	.0	.2
82	0006-0020A	1	.0	.2
82	0006-0020C	1	.0	.2
82	0006-0048	1	.0	.2

UNDERGROUND METAL AND NONMETAL MINES
CITATIONS ISSUED DURING THE PERIOD MARCH 1978 - DEC 1979
 MANDATORY STANDARDS

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Rank by Number of Citations	CFR-Part 57 Standard	Citations Issued	% of Total Citations	% of Citations Blasting Only
82	0006-0075	1	.0	.2
82	0006-0076	1	.0	.2
82	0006-0090	1	.0	.2
82	0006-0091	1	.0	.2
82	0006-0093	1	.0	.2
82	0006-0104	1	.0	.2
82	0006-0108	1	.0	.2
82	0006-0119	1	.0	.2
82	0006-0120	1	.0	.2
82	0006-0125	1	.0	.2
82	0006-0137	1	.0	.2
82	0006-0177B	1	.0	.2
82	0006-2000C	1	.0	.2
83	0006-0106	0	.0	.0
		641	5	100.5

Total Blasting Citations Issued 641 06 Ranks 7th
 Total Citations Issued 11935

APPENDIX C
 UNDERGROUND METAL AND NONMETAL MINES
NOTICES ISSUED DURING THE PERIOD JAN 1972 - March 1978
 MANDATORY STANDARDS

Rank by Number of Notices	CFR-Part 57 Standard	Notices Issued	% of Total Notices	% of Notices Blasting Only
17	06-020	921	1.3	14.8
21	06-001	769	1.1	12.8
31	06-092	466	.6	7.5
35	06-122	498	.5	6.4
39	06-005	380	.5	6.2
46	06-047	328	.5	5.3
61	06-027	224	.3	3.6
64	06-193	212	.3	3.4
71	06-043	189	.3	3.0
73	06-042	187	.3	3.0
77	06-103	167	.2	2.7
84	06-177	141	.2	2.3
92	06-008	119	.2	1.9
94	06-029	115	.2	1.9
100	06-102	102	.1	1.6
101	06-040	101	.1	1.6
105	06-057	94	.1	1.5
106	06-112	90	.1	1.4

UNDERGROUND METAL AND NONMETAL MINES
NOTICES ISSUED DURING THE PERIOD JAN 1972 - March 1978
 MANDATORY STANDARDS

Rank by Number of Notices	CFR-Part 57 Standard	Notices Issued	% of Total Notices	% of Notices Blasting Only
114	06-120C	78	.1	1.3
119	06-030	72	.1	1.3
121	06-002	69	.1	1.1
127	06-162	59	.1	1.0
128	06-127	57	.1	.9
134	06-050	46	.1	.7
135	06-168	45	.1	.7
139	06-056	41	.1	.7
142	06-006	38	.1	.7
145	06-096	35	.1	.6
146	06-020B	34	.0	.5
150	06-020A	30	.0	.5
150	06-044	30	.0	.5
150	06-065	30	.0	.5
152	06-107	28	.0	.5
157	06-090	23	.0	.4
159	06-095	21	.0	.3
159	06-120	21	.0	.3
161	06-020	19	.0	.3

UNDERGROUND METAL AND NONMETAL MINES
NOTICES ISSUED DURING THE PERIOD JAN 1972 - March 1978
 MANDATORY STANDARDS

Rank by Number of Notices	CFR-Part 57 Standard	Notices Issued	% of Total Notices	% of Notices Blasting Only
161	06-110	19	.0	.3
161	06-159	19	.0	.3
162	06-099	18	.0	.3
163	06-045	17	.0	.3
164	06-175	16	.0	.3
165	06-120B	15	.0	.2
165	06-128	15	.0	.2
167	06-200	13	.0	.2
169	06-116	11	.0	.2
170	06-114	10	.0	.2
170	06-120A	9	.0	.2
171	06-097	9	.0	.1
171	06-129	9	.0	.1
171	06-133	9	.0	.1
173	06-106	7	.0	.1
173	06-108	7	.0	.1
173	06-111	7	.0	.1
174	06-012	6	.0	.1

UNDERGROUND METAL AND NONMETAL MINES
NOTICES ISSUED DURING THE PERIOD JAN 1972 - March 1978

MANDATORY STANDARDS

Rank by Number of Notices	CFR-Part 57 Standard	Notices Issued	% of Total Notices	% of Notices Blasting Only
174	06-113	6	.0	.1
174	06-125	6	.0	.1
174	06-194	6	.0	.1
175	06-007	5	.0	.1
175	06-052	5	.0	.1
175	06-054	5	.0	.1
175	06-091	5	.0	.1
175	06-100	5	.0	.1
175	06-159B	5	.0	.1
175	06-170	5	.0	.1
175	06-177A	5	.0	.1
176	06-004	4	.0	.1
176	06-028	4	.0	.1
176	06-077	4	.0	.1
176	06-094	4	.0	.1
176	06-101	4	.0	.1
176	06-131	4	.0	.1
176	06-135	4	.0	.1
176	06-160	4	.0	.1

UNDERGROUND METAL AND NONMETAL MINES
NOTICES ISSUED DURING THE PERIOD JAN 1972 - March 1978
 MANDATORY STANDARDS

Rank by Number of Notices	CFR-Part 57 Standard	Notices Issued	% of Total Notices	% of Notices Blasting Only
177	06-021	3	.0	.0
177	06-022	3	.0	.0
177	06-041	3	.0	.0
177	06-177B	3	.0	.0
177	06-177C	3	.0	.0
177	06-220	3	.0	.0
178	06-053	2	.0	.0
178	06-093	2	.0	.0
178	06-104	2	.0	.0
178	06-109	2	.0	.0
178	06-159C	2	.0	.0
179	06-011	1	.0	.0
179	06-011B	1	.0	.0
179	06-014	1	.0	.0
179	06-017	1	.0	.0
179	06-021	1	.0	.0
179	06-023	1	.0	.0
179	06-025	1	.0	.0

UNDERGROUND METAL AND NONMETAL MINES
NOTICES ISSUED DURING THE PERIOD JAN 1972 - March 1978
 MANDATORY STANDARDS

Rank by Number of Notices	CFR-Part 57 Standard	Notices Issued	% of Total Notices	% of Notices Blasting Only
179	06-029C	1	.0	.0
179	06-031	1	.0	.0
179	06-046C	1	.0	.0
179	06-055	1	.0	.0
179	06-075	1	.0	.0
179	06-076	1	.0	.0
179	06-117	1	.0	.0
179	06-119C	1	.0	.0
179	06-121	1	.0	.0
179	06-111A	1	.0	.0
179	06-123	1	.0	.0
179	06-157	1	.0	.0
179	07-169	1	.0	.0
179	06-190	1	.0	.0
179	06-190A	1	.0	.0
179	06-192	1	.0	.0
179	06-20	1	.0	.0
180	06-003	0	.0	.0

UNDERGROUND METAL AND NONMETAL MINES
NOTICES ISSUED DURING THE PERIOD JAN 1972 - March 1978
 MANDATORY STANDARDS

Rank by Number of Notices	CFR-Part 57 Standard	Notices Issued	% of Total Notices	% of Notices Blasting Only
180	06-005C	0	.0	.0
180	06-010	0	.0	.0
180	06-012B	0	.0	.0
180	06-016	0	.0	.0
180	06-024	0	.0	.0
180	06-024C	0	.0	.0
180	06-037	0	.0	.0
180	06-049	0	.0	.0
180	06-067	0	.0	.0
180	06-069	0	.0	.0
180	06-070	0	.0	.0
180	06-098	0	.0	.0
180	06-130	0	.0	.0
180	06-161	0	.0	.0
180	06-180	0	.0	.0
180	06-181	0	.0	.0
All blasting & Explosives		6264	8.6	
Notices Ranked 7th				
All Notices		72880	100%	

APPENDIX D

MINE VISITS DATA

Summary of Metal Mine Visits

Summary of Non-Metal Mine Visits

Coal Mine Visits

TABLE D 5.1
SUMMARY OF METAL MINE VISITS

	NO. 1	NO. 2	NO. 3	NO. 4	NO. 5	NO. 6	NO. 7	NO. 8	NO. 9	NO. 10	NO. 11
COMMODITY	URANIUM	COPPER	COPPER	URANIUM	TUNGSTEN	METAL	LEAD/ZINC	GOLD	COPPER	MOLBYDEUM	LEAD
MINING SYSTEM	ROOM & PILLAR SAND FILL	CUT & FILL	ROOM & PILLAR	DEVELOPMENT	SUBLEVEL STOPE	CUT & FILL	CUT & FILL	CUT & FILL	SUBLEVEL STOPING	CAVING	ROOM & PILLAR
EQUIPMENT	JACK LEG, LHD, RAIL HAULAGE	JACK LEG, CAVO LOADERS	JACK LEG, LHD RAIL HAULAGE	JACK LEG, LHD	JACK LEG, LHD SLUSHER	JACK LEG RAIL/HOIST	JACK LEG CAVO 11213	JACK LEG, LHD RAIL HAULAGE	JUMBO, LHD TRUCKS	JUMBO, LHD RAIL HAULAGE	JUMBO, LHD TRUCKS
OPERATION SHIFTS/DAY	3	3	3	2	3	2	2	3	3	3	3
PRODUCTION SHIFTS/DAY	2	3	2		3	2	2	2	2	3	2
PRODUCTION/DAY TONS	600	3,000	1,500		Confidential	800	1,500-2,000	5,500	4,800	27,000	5,000
PRODUCTION/WEEK TONS	3,300	15,000	7,500		Confidential	4,000	7,500	27,000	24,000	189,000	25,000
PRODUCTION/MONTH TONS	13,000	65,000	30,000		Confidential	16,000	33,000	120,000	104,000	819,000	109,000
PERSONNEL SALARIED	14	73	25	1	20	28	Unknown	110	13	120	12
HOURLY	145	826	243	10	200	120	300	1,100	106	1,100	90
BLASTING/MINING CREW	30	55	21	2	Variable	8	59	Varies	1	2	Unknown
MEN PER CREW	2	2	2	3	3-5	2	2	2-4	6	8	2
EXPERIENCE-YEARS	<2	Unknown	+5	+3	60% < 2	+5	+10	+15	+10	Unknown	+30
TYPE OF DRILLING	PERCUSSION	PERCUSSION	PERCUSSION	PERCUSSION	PERCUSSION	PERCUSSION	PERCUSSION	PERCUSSION	ROTARY	PERCUSSION	PERCUSSION
EXPLOSIVES	HERCULES 40%	ANFO/ANOGEL 40%	ANFO	HERCULES 60%	HERCULES 60%	ANFO	WATERGEL ANFO	TOVEX, ANFO	ANFO, TOVEX	ANFO, TOVEX	GELADYNE, ANFO
DETONATORS	ELECTRIC	NONEL	NONEL	ELECTRIC	ELECTRIC	ELECTRIC	ELECTRIC	ELECTRIC	NONEL	NONEL	ELECTRIC
PRIMERS	CAP IN STICK	CAP IN STICK	CAP IN STICK	CAP IN STICK	CAP IN STICK	ANFO/DET	CAP IN STICK	DETAPRIME	CAP IN STICK	DETAPRIME	CAP IN STICK
EXPLOSIVES	SURFACE MAG.	SURFACE &	SURFACE	SURFACE MAG.	UNDGR. MAG.	SURFACE MAG.	UNDGR. MAG.	UNDGR. MAG.	SURFACE MAG.	UNDERGROUND	SURFACE MAG.
STORAGE	DAY BOXES	UNDERGROUND	UNDGR. MAG.						& UNDERGROUND	UNDERGROUND	& UNDERGROUND
HOLES/ROUND DEV. 1)	24	40-60	36-100	30	Variable	Unknown	Varies	Varies	43	50	
PROD. 2)	6'	6'	6-10'	6'	Variable	25	Varies	Varies	Varies	Varies	
DEPTH	1 3/8 - 1 5/8"	1 3/8"	1 5/8 - 2"	1 1/2	6-12'	6.5'	8-15'	6-15'	12-50'	10-61'	11 1/2 - 12'
DIAMETER					1 3/8 - 2 1/4"	1 3/8"	1 1/2"	1 1/2 - 6 1/4"	2,3,6 3/4"	1 3/4 - 3"	1 3/4"
SEQUENCE OF DETONATORS	0-10	0-15	0-15	0-12	Variable	0-10	Varies	Varies	0-5	0-14	0-17
EXPLO. CONSUMPTION/ BLAST	50 lbs.	150-250 lbs.	150-300 lbs.	50 lbs.	250 lbs.	100-150 lbs.	Varies	Varies	650 (drift)	2,400 lbs.	500 lbs.
ON SHIFT BLASTING	AS NEEDED	MISFIRES	SECONDARY	AS NEEDED	SECONDARY	MISFIRES	NONE	NONE	SECONDARY	NONE	NONE
GUARDING	AT ACCESS TO WORK AREA	MINE CLEARED	MINE CLEARED	AT ACCESS TO WORK AREA	MINE CLEARED	MINE CLEARED	AT ACCESS TO STOPE	MINE CLEARED	MINE CLEARED	MINE CLEARED	MINE CLEARED
DISPOSAL OF MISFIRES	RESHOOT	RESHOOT	RESHOOT	RESHOOT	RESHOOT	RESHOOT	RESHOOT	RESHOOT	RESHOOT	RESHOOT	RESHOOT

1) DEV. - DEVELOPMENT
2) PROD. - PRODUCTION

TABLE D 5.2
SUMMARY OF NON-METAL MINE VISITS

	NO. 1	NO. 2	NO. 3	NO. 4	NO. 5	NO. 6	NO. 7	NO. 8	NO. 9	NO. 10
COMMODITY	LIMESTONE	POTASH	TALC	COLEMANITE	TRONA	TREMOLITE	SALT	LIMESTONE	SALT	LIMESTONE
MINING SYSTEM	ROOM & PILLAR	ROOM & PILLAR	DEVELOPMENT	SLOT & PILLAR	ROOM & PILLAR	OPEN STOPE	ROOM & PILLAR	ROOM & PILLAR	ROOM & PILLAR	ROOM & PILLAR
EQUIPMENT	JUMBO, LHD, BELT, TRUCK	FACE DRILL, BUGGIES	JACK LEG, LHD	JACK LEG, JUMBO, LHD	FACE DRILL, BUGGIES	JACK LEG, SLUSHER	FACE DRILL, LHD	HYD. JUMBO, TRUCK	LHD, BELT	TRUCK, JUMBO
OPERATING SHIFTS/DAY	3	15/WEEK	1	3	3	1	3	3	3	1
PRODUCTION SHIFTS/DAY	2		1	3	3	1	2	1	2	1
PRODUCTION/DAY TONS	8,000	1230 Shift	150	Unknown	11,000	500	8,000	900	1200	580
PRODUCTION/WEEK TONS	40,000	18,500	750	Unknown	77,000	2,500	40,000	4,500	6,000	3,200
PRODUCTION/MONTH TONS	175,000	80,000	3,300	Unknown	305,000	10,900	150,000	19,000	25,000	14,000
PERSONNEL SALARIED HOURLY	18	12	1	5	80	6	6	2	2	2
BLASTING/MINING CREW MEN PER CREW	110	36	10	13	500	36	62	15	14	18
EXPERIENCE/YEARS	2	3	2	Unknown	14	8	3	1	1	1
	3-5	1	2	Unknown	1	2	2	2	2	2
	4 YEARS	Unknown	>1	+5 YEARS	>5	Unknown	Unknown	Unknown	Unknown	Unknown
TYPE OF DRILLING	PERCUSSION	ROTARY	PERCUSSION	PERCUSSION	AUGER	PERCUSSION	AUGER	PERCUSSION	AUGER	PERCUSSION
EXPLOSIVES	ANFO/HERCULES	ANFO	ANFO/HERCULES	ANFO/TOVEX	TOVEX 300	TOVEX 200	ANFO	ATLAS AMMODYTE	ANFO	ANFO/AQUAGEL
DETONATORS	NONEL	NONEL	FUSE	ELECTRIC	ELECTRIC	ELECTRIC	ELECTRIC	ELECTRIC	NONEL	ELECTRIC
PRIMERS	CAP IN STICK	CAP IN STICK	CAP IN STICK	CAP IN STICK	CAP IN STICK	CAP IN STICK	DETAPRIME	CAP IN STICK	CAP IN STICK	CAP IN STICK
EXPLOSIVES STORAGE	MAGAZINE	MAGAZINE	UNDERGROUND	SURFACE MAG.	SURFACE MAG.	SURFACE MAG.	UNDERGROUND	SURFACE	UNDERGROUND	UNDERGROUND
	DROP TRAILER	PALLETS FOR ANFO		DAY BOXES UNDERGROUND	UNDERGROUND	UNDERGROUND				
HOLES/ROUND	DEV. 1)	21	25	55	12	VARIABLE	54	18-52	104	UNK
PROD. 2)	42-44	21	25	55	12	VARIABLE	54			
DEPTH	12'	10'	8'	8-12'	10'	6'	10'	16'	10'	
DIAMETER	2"	1 5/8"	1 1/2"	1 7/8"	1 3/4"	1 5/8"	2"	1 5/8"	1 3/4"	1 3/4"
SEQUENCE OF DETONATORS	0-15	0-4	Igniter Cord	0-11	0-5	0-14	UNK	UNK	UNK	UNK
EXPLO. CONSUMPTION/BLAST.	600 lbs.	50 lbs.	125 lbs.	350 lbs.	100 lbs.	<250 lbs.>	400 lbs.	UNK	1,200 lbs.	2,200 lbs.
ON SHIFT BLASTING	NONE	NONE	NONE	AS NEEDED	AS NEEDED	SECONDARY	SHIFT CHANGE	END OF SHIFT	SECONDARY	SECONDARY
GUARDING	MINE CLEARED	MINE CLEARED	MINE CLEARED	AT SHAFT	3)	AT SHAFT	MINE CLEARED	3)	MINE CLEARED	MINE CLEARED
DISPOSAL OF MISFIRES	WASHOUT	WASHOUT	WASHOUT	RESHOOT	RESHOOT	RESHOOT	RESHOOT	UNK	RESHOOT	UNK

1) Dev. - Development

2) Prod. - Production

3) Guarding at Access to Work Area

**TABLE D 5.3
COAL MINE VISITS**

	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10
Mine location	Southern West Virginia	Southern West Virginia	Northern West Virginia	Pennsylvania	Central West Virginia	Central West Virginia	East Kentucky	Pennsylvania	Central Alabama	Wyoming
Type of coal mine Mining method	Bituminous Room & pillar	Bituminous Room & pillar	Bituminous Room & Pillar	Anthracite Breast & pillar stoping	Bituminous Room & pillar	Bituminous Room & pillar	Bituminous Room & pillar	Bituminous Room & pillar	Bituminous Room & pillar	Bituminous Room & pillar
Equipment employed	Conventional	Conventional	Continuous	Hand held	Continuous & Conventional	Conventional	Conventional	Conventional	Conventional	Conventional (80%) Continuous (20%)
Operating shifts/day	1	1	3	2	3	1	3	3	3	2
Production shifts/day	1	1	3	2	2	1	2	2	2	2
Production										
Per shift in tons	150	200	3000	250	1000	250	400	420	400	200
Per day in tons	150	-	9000	500	-	-	800	440	1200	400
Per week in tons	1500	750	45,000	2500	4000	1200	4000	4000	12,000	2,000
Month in tons	6000	6000	125,000	10,000	15,000	4500	20,000	20,000	50,000	8,000
Personnel										
salaried	1	1	60	5	7	2	4	6	46	42
Hourly	14	9	500	113	107	12	29	64	150	185
Blasting crew	1	1	9	35	3	1	2	4	7	4
Men per blasting crew	1	1	2	2 or 3	1	1	1	1	1	2
Average age of blasters	35	53	Over 30	35-37	45	40	26	40+	30	28
Type drilling	Hand held auger	Hand held auger	Pneumatic sinkers	Jack legs & air rotary	Mobile auger	Hand held auger	Long Airdox coal drill	Long Airdox coal drill	Shroeder coal drill	Joy coal auger
Explosives	Austin Red D #4	Independent Powder Co.	duPont TOVEX 31) & 32)	Hercogel R (Rock) Hercogel Red H	Independent Powder Co.	Austin Red D #4	duPont TOVEX gel	Austin Red Diamond #6	Hercules Collier C	Atlas and duPont watergel
Type of primer 1)										
Type of Detonators 2)										
Blasting machine	Femco	Unknown	Femco	Femco	Unknown	Gulton Battery	Femco	Femco	Gulton Battery	Dragert
Explosive storage / Underground	Approved wood lined boxes	Concrete blocks & rubber lines	Wooden boxes	Wooden boxes	Particamed wooden box	Wooden boxes	Rubber tire magazine	Wooden boxes	Rail mounted magazine car	Fiberglass
Seam mined /or Type	Freeport 48" Upper	5-block 5'2"	Floor rock Pittsburgh	Steeply pitching	Peerless 39"	Upper Freeport 4' 8"	Pound Creek 30"	"B" Seam 36"	MaryLee Seam 22"	Hanna #8 25'
Blast Round No. of holes	4	4	20	Varied	8	4	21	4	10	15
Depth	8'	8'	1'-6'	Varied	7'	9'	10'	8'	11'	10'
Diameter	2"	2"	1-1/2"	1-3/4"	2"	2"	2"	2"	1-3/4"	1-3/4"
Sequence of Detonators	Instantaneous	Instantaneous	Instantaneous	Instantaneous-coal-delays-rock	Instantaneous	Instantaneous	1,6 delay caps	164 delay caps	1,263 delays	1-6 milli sec. delays
Explosives consumption/day	200 lbs	100 lbs	40 lbs/shot	500 lbs	200 lbs	125 lbs	240 lbs	240 lbs	650 lbs	1500 lbs
Stemming	Rock dust in paper cylinders	Water dummies	Clay dummies in paper cylinders	Sand filled in paper cylinders	Clay dummies	Rock dust in paper cylinders	Clay dummies	11" clay dummies	Water dummies	Water dummies
Miscellaneous			Clear Blast Area-end of Shift							2 Benches being mined

1) All Mines - Electric cap in full stick of powder

2) All Mines - Electric caps