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**ANALYSIS OF
COAL MINE
ELECTRICAL ACCIDENTS**

Bureau of Mines Open File Report 91-82

Contract J0100096
West Virginia University

BUREAU OF MINES★UNITED STATES DEPARTMENT OF THE INTERIOR
Minerals Health and Safety Technology

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16. Abstract (Limit 200 words) Electrical accidents occurring in coal mines from 1975 through 1979 were categorized and analyzed. The data were searched for common electrical hazards, common activities by those injured, and common negligent or careless behavior. The accident data were combined with mine production statistics to form a normalized electrical accident rate. It was found that some mines have consistently more lost workdays per work-hour than other mines. Bureau of Mines electrical safety research contracts were reviewed to determine whether the research effort was directed toward those areas that are related to the most accidents; in some cases it was not. A method was devised and utilized to estimate the relative cost to the mining industry to implement certain safety measures developed through Bureau research and the potential safety benefits. MSHA regulations were reviewed for effectiveness in preventing electrical accidents and suggestions were made for discontinuing, clarifying, or otherwise modifying the regulations.			
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FOREWORD

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EXECUTIVE SUMMARY

This report deals with the analysis of coal mine electrical accidents which were reported to the Mining Health and Safety Administration. Essentially all of the electrical accidents occurring in 1975, 1978, and 1979 were studied in detail. Data was used from 1976 and 1977 also, but only for a few of the many studies carried out. A major portion of the research effort was related to a detailed breakdown of how the Bureau of Mines has distributed its expenditures for contracted electrical safety research over various research categories.

Chapter I is a short introduction. It points out that both the mining industry and the federal government have limited funds to expend on improving mine safety. The purpose of the report is to provide data which will lead to the more effective use of these funds. This is done by separating electrical accidents into categories, and comparing the relative significance of various categories of accidents. Next, an assessment is made of how much Bureau of Mines contract money has been spent on research to reduce accidents in each category. Excluded from this study are such accidents as mine fires and explosions initiated by electricity. Because accidents of this type are not classified as electrical, the benefits of research pertaining to permissibility and intrinsic safety are underestimated by this study.

Chapter II describes how the data was collected. Electrical accident descriptions were collected from the MSHA Health and Safety Analysis Center. Mine production statistics were obtained from MSHA Coal Mine Reference files and from the Keystone Coal Industry Manual. Information on Bureau of Mines safety contract expenditures was obtained from the Mining Research Contract Review, from the Bureau of Mines List of Publications, and from the files of the Bureau as well as interviews with Bureau technical personnel. Data on mine electrical equipment and practices were obtained by visiting a variety of underground and surface coal mines in both eastern and western coal fields. Descriptions of these mine visits are provided in Appendix A of this report.

Chapter III covers the analysis of the accident data. Some 1300 electrical accidents were used to construct a computerized data base. Each accident was listed in detail, along with an analysis of the root causes of the accident. This data was used to study many relationships. It was used to search for "accident prone" mines, which had a significantly higher ratio of work days lost through electrical accidents to the total number of man-hours worked or tons of coal produced. The accident profiles show the prevalence of accidents related to certain electrical hazards or certain types of negligent or careless behavior. Correlation studies were carried out to relate this information to types of equipment being used, severity of accidents, worker activity, etc. A list of common problems was produced which shows that abnormal arcs and sparks is the most common hazard, the most common type of negligent behavior is failure to remove power from a circuit before working on it, and the most common activity of injured persons is handling energized cables. Many accidents are related to the dc trolley system, also. Part 75 of Title 30, Code of Federal Regulations was reviewed to determine whether or not the electrical accidents which occur are addressed by the regulations. It was found that

the regulations could be interpreted to prohibit the behavior or situation surrounding most accidents, but that they did not do so in a clear and unambiguous fashion. Several suggestions were made for eliminating or changing regulations which do not serve a useful purpose as worded, for rewording others to make them clearer, and to alleviate the adversary relationship that exists between mine operators and MSHA inspectors.

Chapter IV deals with the analysis of data concerning Bureau research contracts. Research contracts awarded from 1969 to the present were studied. Research contracts which were related to electrical safety were studied in detail. At least the abstract describing the research was read. In some cases other information was obtained from conference papers, information circulars, conversations with researchers involved, and interviews with appropriate technical project officers at the Bureau. In many cases the research carried out under a particular contract could be applied to more than one category of electrical accident. When such situations occurred, the funds awarded under that contract were divided among the relevant research categories. The division was made according to the estimated percent of effort on each facet. The same funds were never assigned to more than one category, to avoid counting them more than once. Twenty-four specific research categories related to electrical safety research were identified. Three other broad categories were identified also: (1) electrical research not directly affecting electrical accidents, (2) electrical research for which no method could be found for determining the impact on electrical safety, and (3) electrical research having its safety impact on non-electrical accidents. Since data was available on electrical accidents only, the impact or benefits of this research could not be determined.

Chapter V describes the impact of Bureau sponsored research on electrical accidents. Once the twenty-four specific research areas had been clearly described; one or more types of accident were identified as being affected by the research in that category. A computer search routine then produced a listing of all accidents of that type contained in the data base. This list was reviewed carefully by the research team to evaluate the likelihood that each accident would have been impacted by research in that category. Accidents were identified as definitely affected by the research, possibly affected by the research, and not affected by the research. For those accidents which were affected, a record was made of the total number of lost-time days as well as the number of accidents and the number of fatal accidents. This impact data is supplied along with contract funding data for each of the research contract categories.

Chapter VI explains the development of two mine electrical models. These models were developed to provide a basis for calculating the relative expected cost to mine operators to implement certain changes suggested by Bureau research. The models are carefully defined, and are meant to be representative of an underground mine and a surface mine. These models were used to estimate all costs to the industry, and should provide an accurate indication of the relative costs of making various changes, if not the absolute costs. The models were developed from information provided by MSHA and other sources of production statistics, from visits to a variety of coal mines, and from interviews with operators and equipment manufacturers. The surface mine model represents an average-sized operation and is typical

of the mines observed. Underground mines vary more widely in size than do surface mines, from two-man dog holes to extensive operations employing hundreds of persons. The underground model chosen is larger than the average mine, but it is considered typical or representative.

Chapter VII covers the application of research results to the mine models. After a careful study of the research reported in Chapter V, estimates were made of the types of changes in mine electrical equipment that would probably result from this research. An estimate was then made of the cost to implement each change on each of the mine models. Since this exercise was speculative, cost estimates were purposely assigned a wide latitude. Costs were divided into three categories: (1) minimal, where the net cost to the mine would be between zero and three percent of its estimated profit; (2) moderate, where the net cost would be between two percent and 15% of the estimated profit; and (3) high, where the net cost would be more than 10% of the mine's estimated profit. The cost to the mine was determined by considering the cost of purchase, installation, and maintenance of equipment, cost for additional training of employees if necessary, increased paperwork, increased downtime, etc. Also estimated were any expected negative costs (monetary benefits) such as less downtime, longer equipment life, and cheaper replacement costs. No attempt was made to include any monetary savings that might result from fewer lost-time accidents or fatalities, although this effect certainly exists. The costs presented are the net estimated costs (positive minus negative) without any regard to the monetary impact of increased safety.

Chapter VIII contains the final conclusions of the report. Based on the expected cost to the industry and the expected safety benefit, the results of safety research were divided into four categories. Several possible safety-related changes were rated as "highly recommended", since they appear to have significant safety benefits compared to their costs of implementation. Other safety-related changes were rated as "recommended", since they appeared to be cost-effective, but not so dramatically effective as the previous category. The third category is "marginal". This category was reserved for situations in which insufficient information could be gathered to show clearly what costs would be incurred or what safety impact would result. The fourth category is titled "not recommended". These appear to have little safety benefit, and appear to be extremely expensive to implement. Suggestions are made concerning several safety areas in which more research was needed to determine cost-effectiveness more clearly. The most notable of these areas is sensitive ground-fault detection. Comments are also made with respect to required changes in MSHA regulations and the difficulty of assuring compliance with the regulations.

CHAPTER I

INTRODUCTION

Although the rate of electrical accidents fell sharply in 1980, experience over the last few years indicates that this drop may be merely a statistical fluctuation. Over the last six years, mine accidents have remained relatively constant despite concerted efforts to reduce hazards. Buried within these overall statistics, however, is evidence that some corrective action has had an effect. It has been reported, for instance, that since ground check monitors have been required on low-voltage trailing cables in coal mines, not a single fatality has been attributed to a defective ground conductor on a monitored circuit [1]. It would seem that the Mining Safety and Health Administration has eliminated an entire class of electrical hazards from the workplace.

If the elimination of lethal shock hazards due to energized equipment frames has indeed come to pass, it is not without its cost however. The Bureau of Mines spent hundreds of thousands of dollars on research aimed at developing a workable monitor. It supported efforts to document environmental conditions for monitors, to develop a way to list the advantages and disadvantages of competing monitors, and to sponsor the development of particularly promising designs. MSHA spent heavily in this area also, supporting a group of several individuals while they devised a test scheme for assessing monitor performance in simulated field conditions and under actual field tests. And MSHA continues to incur costs associated with their approval process for new monitor designs.

Added to the costs incurred by government agencies are the costs to the industry to comply with MSHA monitor regulations. Many early monitors were ineffective, necessitating their replacement by acceptable MSHA approved models. It was stated by one large operator, for instance, that he was forced to junk over \$1,000,000 worth of monitors because they failed to meet with MSHA approval. Added to these high initial costs of equipping an entire mine with monitors is the high operating cost of maintaining many complex and rather fragile electronic circuits. A single average-sized mine replaced six "defective" \$600 monitors in about 1½ months. A study showed that two of these devices had experienced power-supply failures, whereas the other four were simply misadjusted or miscalibrated [2].

The total cost of implementing the low-voltage ground check monitor requirement has been very high. Is the cost justified? Before ground wires were monitored, an estimated 2 to 3 persons per year lost their lives in the mines as the direct result of open ground wires, whereas not a single death has been attributed to an open ground or a monitored circuit since the monitor requirement has been fully in force. One can justify a rather large cost if several lives per year are saved.

Such a simple calculation of cost versus lives saved or accidents avoided does not fully represent the health and safety issue however. Since the financial resources of the federal agencies and the coal industry are limited, funds expended on monitoring represent funds that were not spent to reduce some other type of accident. It is possible then, that more lives could be

saved for the same total cost if the Bureau had chosen to emphasize other safety research. It is not sufficient merely to demonstrate that the costs incurred have reduced accidents (if indeed they have), but one must compare the effects with the maximum possible reduction that might occur for an optimal distribution of safety-related funds.

The research reported in this document represents an attempt to provide quantitative information of the costs and benefits of Bureau of Mines research on electrical safety. To accomplish this task, over 1300 coal mine electrical accidents were studied in detail. These accidents were categorized as to the type of electrical hazard which existed, the activity of the injured person, any negligent behavior that may have contributed to the accident, and several other accident parameters. All Bureau of Mines research grants and contracts related to electrical safety over the last seven years were studied also. Each of these was identified with the type or types of electrical accidents to which they related. An estimate was then made of the actual percentage of that type of accident which would be alleviated should the research result in safer equipment or work procedures, and the percentage of accidents which might be alleviated. These represent the benefits of research.

Two costs of the research were estimated. The first was the cost of the research itself. This was estimated from research contract data, and includes neither the in-house costs of the Bureau of Mines nor the cost of electrical safety research supported by private funds or other agencies. This information was not available through the sources used. The second cost is the estimated financial impact to a representative mine should they implement new procedures or install new equipment resulting from the safety research. All estimates of costs to the industry were based on two "model" mine power systems which were developed from a detailed study of the power systems of several producing mines located throughout the country.

REFERENCES

1. Massey, A. B. "Providing Safety for Miners Through Ground Wire Monitoring." Presented at Western Mining Industry Electrotechnology Conference. Sept. 14-16, 1981. Reno, NV.
2. Collins, E. W. Personal communication related to Bureau of Mines Contract J0199119. West Virginia University. Morgantown, WV Sept. 1981.

CHAPTER II

DATA COLLECTION

2.1 INTRODUCTION

Many different types of data were collected for the study of electrical safety research costs and benefits. These include coal mine electrical accident reports for several years, mine employment and production data, descriptions of Bureau of Mines research contract expenditures, abstracts of research contractor final reports, and power system descriptions and drawings from a number of producing mines. This chapter describes how that data was obtained.

2.2 ELECTRICAL ACCIDENT DATA

Reports of coal mine electrical accidents were chosen as a source for data on the types of accidents that were occurring and the circumstances surrounding these accidents.

2.2.1 Identification of Electrical Accidents

The choice of which accidents to consider in this study was guided by the classification system developed by the Mining Safety and Health Administration through their Health and Safety Analysis Center (HSAC). It was necessary to use their classification scheme to search for accidents in order to avoid the task of searching the entire accident file for accidents of interest, as will be explained in section 2.4.1. The HSAC classification categorizes accidents as "electrical" if the proximal cause of injury or potential injury was a shock, electrical current, electrical arc, smoke and debris from an electrical arc, or a reflex reaction to these factors. Excluded from this list are such accidents as mine fires and explosions initiated by electricity. Because these accidents are not classified as electrical the benefits of research pertaining to permissibility and intrinsic safety are underestimated. This is unfortunate, but unavoidable within the constraints of the research protocol.

2.2.2 Statistically Significant Sampling

Since the conditions surrounding an accident are dependent on a large number of independent factors, it was necessary to choose a rather large sample to insure that the statistical analysis of accident data would properly reflect occurrences throughout the industry. Initially, a goal was set to analyze all coal mine electrical accidents from 1974 through 1979. These bounds were established by the HSAC data base, since electrical accidents before 1974 could not be identified within their files and data past 1979 was incomplete at the time of the search. The decision to include all types and locations of coal mines was based on the fact that federal regulations applied to all coal mines and that the results of research were uniformly available to all. This initial sample was recovered from the HSAC files, and amounted to approximately 2900 separate accident reports. Since each report was to be studied in detail, a sample this size was beyond the scope of the research effort. The sample size was trimmed to a manageable number by choosing all electrical accidents which occurred within the three years of 1975, 1978 and 1979. The years 1975 and

1979 were chosen because other complementary information was also available for these particular years. The year 1978 was chosen because it represents more recent mining experience than the other years, thereby providing a closer relationship to present conditions. A total of approximately 1350 electrical accidents were obtained from these three years.

Accident records not used for the statistical analysis (years 1974, 1976 and 1977) were retained and used as part of the detailed investigation of accident-prone mines, as explained in section 3.2.

2.2.3 HSAC Accident Coding

All accident reports which are submitted to MSHA are coded by HSAC and placed in a computer file. Figure 2.1 shows the format in which the data is placed in the computer file. Table 2.1 provides a more detailed description of the information contained in the computer printout. The computer printout format shown in Figure 2.1 reproduces in a standard format all of the accident information submitted by mine operators on Form 7000-1, which is shown in Figure 2.2. The only exception occurs if the accident narrative exceeds the allotted computer file space for it, or if the operator submits a sketch or pictures in conjunction with the report.

Although essentially all known accident information is shown succinctly on the HSAC computer printout, there were several reasons why the decision was made to reprocess the accident data for the present study. The most important reason is that the format shown in Figure 2.1 has been in use only since 1978. Before 1978 the accident narrative was not stored in the HSAC computer files, making it necessary to review the actual accident report to extract the necessary information. Even with the recent format, however, HSAC has not attempted to code any information related to item 9 on the form. Paragraph 50.20-6 (a) (3) of Title 30 of the Code of Federal Regulations (CFR-30) states:

"Item 9. Describe fully the conditions contributing to the accident injury or illness and quantify the damage or impairment. Describe what happened and the reasons therefor, identify the factors which led or contributed to the accident, injury or illness and identify any damage or impairment to the mining operation. The narrative shall clearly specify the actual cause or causes of the accident injury or illness and shall include the following:

- (i) Whether the accident injury or illness involved any aspect of compliance with rules and regulations;
- (ii) Whether the accident injury or illness involved mine equipment or the mining system;
- (iii) Whether the accident injury or illness involved job skills and mine proficiency, training and attitude; and
- (iv) Whether the accident injury or illness involved protective items relating to clothing, or protective devices on equipment."

MINE ID - CTR	OCCUPATION TITLE-----	ACCIDENT CLASSIFICATION-
FOFC CNTY CMP	ACTIVITY OF INJURED----	SOURCE OF INJURY-----
--STATE-- SEX	LOCATION OF ACCIDENT-----	NATURE OF INJURY-----
--DATE-- AGE	CANVASS COMMODITY-----	PART OF BODY INJURED----
DOCUMENT# DEG	MINING MACHINE-----	MANUFACTURER --MODEL #---
CLOS DOC# AT	UG MNEMTH DAW DRSA CHGD	MN EXP JB EXP TO EXP PTB
a) Description of Identifiers		
0100329	ELECTRICIAN	EXPLOSIVES,BREAKING AGNIS
0732 073	HAND TOOLS (POWERED)	HAND TOOLS, POWERED, NEC
ALABAMA	OTHER UNDERGROUND	FRACTURE,CHIP
04/11	BITUMIN-COAL (BITUMINOUS)	HAND(NOT WRIST OR FINGER)
28150100	3 HANDTOOL-POWERED (DRILL)	MINE EQUIP CO Q-60
381740047	B CONV/STOPE 0050 0000 0000	10Y 1W 1Y45W 10Y 1W 13
b) Example Accident Listing.		
INJURED WAS USING A POWER RAIL PUNCH TO SHOOT RAIL BOND		
HOLES IN A 60 POUND TRACH TAIL WHEN THE PUNCH FAILED TO FIRE		
HE REMOVED THE FIRING UNIT AND WAS ATTEMPTING TO REMOVE		
THE		

Figure 2.1. HSAC Computer Accident Listing Format.

Table 2.1. Reference list of elements in HSAC computer file

1. Mine ID (-MINE ID-).
2. Contractor code (CTR).
3. Occupation title of injured (--OCCUPATION TITLE--).
4. Accident classification.
5. Narrative description of accident/injury as written on accident/injury form.
6. Field office code for Coal. Subdistrict office code for M/NM (FOFC).
7. County code (CNTY).
8. Narrative completion indicator (CMP).

Yes - Means complete narrative description on accident/injury form was entered.

No - Means that due to size limitation, the complete narrative was not entered.
9. Activity of injured.
10. Source of injury.
11. State.
12. Sex indicator (SEX).

M - Male
F - Female
13. Location of accident.
14. Nature of injury.
15. Accident/injury date. Printed in month/day format (--IDATE--)
16. Age of injured (AGE).
17. Canvass.
 - a. Coal
 1. Anthracite
 2. Bituminous

Table 2.1. Reference list of elements in HSAC computer file (continued)

- b. Metal/Nonmetal
 - 1. Sand and Gravel
 - 2. Stone
 - 3. Nonmetal
 - 4. Metal
- 18. Commodity. Per Standard Industrial Code (COMMODITY-).
- 19. Part of body injured.
- 20. Document number assigned to accident/injury form when it is received with HSAC (DOCUMENT #).
- 21. Degree codes (DEG).
 - a. Fatal (1)
 - b. Permanent total or partial disability (2)
 - c. Days away from work (3)
 - d. Days away from work and days of restricted activity (4)
 - e. Days of restricted activity only (5)
 - f. No lost time (6)
 - g. Occupational illness (7)
 - h. Fatal and nonfatal due to natural causes while on company business (8)
 - i. Fatal and nonfatal for nonemployees on mine property (9)
 - j. Injuries resulting in death, permanent impairment or disability reported in MSHA and determined to be nonchargeable to the mining industry (10)
- 22. Mining machine involved with accident (--MINING MACHINE--).
- 23. Mining machine manufacturer (MANUFACTURER).
- 24. Mining machine model number (--MODEL #--).
- 25. Closure document number assigned to closure document when it is received within HSAC. Only certain degrees might have a closure document (CLOS DOC #).
- 26. Accident type code. As identified in the HSAC Part 50 Operations coding manual (AT).
- 27. Underground mining method (-UG MNEMTH).
- 28. Days away from work. This is the actual days away from work (DAW).
- 29. Days of restricted work activity (DRSA).
- 30. Chargeable (statutory) days. This figure represents the standard industry charge associated with injuries that have degrees 1 and 2 (CHGD).

Table 2.1. Reference list of elements in HSAC computer file (continued)

31. Total experience at mine where injury occurred, printed in years, weeks format (MN EXP).
32. Total experience on current job, printed in years, weeks format (JB EXP).
33. Total mining experience, printed in years, weeks format (TO EXP).
34. Accident code from Section B, of the accident/injury form (7000-1) (PTB).

Mine Accident, Injury and Illness Report

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



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

Section A - Identification Data

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

Section B - Complete for Each Reportable Accident Immediately Reported to MSHA

1. Accident Code (circle applicable code - see instructions)				01 - Death	02 - Serious Injury	03 - Entrapment	
04 - Inundation	05 - Gas or Dust Ignition	06 - Mine Fire	07 - Explosives	08 - Roof Fall			
09 - Outburst	10 - Impounding Dam	11 - Hoisting	12 - Offsite Injury				
2. Name of Investigator		3. Date Investigation Started					
		Month	Day	Year	4. Steps Taken to Prevent Recurrence of Accident		

Section C - Complete for Each Reportable Accident, Injury or Illness

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

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

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

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

6. Date of Accident			7. Time of Accident		8. Time Shift Started	
Month	Day	Year	☐ am	☐ pm	☐ am	☐ pm

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

10. Equipment Involved	Type	Manufacturer	Model Number
------------------------	------	--------------	--------------

11. Name of Witness to Accident/Injury/Illness	12. Number of Reportable Injuries or Illnesses Resulting from This Occurrence
--	---

13. Name of Injured/Ill Employee	14. Sex	15. Date of Birth
	☐ Male ☐ Female	Month Day Year

16. Last Four Digits of Social Security Number	17. Regular Job Title	☐ 18. Check if this Injury/Illness resulted in death.	☐ 19. Check if Injury/Illness resulted in permanent disability (include amputation, loss of use, & permanent total disability).
--	-----------------------	--	--

20. What Directly Inflicted Injury or Illness?	21. Nature of Injury or Illness
--	---------------------------------

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

24. Employee's Work Activity When Injury or Illness Occurred	Experience	Years	Weeks
	25. Experience in This Job Title		
	26. Experience at This Mine		
	27. Total Mining Experience		

Section D - Return to Duty Information

☐ 28. Permanently Transferred or Terminated (if checked, complete items 29, 30 & 31)	29. Date Returned to Regular Job at Full Capacity (or item 28)	Answer 30 & 31 when case is closed	
	Month Day Year	30. Number of Days Away from Work (if none, enter 0)	31. Number of Days Restricted Work Activity (if none, enter 0)

Person Completing Form (name)	Title
-------------------------------	-------

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

MSHA Form 7000-1, Feb 80 (revised)

For Official Use Only

Degree _____

Accident Type _____

Accident Class _____

Scheduled Charge _____

Keyword _____

Contained within this item is information which can be used to identify either hazardous conditions or negligent behavior on the point of the injured, and as such is central to the analysis being pursued. Therefore, it was necessary to read the narrative for each accident and code this additional information.

A third reason for redoing the coding was the difference in format between the WVU computer and the HSAC computer. Since all electrical accidents were being reviewed anyway, the manual transcription step to move the files from HSAC to WVU appeared to be as efficient as attempting to transfer the files directly, computer to computer.

The HSAC accident coding served to identify electrical accidents for study and provide much of the data needed, but it fell short with respect to hazard and negligence information. Therefore it was necessary to recode the accident data for the WVU computer.

2.3 DEVELOPMENT OF ACCIDENT CODING FORM

Prior to this study, West Virginia University had conducted a study of electrical accidents in the metal/non-metal mining industry. The experience gained through that study provided valuable guidance in the design of the WVU accident coding form. The metal/non-metal effort demonstrated that the efficiency of data analysis was strongly dependent on the format of the accident coding form. All computer analysis essentially requires that the data be coded into categories rather than in narrative form. Identifying accidents through narrative descriptions was impossible due to variations in nomenclature (and spelling) from mine to mine. Several categories can be combined in a particular data analysis, but a single category of the original code cannot be further subdivided without referring to the original data sheet, a process which often requires a time-consuming manual search and review. It was imperative that the code format provide the detail and differentiation necessary to fully analyze the data.

In addition to providing detail, it was desirable that the categories chosen be meaningful to those persons who were expected to study it. Utility is enhanced also by good differentiation, whereby accidents are spread rather evenly among alternate categories, rather than being bunched into one or two.

A single-page format was chosen to facilitate handling of the data. The document number was recorded so that the original accident form could be retrieved if such action became necessary. The mine ID number was recorded to be used in the search for accident-prone mines, and also to be used in conjunction with mine employment and production statistics to develop various accident rates (occurrences per thousand man-hours or thousand tons produced). All personal data such as names and social security numbers were dropped in order to maintain worker confidentiality.

The form used to code the data is shown in Figure 2.3. The accompanying notes, definitions, and explanations are listed in Table 2.2. These explanatory notes are rather extensive, and include several pages of examples which are meant to improve consistency during the coding process.

[illegible]

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Table 2.2. Key to code used on WVU accident form

HAZARDS - Mining has some level of risk associated with it that is implicitly assumed to "normal". Particular jobs, such as electrician also have inherent risks which are assumed to be normal. We define a HAZARD as an abnormal risk not usually assumed to be inherent in the job.

H1 - Energized ground or frame - A potential appearing on any normally noncurrent carrying part of electrical equipment or structure.

H2 - Energized power conductor thought to be safe by reason of being disconnected.

H3 - Improperly insulated or guarded power conductor so that personal contact occurs under conditions where it was assumed to be prevented.

H4 - Abnormal arcs or sparks generated by a short circuit, fault, defective switch, or other defect in the power system. Also include short circuits which cause excessive heating without arcs or sparks. Not including flashes which are a result of operator error.

H5 - Defective tool or protective gear, not including defective circuit breakers or other power system protective devices.

H6 - Putting power to an electric circuit which is loaded or shorted when it was assumed to be open-circuited.

H7 - None - no hazard other than normally accepted in the situation.

H8 - Unknown or other electrical hazard not classifiable above.

H9 - Lightning

NEGLIGENCE - Persons performing jobs have a certain error level which is considered "normal" for the situation. The "normal" acceptable error level depends on the level of training of the individual. We define a NEGLIGENCE as an error which is abnormal for a person with a particular title or level of training. A NEGLIGENCE for an electrician may not be an abnormal error for a laborer.*

N1 - Not attempting to remove power to circuit under repair.

N2 - Not tagging, locking out, grounding, or otherwise ensuring that circuit cannot become energized or equipment started while under inspection or repair.

N3 - Failure to test for voltage on conductor.

N4 - Incorrect tool or equipment or improper use of acceptable equipment.

N5 - Failure to maintain clearance with boom, truck bed, pipe (non-electrical tool) while working in the vicinity of energized conductors with normal clearances.

N6 - Failure to maintain clearance with body or hand tool (not working on involved circuit).

N7 - Not wearing or using protective gear.

N8 - Abusing equipment.

N9 - Improper operation or maintenance of electrical devices or equipment.

NA - No errors other than those usually considered to be normal.

NB - Unknown or other negligence or error not classifiable above.

*To be uncertified to perform the work attempted is a special category of negligence.

Table 2.2. Key to code used on WVU accident form (continued)

INJURY TYPE

- I1 - Shock - sensory impression caused by passage of current through the body.
- I2 - Electrical Burn - burned tissue resulting from current passage.
- I3 - Flash Burn - radiation burn caused by arcing or sparking of electrical devices and apparatus.
- I4 - Heat Burn - burned tissue as a result of contact with something which has been heated by current passage.
- I5 - Explosion - injury resulting from flying material or liquid or being forcibly propelled into some machine or structure as a result of an electrical device physically exploding.
- I6 - Smoke Inhalation - inhalation of smoke that originates from a fault or short-circuit or other electrical origin.
- I7 - Reaction to Electrical - injury resulting from a reaction to an electrical explosion, shock, arc, etc..
- I8 - Other - other injury not classifiable above.

Note: The injury type should be classified according to what actually injured the victim.

DEGREE OF INJURY

- D1 - Fatal - death of victim.
- D2 - Permanent Partial or Total Disability - victim injured such that he loses partial or total functional use of his body.
- D3 - Non-Disabling - victim injured such that he has lost-time work but still maintains full use of his faculties.

PART OF BODY INJURED

The entries for this category will be listed in blocks 68, 69, & 70 of card #1 which is at the end of the Job Title category.

- | | |
|---------|--------------------------------|
| A Eyes | F Hand |
| B Face | G Leg |
| C Neck | H Feet |
| D Torso | I Unknown |
| E Arms | J None |
| | K Nervous System (Body System) |

Table 2.2. Key to code used on WVU accident form (continued)

STANDARD LIST OF JOB TITLES

Section Workers

- A 1 Brattice Man/Ventilating/Stopping Builder
- A 2 Continuous Miner Operator/Helper
- A 3 Cutting Machine Operator/Helper
- A 4 Loading Machine Operator/Helper
- A 5 Rock Duster
- A 6 Roof bolter/Helper/Pinner
- A 7 Scoop Car Operator/Unatrac Operator
- A 8 Shotfirer/Shooter/Blaster
- A 9 Shuttle Car Operator/Buggy Operator
- A A Timberman/Propman/Jacksetter
- A B Utility Man
- A C Wireman-Communication

Track Workers

- B 1 Brakeman/Rope Rider/Snapper
- B 2 Motorman
- B 3 Supply Man
- B 4 Trackman

General Underground

- C 1 Belt Man/Conveyor Man
- C 2 Electrician
- C 3 Electrician Helper
- C 4 Laborer/General Inside
- C 5 Mechanic/Mechanic Helper/Repairman
- C 6 Welder
- C 7 Oiler/Greaser/Pumper

Non-Union Workers

- D 1 Inspector
- D 2 Section Foreman
- D 3 Supervisory - (Fire Boss/Mine Foreman/Superintendent/etc.)
- D 4 Maintenance Foreman
- D 5 Surveyor

Surface Workers

- E 1 General Outside Laborer
- E 2 Mobile Equipment Operator
- E 3 Preparation Plant Operator

Table 2.2. Key to code used on WVU accident form (continued)

All other surface jobs can be found in the preceding list and shall be entered as: [E] where the two blanks correspond to the letter and number of the job.

Example: (Surface Mechanic); Entered as E C 5

STANDARD LIST OF INJURED ACTIVITIES

Cables

- F 1 Checking/Inspecting Cable
- F 2 Hanging Cable
- F 3 Making Connection at power center
- F 4 Pulling/Moving Cable
- F 5 Splicing Cable
- F 6 Tapping/Chopping/or otherwise mutilating cable
- F 7 Testing Cable with test equipment

Trolley

- G 1 Loading/Unloading Supplies
- G 2 Maintenance on trolley - (Greasing; extending; replacing)
- G 3 Operating Rail Equipment
- G 4 Placing/Removing Nip on Trolley
- G 5 Repair/Inspection of Rail Equipment
- G 6 Placing Pole on Trolley
- G 7 Working in Vicinity of Trolley - (not on trolley)

Power Center

- H 1 Battery Maintenance/Charging
 - H 2 Standing in Vicinity
 - I Energizing/Deenergizing - Operating
 - J Inspecting/Troubleshooting
 - K Maintenance/Repair
- These last 3 particular activities will be entered with the following appropriate device.

1. Circuit breakers
2. Switches
3. Monitoring/Indicating Circuits
4. Transformers
5. Rectifiers
6. Fuses

Example: Energizing Circuit Breaker: Entered as I 1

Non-Rail Equipment

- L Inspecting/Troubleshooting
- M Maintenance/Repair

Table 2.2. Key to code used on WVU accident form (continued)

N Operating Equipment

These 3 activities will be entered with the following appropriate device.

1. Underground Production Equipment (Miner/roof bolter/shuttle car/loader/scoop car/rock duster/etc.)
2. Surface Production Equipment (draglines/shovels/dozers/loaders/cranes/trucks/etc.)
3. Motor Starters/Motors
4. Power Hand Tools
5. Pumps
6. Beltline

Miscellaneous

- O Escaping a Hazard
P Repairing/Replacing Lighting Circuitry
Q Operating Prep Plant
R Uncontrollable Contact - (person is doing nothing of consequence nor necessarily in vicinity of electric circuit)
S Welding
T Other or unknown

EXAMPLE CATEGORIZATIONS

Trolley

Putting trolley pole on wire, burned eyes	H7	N9
Put pole on trolley wire, had hands on leads and they grounded out	H7	N9
Putting pole on trolley - arced	H7	N9
Placed trolley on wire, wire going from pole to central bar grounded out causing arc	H4	NA
Taking nip off	H7	N9
Nipping motor to outside and burned eyes	H6	N9
Putting nip on trolley wire - arc	H6	N9
Nipping a motor	H6	N9
Putting nip for loader on trolley cable grounded - flashed	H8	NB
Placing a fuse nip on feedline and grounded nip	H7	N1
Taking shuttle car nip out of receptacle and it arcs	H7	N9
Wire coming out of fuse nip on jeep pole arced when pole put back on wire	H4	NA
Jacking on car when jack bar got into trolley	H7	N5
Jacking belt structure - caught control line against structure	H7	N9
Trolley pole came off wire on manbus and grounded	H7	NA
Riding in mantrip when pole came in contact with trolley wire	H7	NA

Table 2.2. Key to code used on WVU accident form (continued)

Operating motor when trolley wire fell on car	H3	NA
Riding in portal bus when bus contacted pump wire	H3	NA
Using jumper cable to get motor past end of wire, jumper cable came loose from pole and flashed	H3	NA
Jumper cable grounded against motor	H3	NA

"WRONG"

Cut into wrong cable	H2	NB
Removed wrong cathead from power box	H2	NB
Splicing cable with power off wrong cable	H2	NB
Splicing cable which was energized because it was in the wrong receptacle	H2	NB

Uncontrollable Contract (R)

Injured was leaning on PEMCO and burned hand	H8	NB
Injured sat down on plug and came into contact with feedthrough on power unit	H3	NB
Sitting on motor during lunch, lead came loose beneath shield of locomotive	H1	NB
Kneeling on shield shoveling rock-felt tingling in knee	H1	NB

H2 N9

Cut into energized cable, thought breaker was knocked but didn't visably check	H2	N9
Splicing cable - thought power was off but it wasn't	H2	N9

Batteries

Jumping battery on truck - exploded	H7	N9
Battery lids were off and when he jumped jeep-arc'd	H7	N9
Jumping loader when caps blew off throwing acid	H7	N9
Battery he was working on got grounded	H8	NB
Checking water in battery and it blew up	H8	NB
Battery blew up	H8	NB
Removing ground cable from battery, cap blew off	H8	NB
Putting battery on charge, wires became grounded	H8	NB
Charging battery crossed terminals - blew up	H7	N9
Inhaled fumes when disconnecting overcharged battery	H7	NA

Fuses

Pulling fuse out of fuse holder and it blew up	H7	N1
Putting fuse in - fuse blew up	H7	N1
Injured was using jumper to check fuses with power energized	H7	N1,4

Table 2.2. Key to code used on WVU accident form (continued)

Pinching Cable

Shuttle dehorned miner cable causing it to catch on fire	H7	N9
Pulled into cable and caught fire	H7	N9
Moving cables when one got twisted around hooked cable causing cable to ground	H7	N9
Cable stretched too tight and broke	H7	N9
Backed over loader cable causing loader to become energized	H1	N9
Pinched cable with shuttle car stepped out in puddle - shocked	H1	NA
Getting out of shuttle car cable shorted out in water	H1	NA

Cables

Shock or electric burn due to bad insulation	H3	N7
Handling it near a splice and splice "blows up"	H4	N9
Splice blows up	H4	NA
(NA or N7 depending on part of body injured)	H4	N7

Working on or Troubleshooting Circuits

("Working" is not troubleshooting)

Troubleshooting to see why machine not getting power, touched screwdriver	H7	N4
Checking load with screwdriver while power on	H7	N4
Changing breaker - allen wrench touched dist. box	H7	N1
Working on line circuit tool touched wire	H7	N1
Working on fuse box while turning around struck screwdriver in box	H7	N6
Watch on arm contacted charger	H7	N6,7
Working on charger when watchband shorted to voltmeter	H7	N6,7
Checking cathead for damage - power sparked to wristwatch	H7	N1,7
Repairing horn when wristwatch band shorted across 2 wires	H7	N1,7

2.4 OBTAINING ACCIDENT DATA

All accident data was obtained from the files of the Health and Safety Analysis Center (HSAC) of MSHA, located in Denver, Colorado. Accident records from 1974 on are kept in several ways. Each accident has been coded and stored in a large computer file which can be searched with relative ease. The file can be searched using up to approximately six descriptors, and hard-copy generated within a few hours or a few days at most. It was this file that was used to identify that fraction of all coal mine accidents which are electrical.

Original Mine Accident, Injury and Illness Reports (7000-1) are also stored at HSAC for two years (after that they are stored in Federal Archives). These documents were completed by the mines reporting accidents, and contain the raw information from which all of the HSAC coding was done for the computer file. These are not easily accessible.

Finally, all the reports are stored at HSAC on microfilm, which contains a photographic image of each 7000-1 form in the HSAC files or the Archives. A poor-quality reproduction of the original form could be obtained from the microfilm image, and these copies provided the source of much of the data obtained.

Accident records were retrieved from the HSAC accident files in two ways. The retrieval process began by obtaining a computer listing of all accidents classified as "electrical" for the years 1974 through 1979. The computer files for 1978 and 1979 contain all the information which was available on the original 7000-1 form, so that the listing for these years could be used directly to provide the required information for the WVU coding form. The computer files for the years 1974 through 1977 do not contain all the information, however. For these years, the computer listing served primarily to identify the electrical accidents. This listing was obtained such that the electrical accidents were listed sequentially by document number. Since the microfilm files are also arranged sequentially by document number, it was fairly easy to search the microfilm files for the actual documents describing these accidents. A hard copy was made of each electrical accident report. Names and social security numbers were then obliterated to preserve worker confidentiality, and these copies were accumulated for later coding on the WVU coding form.

The data carried back to WVU consisted, therefore, of copies of 7000-1 forms for the years 1974 through 1977, and complete HSAC computer listing of accidents from the years 1978 and 1979.

2.4.1 Coding of Accident Data on WVU Form

Accident data was coded on the WVU form by several undergraduate electrical engineering students. These students were given approximately two hours of orientation to coal mining, so that they would be better able to interpret the free-form narrative that appeared with each accident. They were given rather explicit instructions on how to categorize the accidents also. Once they had set to work, their completed forms were reviewed by two graduate student research assistants. They evaluated the coders' work for accuracy and

consistency of categorization, and conducted several additional training sessions aimed at improving these aspects of the coding. These graduate students had a much more intimate knowledge of mine power systems, and reviewed that part of the coding which was derived from the free-form narrative for each accident.

Coding accident data turned out to be an extremely difficult task, mainly because of the extremely poor quality of accident reporting evident in the 7000-1 forms. Many forms are filled out in nearly illegible cursive writing, often with a blue pen. Once the form had been microfilmed and xeroxed, it was often extremely difficult to decipher. Added to this problem was an apparent high level of misinformation, or no information at all. As discussed in section 2.2.3, the reporter is required to provide a clear statement of the accident in narrative form, including whether there was any violation of rules and regulations and whether protective gear was in use. Despite these clear requirements, the narrative was almost always inadequate. Accident descriptions like "Employee moaned and fell dead", or "Got into electricity" provide very little information. Other times, there appeared to be a deliberate attempt to cover up some violation. Statements like "Inspecting breaker when it exploded" or "Bent down to see if breaker switch was turned on and the welder fuse block shorted out" attribute a mystical spirit to many accidents which is hard to believe. One must conclude that the accident reporters were either very naive or very clever in formulating their reports.

Because accident reporting is so inadequate, accident coding became a subjective exercise. As many as 20% of the reports had to be discussed at length by the research team. For each of these reports, several scenarios were postulated describing what actually happened. After discussing each possibility, a category assignment was made based on the consensus judgment of the research team. To reach this consensus the team relied heavily on personal knowledge of mining equipment and activities and estimated probabilities of the various incidents in the mine environment. The advice of MSHA inspectors was sought on occasion, also.

There can be little doubt that the accuracy of any accident study is severely limited by the poor quality of the data reported to MSHA, in which as many as 90% of the accident descriptions are incomplete, and at least 20% are totally lacking in usable information.

2.4.2 Coded Information Punching and Storage

The coded information was then punched on cards. Each data set is stored on three cards. Figure 2.3 shows the information recorded on these three cards, and where the information is punched. For identification purposes, the first nine columns of each card contain the document number. After sorting out bad data and coding errors, the data was stored on active files in the digital computer. A separate punched-cards deck was obtained and used as a back-up source. Separate files were established for each of the years 1975, 1978, and 1979. A file was also formed of combined three years.

2.5 MINE PRODUCTION STATISTICS

Any conclusion based on the number of electric accidents only without considering the coal mine size is not accurate. Therefore, HSAC Coal Mine Reference Tapes for 1975 and 1979 were used to obtain information about coal mine sizes. These tapes contain the Address/Employment file of coal operations reporting to HSAC during 1975 and 1979 years. The information is stored on magnetic tapes with the specifications: 9 track, 1600 BPI, EBCDIC encoded, and Burroughs labelled. Table 2.3 lists the locations on the tape for the different available information. The KEYSTONE COAL INDUSTRY MANUAL is another available source for the total coal production, total number of employers as well as total number of man-hours. Table 2.4 lists these and other information for 1975, 1976, 1977, 1978, and 1979. Both sources for the mine size have been used to draw more accurate conclusions.

TABLE 2.3 - Location of information on HSAC mine reference tapes.

CHARACTER POSITIONS	DATA ELEMENT	PICTURE	DESCRIPTION
1-7	Mine ID	Pic 9(7)	MSHA Mine ID assigned to a mining operation.
8-10	Contractor	Pic X(3)	Contractor performing work at the site of the primary Mine ID operation. Blank if owner. Coal - 1 alpha - 2 numeric characters. Metal/Nonmetal numeric only.
11-12	Controlling Company	Pic 99	Code for selected major coal producing company controlling this mining operation.
13-16	Inspection Office	Pic 9(4)	Code for MSHA Field office exercising jurisdiction over this mining operation. First two characters - District. First three characters - Subdistrict. All four characters designate Field office.
17-18	State Code	Pic 99	FIPS code for state in which mine is located.
19-21	County Code	Pic 999	FIPS code for county within a state in which mine is located.
22-26	SIC	Pic 9(5)	Standard Industrial Code for primary commodity mined.
27	Canvass or Class	Pic 9	Designate a general product class based on SIC code.
28-29	Mine Type	Pic 99	Metal/Nonmetal mine type code. Based on subunit operations code and canvass code.
30	Status Code	Pic X	Code for status of operations of mine (active to permanently closed.) Coal - Alpha A through H. Metal/Nonmetal - Numeric - 1, 2, and 3.
31-36	Status Date	Pic X(6)	Date of latest add or change of status. YYMMDD.
37-40	Seam Height	Pic 9(4)	Coal seam height in inches. Coal only.

TABLE 2.3 - Location of information on HSAC mine reference tapes (continued)

<u>CHARACTER POSITIONS</u>	<u>DATA ELEMENT</u>	<u>PICTURE</u>	<u>DESCRIPTION</u>
41-42	Education & Training District	Pic 99	MSHA Education and Training District office having jurisdiction over this mine.
43	Surface/Underground Indicator	Pic X	Indicator for Education and Training showing surface or underground. U = underground; S = surface.
44-46	Travel Area	Pic X(3)	Metal/Nonmetal inspection travel area. 1 alpha and 2 numeric characters.
47	Mailing Control	Pic 9	Provides for suppression of mailouts. = all mailouts; = suppress selected mailouts.
48-77	Company Name	Pic X(30)	Company owning or having primary responsibility for the operation of this mine.
78-107	Mine or Plant Name	Pic X(30)	Name applied to this mine by the company.
108-137	Street or PO Box Number	Pic X(30)	Mailing address for this mining operation.
138-150	City	Pic X(13)	City to which mail is sent for this mine.
151-152	State Abbreviation	Pic XX	State abbreviation for mailing purposes.
153-157	Zip Code	Pic 9(5)	Zip Code for mailing purposes.
158-181	County Name	Pic X(24)	Name of county in which mine is located.

The next two items represent information supplied quarterly by the mining company on Form 7000-2. They not accurately reflect actual accidents/illnesses reported. Occurs 4 times - once for each reporting quarter.

TABLE 2.3 - Location of information on HSAC mine reference tapes (continued)

<u>CHARACTER POSITIONS</u>	<u>DATA ELEMENT</u>	<u>PICTURE</u>	<u>DESCRIPTION</u>
182	Injury Flag	Pic 9	Company statement that this company had reportable injuries or illnesses during this report quarter. 1 if yes; 2 if no.
183-185	Injury Count	Pic 9(3)	Number of reportable accidents and illnesses given on employment form.
198-199	Filler	Pic XX	
200-201	Update Addition Year	Pic 99	Year address information was added to file.
202-204	Update Addition Year	Pic 999	Update cycle number address information was added to file.
205-206	Update Change Year	Pic 99	Year of latest change to address information.
207-209	Update Change Number	Pic 999	Update cycle number of latest change to addresses information.
210	Subunit Operations (number)	Pic 9	Number of subunit operations (formerly departments for each ID. Employment trailer count.

TABLE 2.3 - Location of information on HSAC mine reference tapes (continued)

Following the address portion of the record, there may be 0, 1, 2, 3, or 4 employment "trailers" each containing 4 quarters of employment data for that operations subunit. See character position 210.

Employment trailer length - 130.

<u>CHARACTER POSITIONS</u>	<u>DATA ELEMENT</u>	<u>PICTURE</u>	<u>DESCRIPTION</u>
211-212	Operations Subunit	Pic 99	Information obtained from Form 7000-2. Subunit operations code. Next four elements are repeated four times representing four calendar quarters.
213-221	Document Number	Pic 9(9)	Number assigned to the document upon receipt in mailroom of HSAC and stamped on form.
222-226	Number of Men	Pic 9(5)	Average number of persons working during quarter in this operations subunit. Item 1 (2).
227-234	Number of Man-Hours	Pic 9(8)	Total employee-hours worked during the quarter in this operations subunit. Item 1 (3).
235-244	Tons of Production	Pic 9(10)	Production of clean coal (short tons) during quarter. Item 1 (4).

The Address-Employment master is an indexed sequential file. The key is the Mine-ID and Contractor Code (Positions 1-10) of each record.

TABLE 2.4. Coal Industry Statistics 1/

Item	1975	1976	1977	1978	1979 (Preliminary)
Method of Mining: 2/					
Underground -----total-----thousand short tons---	292,826	294,880	265,950	242,177	301,435
Percentage mined by underground methods ----	45.2	43.3	38.4	36.4	39.1
Surface -----total-----thousand short tons---	355,612	383,805	425,394	422,950	468,565
Percentage mined by surface methods ----	54.8	56.6	61.6	63.6	60.9
Number of mines 2/-----	6,168	6,161	6,077	6,229	6,000
Average number of men working daily: 2/					
Underground mines -----	134,710	140,260	151,495	146,050 3/	169,585
Surface mine -----	55,170	62,020	69,933	77,250 3/	82,147
Total -----	189,880	202,280	221,428	223,300 3/	251,732
Average number of days worked: 2/					
Underground mines -----	228	231	202	201 3/	225
Surface mines -----	241	235	229	219 3/	230
Total -----	232	232	210	207 3/	227
Production per man per day: 2/					
Underground mines -----short tons-----	9.54	9.10	8.69	8.25	7.90
Surface mines -----do-----	26.69	26.40	26.59	25.00 3/	24.80
Total -----	14.74	14.46	14.84	14.26 3/	13.50

1/ Data taken from 1980 Keystone Coal Industry Manual, McGraw-Hill Publishers.

2/ Energy Information Administration, "Bituminous Coal and Lignite, Production and Mine Operation - Annual Report" (Form EIA-7), and Bureau of Mines Form 6-1385A.

3/ Subject to revision.

CHAPTER III

ANALYSIS OF DATA

3.1 INTRODUCTION

The primary objective of this chapter is to show, in detail, how the electrical accident data was statistically analyzed. This analysis was used to identify accident-prone mines as well as common electrical safety problems.

3.1.1 Computerized Data Base

After sorting out bad data and coding errors, the data was stored on active files in the digital computer. One set of data was then adapted to suit the Statistical Analysis System (SAS) input format. A sample of 527, 327, and 412 electrical accidents in coal mines for 1975, 1978, and 1979 respectively, was used. These data include almost all electrical accidents which occurred in those years.

3.1.2 Statistical Analysis System (SAS)

SAS is a comprehensive statistical analysis system. The number of the statistical operations which the system can perform is very large. Among these are: regression analysis, correlations, frequencies, tabulation, and many other options. The system has been developed by SAS Institute Inc., Post Office Box 10066, Raleigh, NC 27605. Many university professors have contributed and still contribute to the system.

3.2 ACCIDENT-PRONE MINES

An identification of accident-prone mines based only on the number of electrical accidents and/or number of days lost is not conclusive. For a more comprehensive identification the mine size (number of men working and production) has to be considered also.

3.2.1 Initial Manual Search

A manual search of the data obtained from HSAC for the years 1975 - 1978 indicated 11 accident-prone mines. These were determined by taking the 10 worst mines for each year, based solely on number of accidents, and selecting those mines that appeared two or more years out of the four. Six of these eleven mines were contacted to secure permission to visit. Although no indication was given to them that they had been identified as "accident-prone", five of the six mines refused to grant permission to visit, despite repeated attempts to secure this permission at various levels of mine management. This response is in sharp contrast to that received generally, in which similar calls to more than twenty other mines of various types resulted in only one refusal. It is not known whether or not there is a causal relationship between a poor safety record and an uncooperative mine management, but this seems to be the case.

3.2.2 Detailed Computer and Manual Analysis

The previous manual search was carried out to determine quickly some candidates for mine visitations. To be able to draw valid conclusions about accident-prone mines, a comprehensive analysis had to be carried out. This analysis incorporated both electrical accident data and the mine size information. Due to the sample size, computerized analysis appeared to be the only possible way to reach valid conclusions. A large number of tables was generated as the result of this analysis. Table 3.1 is a guide to these tables, showing the analytical results contained in each.

3.2.2.1 Accident Data

Electrical accident reports and information from 1975, 1978 and 1979 were used for most of the analyses. This information was stored on a computer file for ease of access and processing. The first computer program was written to read the accident data and print it in a more organized form. This was used to check for incongruities (i.e. keypunching errors) between the computer data and the actual accident reports. A sample accident listing is given in Table 3.2.

3.2.2.2 Mine Size Data

The 1979 mine file reference tape was used to obtain the coal mine size information. The file contains 11,069 mine records. Table 3.3 shows the number of active sub-units (producing coal) in the 2nd column. Also columns 3-6 give the number of men working in the sub-units in the four quarters of the year. The average is given in the last column. Table 3.4 and 3.5 show both man-hours and production. The annual number of men, man-hours and production for an average sub-unit is given in Table 3.6. Since Table 3.3 shows the number of active sub-units, it is important to see how that compared to the total number of sub-units. Table 3.7 shows the total number of sub-units and the active percentage. Table 3.8 gives the frequency of the mine status.

The 1975 mine reference tape was used to obtain similar information for 1975. Table 3.9 shows the number of employees in the coal industry in 1975. Column 1 gives the code assigned by HSAC as well as the description in column 2. Columns 3-6 give the number of men working the sub-units in the four quarters of the year. The average is given in the last column. Tables 3.10 and 3.11 show both man-hours and production. Table 3.12 shows the frequency of the mine status. By comparing this with Table 3.8, it is apparent that the active mine percentage went down (71% to 56%) from 1975 to 1979. Table 3.13 gives the number of active as well as the total sub-units.

The 1980 KEYSTONE COAL INDUSTRY MANUAL is another available source for information. Table 3.14 and 3.15 show comparisons between the data from the KEYSTONE MANUAL with that of the tape files for 1975 and 1979. In spite of some differences, the production/man/day results are in agreement. It is surprising that the production/man/day went down in 1979 compared to 1975 in spite of advances in technology in almost five years.

3.2.2.3 Accident-Prone Mines in 1975 and 1979

This section demonstrates that drawing a conclusion about the coal mine electrical accidents based on number of accidents and/or number of days lost is not very meaningful. Table 3.16 shows a subset of mine ID numbers which have been identified as being the most hazardous based on the number of electrical accidents which occurred in 1979. Also, column 3 gives the number of days lost. The 1979 mine file reference tape has been used to generate the information listed in columns 4-6. The number of men working, number of man-hours, and the production of each mine have been used to obtain more insight into the accident-prone mines. Table 3.17 shows the number of days lost per hundred workers, per million man-hours and per million tons production. The conclusive results are given in Table 3.18. These are very valuable in evaluating the degree of hazard in the different mines. In general, a mine with a large number of men working has a larger probability for accidents compared with one with a small number of men working. Tables 3.19, 3.20, and 3.21 are the similar tables for 1975 electrical accidents. A careful examination of Table 3.20 indicates that drawing conclusions based solely upon number of accidents and/or number of days lost is not complete. Table 3.22 gives a comparison between the 1975 and 1979 accident rates. This table shows a big improvement in 1979 compared to 1975.

3.2.2.4 Accident-Prone Mines for the Five-Year Period, 1975 through 1979

The previous section was devoted to the accident-prone mines for 1975 and 1979. The profile of electrical accidents through the years is very interesting also. Any mine which appears in the most hazardous mines list in more than one year should be given special attention. Table 3.23 shows the subset of the most hazardous mines in 1978 in terms of electrical accidents. Since the electrical accident data for 1976 and 1977 was not computerized, the search for the twenty mines with the greatest number of days lost due to electrical accidents had to be conducted manually. Due to the large number of accidents, it was impractical to find the total number of days lost for each mine and then rank them. Instead, for 1976 a list of all mines having at least one accident of ten or more days lost was compiled. From this list, the top 52 mines were selected and all accidents for each mine were researched. This information was used to list the 20 most hazardous mines for 1976. These are shown in Table 3.24. The accidents occurring in 1977 had a generally higher number of lost days associated with them. For this reason every mine with at least one accident of 100 or more days lost was researched for the total number of lost days from every accident associated with that mine. From the resulting list of 54 mines, the 20 most hazardous mines were selected and given in Table 3.25. Table 3.26 shows a display for the mines appearing among the most hazardous in two or more years of the five-year period. Each cell of the table contains four entries. These are: number of days lost, rank by number of days lost for that year, number of electrical accidents, and the rank by number of electrical accidents for that year. Table 3.27 and Figure 3.1 show the cumulative yearly statistics.

3.3 ACCIDENT CATEGORY STATISTICS

The purpose of this section is to present a comprehensive statistical

analysis of the electrical accidents which have occurred in the coal mines. As pointed out earlier, a considerable amount of time and effort was spent in assigning each accident to the appropriate categories. SAS was very helpful in the analysis. The analysis was performed for 1975, 1978, and 1979 electrical accident data. The data for the combined three years was analyzed also. This was done mainly to examine the accident profile along the years.

3.3.1 1975 Accident Analysis

Table 3.28 and Table 3.29 show the types and degrees of injuries which occurred in 1975. Flash burn, electrical burn, and shock are the dominant injury types. Fatalities account for 2% of the total accidents, whereas disabling accidents represent an extremely small percentage. Tables 3.30 and 3.31 show the number of accidents with both hazard and the negligence types for 1975. H7, H4, and H3 as well as NA, N1, and N9 dominate the 1975 electrical accidents. The job title classifications for the 1975 electric accidents is given in Table 3.32. Mechanics and electricians scored the highest percentage. This is expected since their work is associated with electricity. Table 3.33 through 3.35 give the injured activity and the accident location at both underground and surface mines.

3.3.2 1978 Accident Analysis

The 1978 electrical accident file was used to generate statistics similar to those produced for 1975. Table 3.36 shows that flash burn, electrical burn, and shock are again the dominant injury types. Table 3.37 does not show any disabling injuries for 1978. The fatal electrical accidents are around 3% of the total electrical accidents. H7 and H4 are among the dominant hazards, which is consistent with the 1975 results. Table 3.38 shows the classification of the hazard type; Table 3.39 lists the negligences. Again NA and N1 are among the dominant negligences. Table 3.40 shows the classification by the job title. Mechanics and electricians score the highest percentage (30%). As shown in Table 3.41, pulling or moving cables are the most common injured activities for both 1975 and 1978 electric accidents. The research team feels that cables in general showed the highest source of electrical hazards and deserves special attention from researchers in the field. Splicing cable contributes 7% of the electrical accidents in 1975 and 2% in 1978. This shows that people simply are not de-energizing the circuit before attempting repair. The same is true of repair/inspection of rail equipment, in which the workers are not removing the trolley pole before working. These two particular activities contribute to the N1 negligence. Tables 3.42 and 3.43 show the electrical accident location classifications.

3.3.3 1979 Accident Analysis

The 1979 electrical accident file was used to conduct statistical analyses for the accidents which occurred in that year. Tables 3.44 and 3.45 show injury type and degree of injury for 1979. Splicing and pulling cables scored the highest percentage in the 1979 accidents. Table 3.46 gives the injured activity classifications. Table 3.47 shows an aggregate for the accidents involving equipment. This table supports what has been

mentioned before about cable hazards. Tables 3.48 and 3.49 show both the hazard and negligence classifications. The pattern of both hazard and negligence agrees with that of 1975 and 1978. Table 3.50 gives the correlation between the hazard and the negligence types. The pairs (H4, NA), (H7, N1), and (H8, NB) are strongly correlated.

3.3.4 Combined 1975, 1978, 1979 Accident Analysis and Common Problems

The electrical accidents files for the years 1975, 1978, and 1979 were combined together and used to generate a statistical analysis similar to what was given in the previous sections for each individual year. Also, interactions between different types of hazard and negligence were investigated. Additionally, the relations between these types and the injury activities were explored.

Table 3.51 shows the electrical accident classification by injury type. Flash burn counts for 50%, electrical burn for 22%, and electrical shock for 14% of the electrical accidents. Table 3.52 shows that 97% of electrical accidents are non-disabling, while 2% are fatal accidents. Abnormal arcs and sparks is the most dominant hazard (23%), and improper insulation makes up 9% of the electrical accidents. The accident classification by hazard types is given in Table 3.53. Table 3.54 indicates that N1 and N9 are the most dominant negligences. Table 3.55 shows interactions between hazard and negligence types. Weak correlations have been found except for H3-N7, H4-N7, and H6-N9 interactions. Mechanics and electricians score the highest percentage of electrical accidents as shown in Table 3.56. Pulling/moving cables and repair/inspection of rail equipment are the most dominant injured activities. Table 3.57 gives the classification of the electrical accidents by injured activity. Table 3.58 and Table 3.59 give the classification by location. Table 3.60 shows the interaction between injured activity and the hazards. Energizing/de-energizing circuit breakers-abnormal arcs/sparks shows a strong relationship, which is expected. Also, Table 3.61 shows the connections between injured activity and the negligences involved.

3.4 ILLEGAL PRACTICES CAUSING ACCIDENTS

Another facet of the study of electrical accident statistics is to investigate what relationships exist between the most common accidents and Federal safety regulations. Since accidents continue to occur, two possibilities exist: (1) there are no regulations which prohibit practices which lead to certain accidents, or (2) accidents occur because applicable regulations are being violated. In either case, it is instructive to know how the regulations relate to accidents.

3.4.1 Review of Specific Regulations

Most of the federal regulations which relate to coal mine electrical safety and accidents are found in paragraphs 75.500 through 75.1003 and paragraphs 77.500 through 77.906 of Title 30 of the Code of Federal Regulations, although other paragraphs such as 75.1720 can apply also. These paragraphs were reviewed by relating them to the accidents in a data base of about 900 reported accidents. These 900 accidents comprise the twenty most

common injured activities of injured persons taken from Table 3.57. Altogether, they represent about two thirds of all electrical accidents studied. Each accident was studied to determine if it probably involved some violation of the electrical regulations, and a count was made of these apparent violations. This exercise led to the observations which follow.

A. 75.509 relates to a very large number of accidents, including nearly all those labeled as negligence N1 in the tables of statistics. In the sample studied, 31% of all accidents were related to violation of this regulation. This regulation is one of those which attempts to enforce safe practice rather than safe equipment. Since it does relate to behavior, it is largely unenforceable unless MSHA receives cooperation from all levels of management. Besides being basically unenforceable, the paragraph is loosely worded. It allows work on energized circuits for "trouble-shooting and testing". The accident record indicates that many injuries occur when persons are "checking" live circuits which could be checked by some other means with the power off. The use of cable fault locators could conceivably eliminate accidents related to the handling of energized cables with known (or suspected) faults as a means of locating the fault. There were at least 18 such accidents in the three years studied.

B. Paragraph 75.511 also relates to behavior, and cannot be enforced without management cooperation. The inspector can verify that locks and tags exist and can be used easily, but he can do little else. Sixteen accidents in three years were related to violations of this regulation.

C. Violations of paragraph 75.512 may be related to nearly half of the electrical accidents listed, but no way exists to determine the true number. An accident that occurs because "the controller lead grounded" certainly indicates deterioration of equipment. To assume that a frequent examination and testing program would have necessarily prevented the accident is fallacious, however. An inspection and testing program cannot locate all such deterioration, and in some cases can be the primary cause of the deterioration. Besides wearing things out by testing them, a overzealous testing program can lead to additional accidents which occur while the tests are being performed. Twelve accidents were identified as resulting from the testing of circuit breakers for instance, and fifteen accidents resulted from failure of meters used for making tests. The costs versus the benefits of any testing program should be studied thoroughly.

D. Paragraph 75.514 is undoubtedly violated many times, but this is largely indeterminable from the accident data. Although an accident may occur at a splice, for instance, this does not necessarily mean that the splice was poorly done, since many cable accidents occur where there is no splice.

E. Paragraph 75.517 is relevant, and more enforceable than some of the preceding paragraphs, since there may be physical evidence of a violation. About 8 percent of the electrical accidents were attributable to violations of this type.

F. More than 30 accidents occurred when fuses and circuit breakers exploded as a circuit was energized. Some of these failures are undoubtedly

due to misapplication of the devices. Unfortunately, fuses and breakers of different maximum interrupting capacities may be interchanged, since their mounts are often similar or identical. It is not known what percent of fuse and breaker failures are due to incorrect application, as covered by paragraph 75.518.

G. Paragraph 75.520 seems to be violated routinely. Apparently many types of switches and control equipment can be operated with doors open or covers off, and nearly 50 accidents were identified as being of this type. It would appear that manufacturers have the capability of providing interlocks to prevent this, but do not. It appears also that MSHA and mine operators have provided no incentive for them to do so.

H. Paragraph 75.601 requires that disconnecting devices used to disconnect power from trailing cables be plainly marked and identified. At least 8 of the accidents studied indicate that the injured had turned off power to the wrong circuit before working on a cable, a clear indication that cables were not plainly marked. This paragraph also relates to providing adequate interrupting capability. Since breakers of different interrupting capacity are often interchangeable, mines sometimes violate this regulation by installing an incorrect replacement. It is not known how many of the 52 accidents occurring while operating circuit breakers are the result of incorrect application.

I. Violation of paragraph 75.602 appears to be infrequent. This should be almost completely enforceable.

J. Paragraph 75.603 appears to be largely adhered to as far as splices are concerned. The statement prohibiting the use of cables with exposed wires is often violated, however. Many injuries have occurred as a result of contacting exposed leads in a cable. Often the personnel were apparently unaware of the danger, but at least four injuries occurred while a person was reinsulating exposed wires on an energized cable. Nearly twenty other accidents occurred as persons handled energized cable to search for suspected damage. One accident even occurred when a foreman handled a cable looking for a place where one of his people had just been shocked.

K. Paragraph 75.606 is ambiguous. Cables must be adequately protected to prevent damage, but does this mean that they must be sufficiently well-protected to prevent any damage, or that they must be protected against damage to a reasonable degree? There appear to be nearly twenty accidents clearly related to cable damage by mobile equipment in the sample studied.

L. Paragraphs 75.700 through 75.704 relate to physical design of equipment. These are relatively easy to enforce, but about twelve accidents resulted from violations of these regulations, usually because the ground system was faulty or damaged in some way.

M. Paragraph 75.705 and its subparagraphs are usually adhered to, although two accidents can be ascribed to violations of this paragraph.

N. Violations of paragraph 75.812 have resulted in two identified accidents. It is difficult to estimate how often high-voltage cables are handled while they are energized.

O. Paragraph 75.900, especially subparagraph 75.900-3 is very broad. The tests and examinations prescribed require a major effort to do correctly, since most breakers must be dismantled to visually inspect all components. Compliance is assisted by requiring a written record of all tests, but it is suspected that many of the tests on record were short-cut in some manner or fictionalized in the record. Unless mine management insists, this very important regulation is largely unenforceable. There were, however, about 12 accidents which occurred while breakers were being inspected. As stated earlier in comment C, the hazards inherent in testing and inspecting must be weighed against the benefits of the testing process. It may be more effective to provide external (but safe) test points for breakers and forego the visual inspection in favor of keeping the breaker sealed against contamination.

P. Paragraph 75.903 is very important to safety. Few accidents have resulted from violations of this paragraph, since it is largely enforceable. Accidents do result from failure to use the visible disconnect when it is provided, however.

Q. About 20 accidents were identified as being probable violations of Paragraph 75.1003. Several accidents occurred when crews were bolting roof near the trolley wire, while the remainder consisted of contact with the trolley wire while crossing the track, unloading tools or supplies, etc. It is not clear whether one is required to guard the trolley before unloading tools in an area where persons do not normally work or pass regularly. It is such "one-time" situations which appear to be related to most of these accidents.

R. Paragraph 75.1720 may be interpreted to require that gloves should be worn when handling energized low-voltage trailing cable. It is not clear however. Many accidents are related to handling cable bare-handed. About 7 percent of all accidents appeared to be of this type.

S. Paragraph 75.1725 can be related to such accidents as those which occur when breakers are operated with the covers off, although this is not made clear.

3.4.2 Enforceability of Regulations

When compliance with a regulation results in a certain physical structure, this structure provides clear evidence to a federal inspector that the regulation is being obeyed. When compliance requires a certain behavior, enforcement by inspection is ineffective. Proper behavior exists while the inspector is watching, but disappears as soon as he leaves. It is quite clear from the study of accidents that most accidents can be shown to be related to violations of the regulations. It is also clear that the majority of accidents can be related to violations of "behavioral" regulations. Once electrical repair work has been finished, for instance, there is no way for an inspector to verify that the circuit was locked out as required.

Paragraphs 75.509, 75.510, 75.511, 75.812, 75.1720, and 75.1725 are all "behavior" regulations which cannot be enforced by any system of occasional inspections. An attempt to enforce these may even be counterproductive to safety, since they intensify the adversary relationship with the inspector.

If the inspector perceives that a "show" of good behavior is the extent of a mine's compliance with these regulations, he may resort to overzealous enforcement of those rules which he can enforce. Such a situation does not lead to increased safety.

It is strongly recommended that all mandatory regulations which cannot be effectively enforced by periodic inspection be reviewed. As they stand they are of no benefit, and may be counterproductive.

3.4.3 Ambiguity of Regulations

Many regulations are unclear. They may be interpreted one way by the inspector and another way by the mine operator. In fact, they can be interpreted entirely differently by two different inspectors in the same district. A few examples are:

A. Paragraph 75.509 allows work on energized circuits when "necessary" for trouble-shooting or testing. What is "necessary" depends on what diagnostic equipment is available, how educated the miner is in its use, and how willing the person is to make the extra effort which is usually necessary to work safely. Many electricians sincerely believe that it is necessary to troubleshoot in certain ways, and do not feel that they are violating federal regulations when they do so.

B. Paragraph 75.511 requires that disconnecting devices be tagged or locked out before repairs can be made. It is not clearly explained that this means "visible disconnect devices". Many accidents attest to the mistaken belief that opening a switch or circuit breaker was a satisfactory way to disconnect a circuit.

C. Paragraph 75.1720 states that gloves shall be worn when performing work which might cause injury to the hands. Accident statistics clearly show that handling energized cable is such work, yet many inspectors do not interpret this regulation to require gloves while handling cable. And if inspectors do not clearly see the danger, how can the working miner be expected to properly interpret this regulation?

It is recommended that the regulations should be written to state clearly what is required. Most miners want to obey the regulations, but in many cases they do not understand what is required, or why it is required. This confusion is often fostered by MSHA. Many times the company will make changes to satisfy one inspector, only to find that another inspector will come along and require them to undo what they had been required to do. Such capricious behavior promotes the belief that MSHA regulations are not closely related to safety. Indeed, a large operator (metal mine) has recently published a paper entitled "White Pine Separates Safety and MSHA Compliance Functions" which states this philosophy rather clearly [1].

3.4.4 Implicit-Guilt Regulations

Several of the electrical regulations are open to interpretations which continually strain relations between MSHA and the mine operators. Such regulations are those under which the occurrence of an accident provides

sufficient evidence of violation to result in a citation. A few examples are:

A. Paragraph 75.512 states that all electrical equipment shall be properly maintained to assure safe operating conditions. Any equipment failure which results in an accident is evidence that it was not maintained in a safe condition.

B. Paragraph 75.517 states that all power wires and cables shall be insulated adequately. Any shock or short-circuit is evidence that the insulation was not adequate.

C. Paragraph 75.606 states that trailing cables shall be adequately protected to prevent damage by mobile equipment. Any damage by mobile equipment is evidence that the protection was not adequate.

D. Paragraph 75.1725 states that equipment in an unsafe condition shall be removed from service immediately. Any accident related to an equipment failure is evidence that unsafe equipment was in service.

While these regulations have their obvious use, they allow the inspector to take advantage of hindsight, and put the operator in a "guilty till proven innocent" situation. An inspector can inspect a power center minutely and find nothing wrong, but if a miner is injured 10 seconds later because a component failed, many inspectors will write up a citation. This is extremely frustrating to those maintenance people who sincerely try to do a good job. Although it may force them to maintain their equipment better, it nearly always has the opposite effect.

It is strongly recommended that such regulations as 75.512, 75.517, 75.606, and 75.1725 be tempered by such words as "at the time of construction" or "at the time of inspection or repair". This allows them to be put in the proper perspective as design goals. Violations should be cited when there is evidence of willful disregard of the regulation, not as the routine accompaniment to nearly every accident.

3.4.5 Topics Not Covered Under Regulations

Some requirements for electrical safety are not covered explicitly within the regulations. These include:

- A. Wearing of gloves when handling energized cable.
- B. Not handling any energized cable suspected of being damaged, even with gloves.
- C. Not wearing rings or metal bracelets or watches when working near electricity.
- D. Not connecting or disconnecting batteries with power on the charger.
- E. Instructive regulations on how to make or break connections to a battery.

F. Requirement to turn off power when working in close proximity to energized circuits.

G. When working in the vicinity of energized trolley wires, place guards or deenergize before doing any work, not just track work or moving equipment.

H. No requirement to deenergize a circuit before testing, removing, or replacing a fuse.

I. Not changing light bulbs with power on to them.

J. Not operating switches, circuit breakers, and contactors, with doors open, covers or guards off, etc.

K. Not opening cover on breaker box, switch box, contactor, etc., even for visual inspection, when circuit is energized.

L. Testing for voltage on all conductors before working on them.

M. Requirement to pull pole immediately if vehicle derails, before any other action is taken.

N. More instructive regulations on nipping and removing nips, and placing trolley poles. All loads must be turned off before these are done.

Although a competent inspector can find ways to interpret the regulations which cover all these points, they are not made explicit. It is strongly recommended that the regulations be written to be as explicit as possible.

3.4.6 Practices Observed on Mine Visitations

Several illegal or improper practices were observed during mine visitations, which could possibly contribute to serious accidents. One mine carried the safety ground wire as a bare conductor below the phase conductors on their pole line. This provides a good opportunity for a short circuit which could be made less likely by using an insulated ground wire, and the ground wire might be made somewhat less susceptible to lightning. In another mine, a foreman was stationed beside a power center to reset a breaker which was tripping two or three times a minute. This was observed by the electrical people who were conducting the tour, but they did not consider this unusual or unsafe. Other mines were very dirty and disorganized, with their cables laid in a great tangled mass around the power center.

3.4.7 Summary

Mine operators had a generally low opinion of MSHA inspectors and many MSHA regulations. They were unable to meet some of the regulations, so they just tried to steer the inspector away from that area. Several people suggested that MSHA had a quota of citations to meet, and they would receive approximately the same level of fines independently of how much effort they spent on compliance. It was stated that no good electrical person would work for MSHA, since he could make more money elsewhere. "Inspectors are

nit-pickers, and blindly adhere to the book. They have lost all sense of reason".

Since the federal regulations are not easily changed as new ideas and information come forth, adjustments are made in the "interpretation" of the broadly written mine regulations in order to match current thinking. While this approach prevents mine operators from circumventing the regulations on technicalities (a desirable feature), it encourages misuse of their powers by inspectors and frustrates mine operators who must try to keep up with the latest interpretations. This fluidity of interpretation of the broad generalizations that characterize much of the mine electrical regulations causes four different kinds of problems with them. Suggestions have been made to alleviate each of those problems.

3.4.8 Reference

1. Anderson, Orville. "White Pine Separates Safety and MSHA Compliance Functions". Mining Congress Journal. May, 1981.

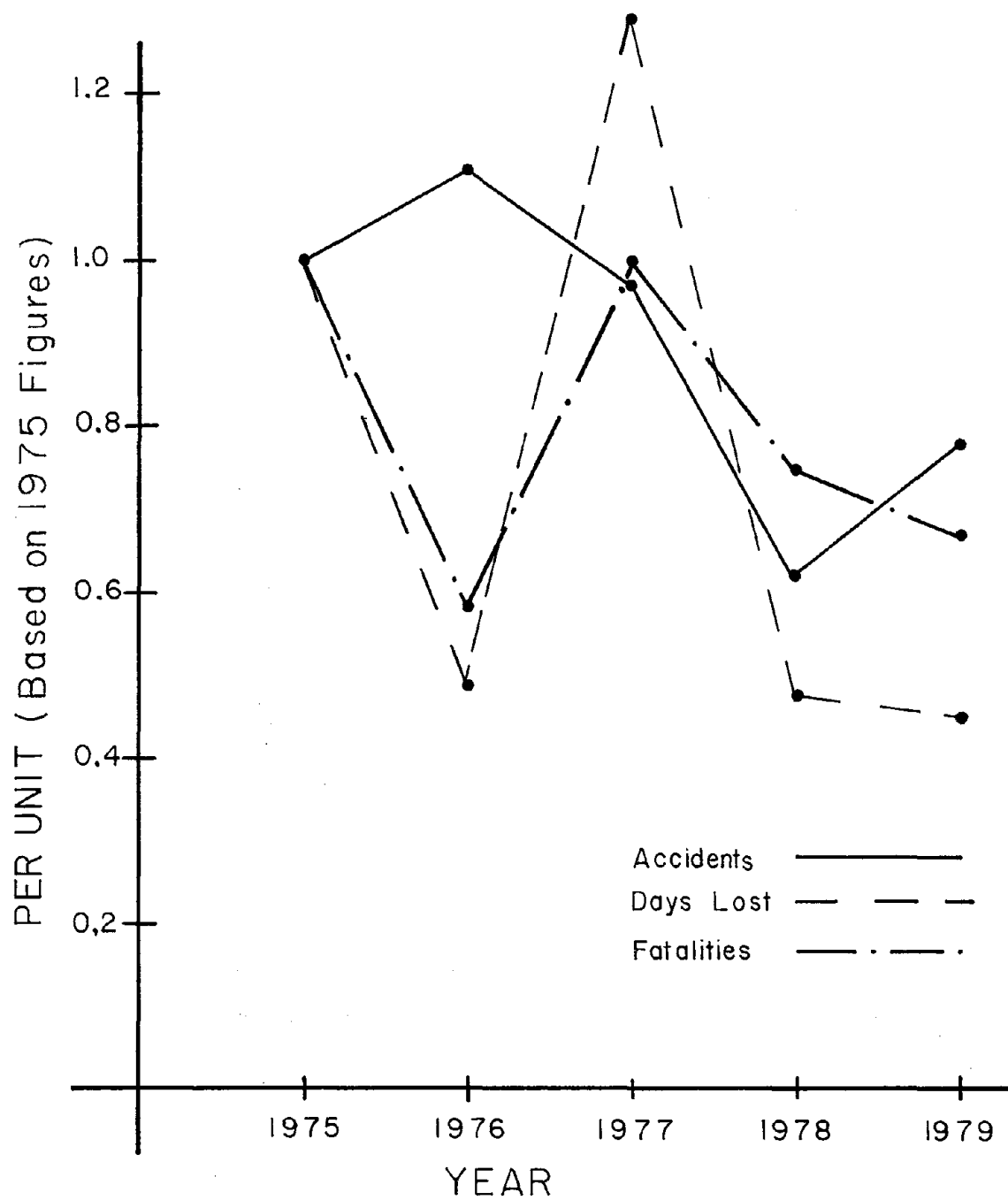


FIGURE 3.1. Graphical representation of yearly electrical accident statistics.

TABLE 3.1. Guide to data tables

Table	Description
3.2	Shows a sample WVU computerized accident listing, including assessed hazard and negligence.
3.3	Persons employed in coal mining in 1979. See table 3.9 for 1975 data.
3.4	Man-hours worked in coal mining in 1979. See table 3.10 for 1975 data.
3.5	Coal mine production statistics for 1979. See table 3.11 for 1975 data.
3.6	Breakdown of coal production by type of mine in 1979.
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3.8	Status of all coal mines in 1979. See table 3.12 for 1975 data.
3.9	Persons employed in coal mining in 1975. See table 3.3 for 1979 data.
3.10	Man-hours worked in coal mining in 1975. See table 3.4 for 1979 data.
3.11	Coal mine production statistics for 1975. See table 3.5 for 1979 data.
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3.13	Percent active mines by type in 1975. See table 3.7 for 1979 data.
3.14	Comparison of MSHA and Keystone Manual coal mine statistics for 1975 and for 1979.
3.15	Accident prone mine statistics for 1979. See tables 3.18, 3.22, 3.23, and 3.24 for other years.
3.16	Normalized electrical accident rates for 1979. See table 3.19 for 1975 data.
3.17	Most hazardous mines in 1979 ranked by normalized statistics. See table 3.20 for 1975 data.
3.18	Accident prone mine statistics for 1975. See tables 3.15, 3.22, 3.23, and 3.24 for other years.
3.19	Normalized electrical accident rates for 1975. See table 3.16 for 1979 data.
3.20	Most hazardous mines in 1975 ranked by normalized statistics. See table 3.17 for 1979 data.
3.21	Comparison of 1975 and 1979 electrical accident rates.
3.22	Accident prone mine statistics for 1978. See tables 3.15, 3.18, 3.23, and 3.24 for other years.
3.23	Accident prone mine statistics for 1976. See tables 3.15, 3.18, 3.22, and 3.24 for other years.
3.24	Accident prone mine statistics for 1977. See tables 3.15, 3.18, 3.22, and 3.23 for other years.
3.25	Most hazardous mines over 5 years. Combination of tables 3.16, 3.19, 3.22, 3.23, and 3.24.

TABLE 3.1. Guide to data tables (continued)

Table	Description
3.26	Cumulative yearly accident statistics. Accidents, fatalities, and days lost.
3.27	Accident classification by type of injury for 1975. See tables 3.35, 3.43, and 3.50 for other years.
3.28	Accident classification by degree of injury for 1975. See tables 3.36, 3.44, and 3.51 for other years.
3.29	Accident classification by electrical hazard involved in 1975. See tables 3.37, 3.47, and 3.52 for other years.
3.30	Accident classification by negligence of injured persons in 1975. See tables 3.38, 3.48, and 3.53 for other years.
3.31	Accident classification by job title in 1975. See tables 3.39 and 3.55 for other years.
3.32	Accident classification by activity of injured persons in 1975. See tables 3.40, 3.45, and 3.56 for other years.
3.33	Accident classification by involved location in underground mines in 1975. See tables 3.41 and 3.57 for other years.
3.34	Accident classification by involved location in surface mines in 1975. See tables 3.42 and 3.58 for other years.
3.35	Accident classification by type of injury for 1978. See tables 3.27, 3.43, and 3.50 for other years.
3.36	Accident classification by degree of injury for 1978. See tables 3.28, 3.44, and 3.51 for other years.
3.37	Accident classification by electrical hazard involved in 1978. See tables 3.29, 3.47, and 3.52 for other years.
3.38	Accident classification by negligence of injured persons in 1978. See tables 3.30, 3.48, and 3.53 for other years.
3.39	Accident classification by job title in 1978. See tables 3.31 and 3.55 for other years.
3.40	Accident classification by activity of injured persons in 1978. See tables 3.32, 3.45, and 3.56 for other years.
3.41	Accident classification by involved location in underground mines in 1978. See tables 3.33 and 3.57 for other years.
3.42	Accident classification by involved location in surface mines in 1978. See tables 3.34 and 3.58 for other years.
3.43	Accident classification by type of injury for 1979. See tables 3.27, 3.35, and 3.50 for other years.
3.44	Accident classification by degree of injury for 1979. See tables 3.28, 3.36, and 3.51 for other years.
3.45	Accident classification by activity of injured persons for 1979. See tables 3.32, 3.40, and 3.56 for other years.

TABLE 3.1. Guide to data table (continued)

Table	Description
3.46	Accident classification by type of equipment involved in 1979.
3.47	Accident classification by electrical hazard involved in 1979. See tables 3.29, 3.37, and 3.52 for other years.
3.48	Accident classification by negligence of injured persons in 1979. See tables 3.30, 3.38, and 3.53 for other years.
3.49	Accident classification by combined hazard and negligence types in 1979. See table 3.54 for combined data.
3.50	Accident classification by type of injury, combined 3-year total. See tables 3.27, 3.35, 3.43 for individual years.
3.51	Accident classification by degree of injury, combined 3-year total. See tables 3.28, 3.36, and 3.44 for individual years.
3.52	Accident classification by electrical hazard involved, combined 3-year total. See tables 3.29, 3.37, and 3.47 for individual years.
3.53	Accident classification by negligence of injured persons, combined 3-year total. See tables 3.30, 3.38, and 3.48 for individual years.
3.54	Accident classification by combined hazard and negligence type, 3-year total. See table 3.49 for 1979 data.
3.55	Accident classification by job title of injured person, 3-year total. See tables 3.31 and 3.39 for individual years.
3.56	Accident classification by activity of injured persons, combined 3-year total. See tables 3.32, 3.40, and 3.45 for individual years.
3.57	Accident classification by involved location in underground mines, 3-year total. See tables 3.33 and 3.41 for individual years.
3.58	Accident classification by involved location in surface mines, 3-year total. See tables 3.34 and 3.42 for individual years.
3.59	Relationship between injured activity and electrical hazards involved, 3-year total.
3.60	Relationship between injured activity and negligence of injured, 3-year total.

TABLE 3.2. Sample accident listing

DOCUMENT NO 292140156 (CLW) MINE ID: 46 1433 1979
 LOCATION: UNDERGROUND - POWER CENTER
 JOB TITLE: D3 MINING EXP: 10 YRS, 0 WKS
 PERFORMING ELEC WORK: NO JOB EXP: 10 YRS, 0 WKS
 QUALIFIED: YES INJURED AGE: 35
 DESCRIPTION: PLUGGED JUMPER CABLE FROM BATTERY INTO SCOOP
 WIRE CAME LOOSE IN PLUG
 TYPE OF OPERATION: UNDERGROUND
 INJURY TYPE: I1, INJURED ACTIVITY: N1
 INJURY DEGREE: D3 HAZARD: H5.
 DAYS LOST: 15 NEGLIGENCE: NA,
 PART OF BODY: K

TABLE 3.3. Employees of coal mining units in 1979

Type Sub-Unit	Number of Sub-Units	Number of Employees				
		Quarter				Av.
		1	2	3	4	
1. UNDERGROUND OPERATION: Below the surface of the ground.	2,065	115,258	115,700	116,246	116,112	115,829
2. SURFACE AT UNDERGROUND: Includes associated shops and yards and tippie when located at the mine.	1,520	12,042	12,312	12,439	12,711	12,376
3. SURFACE: Open Pit, Strip Includes associated shops and yards.	2,547	58,419	60,406	61,766	61,659	60,562.5
4. AUGER: Surface Mining done with boring machine.	254	361	216	332	428	334.25
5. CULM BANK or REFUSE PILE: Reworkings of previously processed coal.	69	198	242	220	253	228.25
6. DREDGE: Mining Underwater from floating platform.	3	3	2	9	11	6.25
7. INDEPENDENT SHOPS AND YARDS	163	3,904	3,840	3,761	3,853	3,839.5
8. MILL OR PREPARATION PLANT	1,525	18,411	18,943	19,599	19,920	19,218.25
9. OFFICE	2,137	7,429	7,835	8,182	8,441	7,971.75

TABLE 3.4. Hours worked in coal mining in 1979

Type Sub-Unit	Number of Sub-Units	# MAN-HOURS				
		Quarter				Av.
		1	2	3	4	
1. UNDERGROUND OPERATION: Below the surface of the ground.	2,065	55,017,207	55,037,282	49,592,987	54,058,687	53,426,541
2. SURFACE AT UNDERGROUND: Includes associated shops and yards and tippie when located at the mine.	1,520	6,021,675	6,000,249	5,558,671	6,136,872	5,929,366.8
3. SURFACE: Open Pit, Strip Includes associated shops and yards.	2,547	30,751,022	32,557,320	31,940,375	32,700,297	31,987,254
4. AUGER: Surface Mining done with boring machine.	254	145,993	82,581	139,936	176,929	136,359.75
5. CULM BANK or REFUSE PILE: Reworkings of previously processed coal.	69	77,827	108,706	100,633	92,329	94,873.75
6. DREDGE: Mining Underwater from floating platform.	3	400	1,500	1,648	1,913	1,365.25
7. INDEPENDENT SHOPS AND YARDS	163	2,002,339	1,892,263	1,749,989	1,856,264	1,875,213.8
8. MILL OR PREPARATION PLANT	1,525	9,315,901	9,484,455	9,353,198	9,832,434	9,496,497
9. OFFICE	2,137	3,879,028	4,061,775	4,001,443	4,210,710	4,038,239

TABLE 3.5. Coal production in 1979

Type Sub-Unit	Number of Sub-Units	Production (Clean Coal) Tons				
		Quarter				Av.
		1	2	3	4	
1. UNDERGROUND OPERATION: Below the surface of the ground.	2,065	71,213,904	74,230,080	63,157,607	72,776,872	70,344,616
2. SURFACE AT UNDERGROUND: Includes associated shops and yards and tippie when located at the mine	1,520	0	0	0	0	0
3. SURFACE: Open Pit, Strip Includes associated shops and yards.	2,547	90,891,254	107,901,075	108,650,926	116,208,491	105,912,936
4. AUGER: Surface Mining done with boring machine.	254	420,051	411,006	498,483	459,740	447,320
5. CULM BANK or REFUSE PILE: Reworkings of previously processed coal	69	339,223	609,703	523,112	291,431	440,867.25
6. DREDGE: Mining Underwater from floating platform.	3	0	2,064	1,892	2,286	1,560.5
7. INDEPENDENT SHOPS AND YARDS	163	0	0	0	0	0
8. MILL OR PREPARATION PLANT	1,525	0	0	0	0	0
9. OFFICE	2,137	0	0	0	0	0

TABLE 3.6. Characteristics of average coal mining sub-unit in 1979

SUB-UNIT TYPE	NUMBER OF EMPLOYEES	HOURS WORKED	PRODUCTION TONS
1	56.09	103,489.67	136,260.76
2	8.14	15,603.60	0
3	23.78	50,235.18	166,333.63
4	1.32	2,147.40	7,044.41
5	3.31	5,499.93	25,557.52
6	2.08	1,820.33	2,080.67
7	23.56	46,017.52	-
8	12.60	24,908.84	-
9	3.73	7,881.53	-

TABLE 3.7. Active coal mining sub-units in 1979

Sub-unit	1	2	3	4	5	6	7	8	9
Total #	4132	2453	4092	421	131	9	190	2008	3032
Active %	50	62	62	60	53	33	85	76	70

TABLE 3.8. Status of coal mine sub-units in 1979

Status*	A	B	C	D	E	F	G	H
Frequency	6227	45	1636	2013	363	172	276	337
%	56.26	.41	14.78	18.19	3.28	1.55	2.49	3.05

*(A = active, B=closed by MESA, C=temporarily closed, D=permanently abandoned, E=active, not producing, men working, F=active, not producing, men not working, G=New under construction, H=New, no men working).

TABLE 3.9. Employees of coal mining units in 1975

		Quarter				# of Employees
Code	Description	1	2	3	4	Avg.
1	Underground Operations	102,666	108,944	113,274	114,083	109,742
2	Surface at Underground	10,301	12,766	12,781	12,607	12,114
3	Surface	37,946	44,709	49,058	48,364	45,019
4	Auger	674	1,227	654	1,234	947
5	Culm Bank or Refuse Pile	157	267	272	265	240
6	Dredge	6	9	14	208	59
17	Independent Shops and Yards	3,008	3,226	3,306	3,410	3,238
30	Mill or Prep Plant	13,772	15,926	15,983	16,765	15,612
99	Office	4,952	4,894	5,369	5,525	5,185

TABLE 3.10. Hours worked in coal mining in 1975

Code	Description	Quarter				Tot.	Avg.
		1	2	3	4		
1	Underground Operations	50,934,250	52,898,557	46,885,304	55,458,525	206,176,636	51,544,159
2	Surface at Underground	5,231,909	5,995,609	5,479,166	6,158,902	22,865,586	5,716,397
3	Surface	20,316,594	22,997,050	24,018,375	25,165,036	92,497,055	23,124,264
4	Auger	260,974	367,005	272,010	400,519	1,300,508	325,127
5	Culm Bank or Refuse Pile	60,423	93,590	119,464	121,730	395,207	98,802
6	Dredge	2,398	2,868	5,206	35,449	45,921	11,480
17	Independent Shops and Yards	1,548,695	1,622,804	1,431,862	1,700,276	6,303,637	1,575,909
30	Mill or Prep. Plant	6,851,381	7,339,481	6,631,843	7,744,769	28,567,474	7,141,869
99	Office	2,582,118	2,626,262	2,729,557	2,882,437	10,820,374	2,705,094

TABLE 3.11. Coal production in 1975 (Tons)

Code	Description	Quarter					Tot.	Avg.
		1	2	3	4			
1	Underground Operations	73,215,544	71,915,521	56,480,399	71,106,689		272,718,153	68,179,538
2	Surface at Underground	0	0	0	0		0	0
3	Surface	70,271,279	79,669,395	82,035,735	83,728,209		315,704,618	78,926,155
4	Auger	794,860	1,199,239	1,127,531	1,038,677		4,160,307	1,040,077
5	Culm Bank or Refuse Pile	569,701	635,432	1,125,543	946,828		3,277,504	819,376
6	Dredge	3,581	8,568	23,009	12,997		48,155	12,039
17	Independent Shops and Yards	-	-	-	-		-	-
30	Mill or Prep. Plant	-	-	-	-		-	-
99	Office	-	-	-	-		-	-

TABLE 3.12. Status of coal mine sub-units in 1975

Status*	A	C	D
Frequency	5841	1559	833
%	71	19	10

*(A= active, C= temporarily closed, D= permanently abandoned)

TABLE 3.13. Active coal mining sub-units in 1975

Sub-Unit Code	1	2	3	4	5	6
Active	2468	1061	1831	201	50	5
Total	3904	1267	2151	249	69	5
%	63	84	85	81	72	100

TABLE 3.14. Comparison of Keystone and MSHA statistics
for 1975 and 1979

Source	Year	Av. # of Men		Production (10 ³ tons)		Production/man/day	
		UG	S	UG	S	UG	S
Keystone	1975	134,710	55,170	292,826	355,612	9.54	26.69
MSHA	1975	121,856	46,265	272,718	323,191	9.53	27.4
Keystone	1979	169,585	82,497	301,435	463,565	7.9	24.8
MSHA	1979	128,205	61,131	281,378	427,211	9	26

TABLE 3.15. Accident-prone mine statistics (1979)

MINE ID	NUMBER OF ACCIDENTS	NUMBER OF LOST DAYS	NUMBER OF MEN WORKING	NUMBER OF MAN-HOURS	PRODUCTION IN TONS
4200121	7	28	596	1,015,188	1,863,220
3602374	5	0	416	753,883	836,564
4200080	5	384	293	506,884	661,813
3301157	5	59	1241	1,958,708	1,168,007
1100600	5	36	786	1,517,192	1,305,224
1100598	5	77	557	1,073,737	925,456
4401520	4	88	433	830,939	802,898
4601266	4	13	286	476,366	622,770
1100628	3	33	294	651,444	744,537
3301173	3	31	666	1,216,723	1,852,363
3600823	3	39	438	882,217	1,215,888
3600904	3	144	517	983,460	821,000
1502117	3	26	195	352,639	317,637
3300989	3	307	679	1,428,594	3,450,931
3301172	3	9	454	860,751	918,242
1100877	3	11	722	1,317,811	1,830,260
1100599	4	77	615	1,090,125	931,654
4400302	4	29	278	478,745	311,743
4601397	8	94	186	385,118	202,800
1106585	7	91	853	1,974,866	2,898,334
0100758	4	44	689	1,365,672	858,127
3600970	4	68	425	826,711	870,736

TABLE 3.16. Weighted accident statistics (1979)

MINE ID	NUMBER OF LOST DAYS/ 10^2 MEN	NUMBER OF LOST DAYS/ 10^6 MAN-HOURS	NUMBER OF LOST DAYS/ 10^6 TONS OF PRODUCTION
4200121	4.7	27.58	15.03
3602374	0	0	0
4200080	131	757.57	525.83
3301157	4.75	30.12	50.51
1100600	4.58	23.73	27.58
1100598	13.82	71.71	83.20
4401520	20.32	105.9	109.60
4601266	4.55	27.29	20.87
1100628	11.22	50.66	44.32
3301173	4.65	25.48	16.74
3600823	8.9	44.21	32.08
36000904	27.85	146.42	175.4
1502117	13.38	73.73	81.85
3300989	45.21	214.4	88.96
3301172	1.98	10.46	9.8
1100877	1.52	8.35	6.01
1100599	6.02	33.94	39.71
4400302	10.43	60.58	93.03
4601397	50.54	244.08	463.51
1100585	10.67	46.08	31.4
0100758	6.39	32.22	51.27
3600970	16	82.25	32.16

TABLE 3.17. Mines ranked by weighted accident statistics (1979)

MINE ID	RANK BY NUMBER OF ACCIDENT	RANK BY LD	RANK BY #/LD/10 ⁷ MEN	RANK BY #/LD/10 ⁶ MAN-HRS	RANK BY #/LD/10 ⁶ TONS
4200080	5	1	1	1	1
4601397	1	4	2	2	2
3300989	18	2	3	3	6
3600904	22	3	4	4	3
4401520	13	6	5	5	4
3600970	14	8	6	6	13
1502117	17	18	8	7	8
1100598	8	7	7	8	7
4400302	11	16	11	9	5
1100628	15	14	9	10	11
1100585	5	3	10	11	15
3600823	21	11	12	12	14
1100599	10	12	14	13	12
0100758	9	10	13	14	9
3301157	6	9	15	15	10
4200121	2	17	16	16	19
4601266	12	19	19	17	17
3301173	20	15	17	18	18
1100600	7	13	18	19	16
3301172	19	21	20	20	20
1100877	16	20	21	21	21
3602374	4	22	22	22	22

TABLE 3.18. Statistics on 1975 "accident-prone" mines

Mine ID	# of Accidents	# of Days Lost	# of Men Working	# of Man-Hours	Production (tons)
4601516	3	476	222	399,793	305,253
4601809	7	132	257	468,731	293,884
1502060	7	91	187	386,523	571,255
4601437	6	82	425	678,210	1,129,456
4601536	9	69	463	843,355	765,647
4400304	3	68	344	624,988	497,732
1100599	4	66	430	887,845	1,373,371
1100600	4	65-1F	614	1,249,706	1,957,096
0100758	4	62	346	938,556	293,153
4601431	3	59	492	573,810	716,979
4601329	3	58	278	442,224	268,164
0100328	3	51	249	562,413	345,963
4601407	5	44	377	752,623	791,847
4601272	4	43	275	491,357	452,712
4601616	3	33	100	209,239	331,068
4601455	9	32	373	725,479	1,574,794
1100605	3	32	460	918,718	1,802,434
4601453	11	31	554	1,168,232	2,068,816
4200121	3	31	306	625,608	1,031,347
4601962	3	30	82	175,278	116,831

TABLE 3.19. Weighted statistics for 1975 "accident-prone" mines

Mine ID	# Lost days/ 10^2 men	# Lost days/ 10^6 man-hours	# Lost days per 10^6 Tons of Production
4601516	214	1191	1559
4601809	51	282	449
1502060	49	235	159
4601437	19	121	73
4601536	15	82	90
4400304	20	109	137
1100599	15	74	48
1100600	11	52	33
0100758	18	66	211
4601431	12	103	82
4601329	21	131	216
0100328	20	91	147
4601407	12	58	56
4601272	16	88	95
4601616	33	158	100
4601455	9	44	20
1100605	7	35	18
4601453	6	27	15
4200121	10	50	30
4601962	37	171	257

TABLE 3.20. Ranking of most hazardous mines (1975)

Mine ID	Rank by # of Accidents	Rank By Lost Days	Rank by #LD/10 ² Men	Rank by #LD 10 ⁶ Man-hr	Rank By #LD 10 ⁶ Tons
4601516	18	1	1	1	1
4601809	5	2	2	2	2
1502060	4	3	3	3	6
4601962	20	20	4	4	3
4601616	19	15	5	5	9
4601329	16	11	6	6	4
4601437	6	4	9	7	13
4400304	15	6	7	8	8
4601431	17	10	14	9	12
0100758	12	12	8	10	7
4601272	11	14	11	11	10
4601536	3	5	12	12	11
1100599	9	7	13	13	15
0100328	8	9	10	14	5
4601407	7	13	15	15	14
1100600	10	8	16	16	16
4200121	14	19	17	17	17
4601455	2	16	18	18	18
1100605	13	17	19	19	19
4601453	1	18	20	20	20

TABLE 3.21.- Comparison between 1975 and 1979 accident rates

Accident Rate	1975	1979
Number of days lost/ 10^6 man-hours	33.75	13.01
Number of days lost/ 10^2 men	7.19	2.83
Number of days lost/ 10^6 ton production	20.28	7.56
Number of accidents/ 10^6 man-hours	1.47	1.01
Number of accidents/ 10^2 men	0.31	0.22
Number of accidents/ 10^6 ton production	.89	0.58

TABLE 3.22. 1978 Most hazardous mines

Mine ID	Number of Lost Days	Rank By # Days Lost	Number of Accidents	Rank by # of Accidents
1100609	222	1	2	29
4602067	142	2	3	13
4601535	133	3	4	4
4601888	117	4	4	4
4400304	105	5	4	4
3600966	84	6	3	13
4601404	72	7	4	4
3301157	67	8	5	1
1100600	58	9	5	1
4601400	58	9	3	13
3301159	52	11	4	4
1100598	51	12	4	4
1200330	47	13	3	13
4601407	46	14	5	1
4601514	46	14	4	4
4403614	42	16	3	13
1100585	36	17	4	4
4601429	33	18	3	13
1509546	27	19	2	29
3302624	23	20	2	29
3300939	22	21	3	13
4601495	19	22	3	13
0100324	11	23	4	4
0152082	11	23	2	29
4601417	10	25	3	13
0100322	10	25	2	29
1100588	9-1F	27	2	29
1502028	9	28	2	29
0100340	8	29	2	29
4601266	5	30	3	13

TABLE 3.23. 1976 Most hazardous mines

Mine ID	# of Lost Days	Rank by Lost Days	# of Accidents	Rank by # of Accidents
3600838	341	1	2	6
1502065	258	1	2	13
1502096	203	3	1	13
4400246	186	4	3	4
1502107	169	5	8	2
4600868	156	6	2	6
3301172	144	7	5	3
4800086	125	8	1	13
3301069	122	9	1	13
4601513	120	10	2	6
1100589	112	11	3	4
4601969	99	12	1	13
4601863	97	13	1	13
3600958	88	14	9	1
4601923	88	14	2	6
3602732	86	16	1	13
4601404	85	17	2	6
3603248	83	18	2	6
4500416	79	19	1	13
4603806	78	20	1	13
4601329	77	21	2	6

TABLE 3.24. 1977 Most hazardous mines

Mine ID	Number of Lost Days	Rank by Days Lost	Number of Accidents	Rank by # of Accidents
3300967	480	1	5	1
3303510	469	2	1	12
3600962	435	3	2	8
4603793	421	4	1	12
4601517	407	5	2	8
1100629	400	6	1	12
4601536	385	7	3	6
4603758	372	8	1	12
4800677	368	9	5	1
4605210	347	10	1	12
1507039	307	11	1	12
1502066	301	12	2	8
3600834	289	13	1	12
1506365	270	14	1	12
4001735	255	15	1	12
3300977	255	15	1	12
4400285	239	17	1	12
4604267	239	17	1	12
4601404	239	17	3	6
3300939	230	18	5	1
4601537	223	19	4	4
3301159	222	20	4	4
4601510	212	21	2	8

TABLE 3.25. Mines displaying hazardous characteristics in two or more years

Mine ID	1975	1976	1977	1978	1979
4200121	18* 30+ 31** 3†				16 2 29 7
1100585	25 19 18 4			17 4 36 4	5 2 91 7
1100600	8 19 65- 1F 4			9 1 58 5	13 4 36 5
1100598				12 4 51 4	7 4 77 6
3301157				8 1 67 5	9 4 59 5
0100758	9 19 62 4				10 9 44 4
1100599	7 14 66 4				12 9 37 4
4601266				30 13 5 3	19 9 13 4
4401520	28 30 16 3				6 9 88 4
3600970	37 30 0 3				8 9 68 4
4601407	13 16 44 5			14 1 46 5	
4400304	6 30 68 3			5 4 105 4	
4601404	34 3 5 7	17 6 85 2	17 6 239 3	7 4 72 4	
4601535	37 3 0 7			3 4 133 4	
3300939	29 30 14 3		18 1 230 5	21 13 22 3	
4601329	11 30 58 3	21 6 77 2			

TABLE 3.25. (continued)

Mine ID	1975	1976	1977	1978	1979
4601429	37 19 0 4			18 13 33 3	
4601536	5 2 69 9		7 6 385 3		
3301159			20 4 222 4	11 4 52 4	
3300967	24 19 20 4		1 1 480 5		
1502107	26 3 17 7	5 2 169 8			
4400246	26 19 17 4	4 4 186 3			
3600962	31 30 9 3		3 8 435 2		
4601537	32 12 7 6		19 4 223 4		

* Rank by number of days lost

** Number of days lost

+ Rank by number of accidents

† Number of accidents

TABLE 3.26. Cumulative yearly statistics

Year	1975	1976	1977	1978	1979
Total # of Accidents	527	587	512	327	412
Total # of Days Lost	11,456	5,633	14,817	5,486	5,239
Total # of Fatalities	12	7	12	9	8

TABLE 3.27. Accident classification by injury type (1975)

# Accidents	%	Injury Type
318	60.456	I3 - Flash Burn
133	25.285	I2 - Electrical Burn
60	11.407	I1 - Shock
5	0.951	I7 - Reaction to Electrical
4	0.760	I5 - Explosion
3	0.570	I8 - Other
2	0.380	I4 - Heat Burn
1	0.19	I6 - Smoke Inhalation
2	0.38	I ₁ , I ₂
2	0.38	I ₃ , I ₇
1	0.19	I ₁ , I ₃
1	0.19	I ₁ , I ₄
1	0.19	I ₃ , I ₅
1	0.19	I ₇ , I ₂

TABLE 3.28. Accident classification of injury degree (1975)

# of Accidents	%	Degree
514	97.533	3 - Non-Disabling
12	2.277	1 - Fatal
1	0.190	0 - Unknown

TABLE 3.29. Number of accidents vs. hazard type (1975)

# of Accidents	%	H	Hazard
254	48.197	7	None
125	23.719	4	Abnormal arcs/sparks
52	9.867	3	Improper insulation
31	5.882	8	Unknown or not classifiable
26	4.934	2	Energized power conductor thought to be safe
21	3.985	6	Loaded electrical circuit assumed open
17	3.226	1	Energized ground/frame
1	0.190	9	Lightning

TABLE 3.30. Number of accidents vs. negligence type (1975)

# of Accidents	%	N	Negligence
142	26.945	A	No errors
108	20.493	1	Not removing power to ckt under repair
88	16.698	9	Improper operation
46	8.729	13	Unknown or non-classifiable
38	7.211	4	Incorrect tool
35	6.641	5	Failure to maintain clearance with boom truck-load, etc.
31	5.882	7	Not wearing protective gear
25	4.744	6	Failure to maintain clearance with body or hand tool
11	2.087	2	Not ensuring that ckt cannot become energized
3	0.569	8	Abusing equipment

TABLE 3.31. Accident classification by job title (1975)

# of Accidents	%	Job Title
91	17.433	C5 - Mechanic - General Underground
70	13.410	C2 - Electrician - General underground
40	7.663	B2 - Motorman - Track worker
30	5.747	A9 - Shuttle car operator - section worker
30	5.747	C4 - laborer - general underground
24	4.598	A6 - Roof bolter - section worker
24	4.598	D2 - Section foreman - non-union
18	3.448	A2 - Continuous miner or - section worker
16	3.065	D3 - Supervisor - non-union
16	3.065	EC2 - Surface electrician
13	2.490	C1 - Beltman - general underground
12	2.299	A4 - loading machine foreman - section worker
11	2.107	EC5 - Surface mechanic
10	1.916	B4 - Trackman
10	1.916	D4 - Maintenance foreman non-union
9	1.724	AC - Wireman - communication
9	1.724	C7 - Oiler/greaser/pumper
9	1.724	E2 - Mobile equipment op. surface
8	1.553	A7 - Scoop car op. - section worker
7	1.341	E3 - Prep. plant operator - surface
6	1.149	AB - Utility man
6	1.149	B3 - Supply man

TABLE 3.32. Accident classification by injured activity (1975)

# of Accidents	%	Injured Activity
38	7.211	F5 - Splicing cable
37	7.021	G3 - Operating rail equip
32	6.072	G5 - Repair/inspection rail equip
29	5.503	T - Other
28	5.313	N1 - Operating underground production equip
27	5.123	F4 - Pulling/moving cable
27	5.123	G4 - Placing/removing nip on trolley
22	4.175	F1 - Checking inspecting cable
22	4.175	I2 - Operating switches
20	3.795	G6 - Placing pole on trolley
20	3.795	R - Uncontrollable contact
19	3.605	I1 - Energizing/deenergizing - circuit breakers
18	3.416	H1 - Battery maintenance
18	3.416	K6 - Maintenance/repair fuses
16	3.036	K1 - Maintenance/repair circuit breakers
16	3.036	M1 - Maintenance/repair underground prod equip
15	2.846	G7 - Working near trolley
14	2.657	P - Repairing/replacing lighting circuitry
12	2.277	K2 - Maintenance/repair switches
12	2.277	L1 - Inspecting/troubleshooting under- ground prod equip
10	1.898	F3 - Making connection at power center
9	1.708	J1 - Inspecting/troubleshooting circuit breakers
8	1.518	F7 - Testing cable with test equipment
7	1.328	M3 - Maintenance/repair
5	0.949	F2 - Hanging cable
5	0.949	N2 - operating surface production equip
5	0.949	S - Welding
4	0.759	G2 - Trolley maintenance
4	0.759	L3 - Inspecting/troubleshooting motors/ motor starters
4	0.759	M6 - Maintenance/repair belt line
3	0.569	M2 - Maintenance/repair transformers surface production equip
3	0.569	N4 - Operating equipment, power hand tools
2	0.380	G1 - Loading/unloading supplies
2	0.380	J3 - Inspecting/troubleshooting indicating circuits
2	0.380	0 - Escaping hazard

TABLE 3.33. Classification by accident location (1975)
Underground mines

# Accidents	%	Location
150	33.482	Track
116	25.893	Outby Entry
116	25.893	Section/Face
61	13.616	Power Center
5	1.116	Shop/Office

TABLE 3.34. Classification by accident location (1975)
Surface mines

# Accidents	%	Location
16	27.119	Mobile Equip
10	16.949	Other
9	15.254	Prep. Plant
9	15.254	Distribution
8	13.559	Shop
7	11.864	Track

TABLE 3.35. Accident classification by injury type (1978)

# Accidents	%	I Injury Type
155	45.723	3 Flash burn
63	18.584	2 Electrical burn
58	17.109	1 Shock
40	11.799	4 Heat burn
13	3.835	7 Reaction to electrical
6	1.770	8 Other
3	0.885	6 Smoke inhalation
1	0.295	5 Explosion
1	0.295	1, 2
3	0.885	4, 5
3	0.885	1, 7

TABLE 3.36. Accident classification of injury degree (1978)

# Accidents	%	D Injury Degree
329	97.050	3 Non-disabling
10	2.950	1 Fatal

TABLE 3.37. Accident classification by hazard type (1978)

# Accidents	%	H Hazard
150	44.248	7 None
75	22.124	4 Abnormal arcs/sparks
45	13.274	8 Unknown or not classifiable
32	9.440	3 Improper insulation
14	4.130	1 Energized ground/frame
13	3.835	2 Energized power conductor thought to be safe
5	1.475	6 Loaded electrical circuit assumed open
4	1.180	9 Lightning
1	0.295	5 Defective tool/protective gear
1	0.295	3, 5

TABLE 3.38. Accident classification by negligence type (1978)

# Accidents	%	Negligence
95	28.024	A No errors
55	16.244	1 Not removing power to circuit under repair
53	15.634	B Unknown or non-classifiable
41	12.094	9 Improper operation
29	8.555	4 Incorrect tool
24	7.080	5 Failure to maintain clearance with boom, truck bed, etc.
21	6.195	7 Not wearing protective gear
18	5.310	6 Failure to maintain clearance with body or hand tool
2	0.590	2 Not ensuring that circuit cannot become energized
1	0.295	8 Abusing equipment

TABLE 3.39. Accident classification by job title (1978)

# Accidents	%	Title
58	17.365	C5 Mechanic - general underground
42	12.575	C2 Electrician - general underground
25	7.485	C4 Laborer - general underground
25	7.485	B2 Motorman - track worker
20	5.988	A6 Roof bolter - section worker
20	5.988	D3 Supervisor - non-union
18	5.389	EC2 Surface electrician
13	3.892	A9 Shuttle car operator - section worker
8	2.395	A2 Continuous miner operator - section worker
8	2.395	E2 Mobile equipment operator - surface
7	2.096	D4 Maintenance foreman - non-union
6	1.796	C1 Beltman - general underground
6	1.796	EC4 Surface laborer - general inside
6	1.796	ED3 Surface supervisory
6	1.796	E3 Prep plant operator - surface
5	1.497	B4 Trackman
4	1.198	AC Wireman - communication
4	1.198	A1 Brattice man/ventilating/stopping builder
4	1.198	A7 Scoop car operator - section worker
4	1.198	C3 Electrician helper
4	1.198	C7 Oiler/greaser/pumper
4	1.198	UN Unknown

TABLE 3.40. Accident classification by injured activity (1978)

# Accidents	%	Injured Activity
40	11.799	T Other
23	6.785	F4 Pulling/moving cable
21	6.195	I1 Energizing/de-energizing circuit breaker
19	5.605	G5 Repair/inspection rail equipment
19	5.605	R Uncontrollable contact
15	4.425	G7 Working in vicinity of trolley
15	4.425	M1 Maintenance/repair underground production equipment
13	3.835	G3 Operating rail equipment
12	3.540	G6 Placing pole on trolley
10	2.950	K2 Maintenance/repair - switches
9	2.655	I2 Operating switches
9	2.655	G4 Placing/removing nip on trolley
9	2.655	K6 Maintenance/repair fuses
8	2.360	F5 Splicing cable
8	2.360	G1 Loading/unloading supplies
8	2.360	J1 Inspecting/trouble shooting circuit breakers
8	2.360	P Repairing/replacing lighting circuitry
7	2.065	H1 Battery maintenance
7	2.065	K1 Maintenance/repair circuit breakers
7	2.065	L1 Inspecting/trouble shooting underground production equipment
7	2.065	M2 Maintenance/repair transformers, surface production equipment
7	2.065	N1 Operating underground production equipment
4	1.180	F2 Hanging cable
4	1.180	F7 Testing cable with test equipment
4	1.180	G2 Trolley maintenance
4	1.180	J6 Inspecting/trouble shooting fuses
4	1.180	L5 Inspecting/trouble shooting pumps
4	1.180	M3 Maintenance/repair

TABLE 3.41. Classification by accident location (1978)
Underground mines

# Accidents	%	Location
88	34.646	Track
84	33.071	Section/face
38	14.961	Power center
24	9.449	Outby entry
11	4.331	Shop/office
9	3.543	Other

TABLE 3.42. Classification by accident location (1978)
Surface mines

# Accidents	%	Location
20	33.898	Prep plant
19	32.203	Distribution
12	20.339	Mobile equipment
6	10.169	Shop
2	3.390	Other

TABLE 3.43. Number of accidents vs injury type, 1979

# of Accidents	%	Injury Type
186	46.5	I3 - Flash Burn
83	20.75	I2 - Electrical Burn
69	17.25	I1 - Shock
17	4.25	I7 - Reaction to Electrical
16	4.0	I4 - Heat Burn
10	2.5	I5 - Explosion
10	2.5	I6 - Smoke Inhalation
5	1.25	I8 - Other
2	0.5	I1, I7
1	0.25	I2, I3
1	0.25	I5, I7

TABLE 3.44. Number of accidents vs degree of injury, 1979

# of Accidents	%	Injury Degree
390	97.5	D3 - Nondisabling
8	2.0	D1 - Fatal
2	0.5	D2 - Disabling

TABLE 3.45. Number of accidents vs injured activity, 1979

# of Accidents	%	Injured Activity
36	9.0	T - Other/Unknown
30	7.5	H1 - Battery Maintenance/Charging
23	5.75	F5 - Splicing Cable
22	5.5	F4 - Pulling/Moving/Handling Cable
22	5.5	R - Uncontrollable Contact
21	5.25	N1 - Operating Underground Production Equip.
16	4.0	M1 - Maintenance/Repair of Underground Prod. Equip.
15	3.75	G5 - Repair/Inspection of Rail Equip.
12	3.0	G3 - Operating Rail Equipment
12	3.0	I1 - Operating Circuit Breakers
11	2.75	G6 - Placing Pole on Trolley
11	2.75	O - Escaping a Hazard
10	2.5	K6 - Maintenance/Repair of Fuses
9	2.25	G2 - Maintenance on Trolley
9	2.25	I2 - Operating Switches
9	2.25	K1 - Maintenance/Repair of Circuit Breakers
9	2.25	K2 - Maintenance/Repair of Switches

TABLE 3.45. (continued)

# of Accidents	%	Injured Activity
8	2.0	F3 - Making Connection at Power Center
8	2.0	J1 - Inspecting Circuit Breakers
8	2.0	L1 - Inspecting Underground Prod. Equipment
7	1.75	G1 - Loading/Unloading Supplies
7	1.75	G4 - Placing/Removing Nip on Trolley
7	1.75	L3 - Inspecting Motors
7	1.75	M3 - Maintenance/Repair Motors
7	1.75	N2 - Operating Surface Production Equipment
7	1.75	P - Repairing/Replacing Lighting Circuitry
7	1.75	S - Welding
6	1.5	K4 - Maintenance/Repair of Transformers
5	1.25	F1 - Checking/Inspecting Cable
4	1.0	F2 - Hanging Cable
4	1.0	F7 - Testing Cable with Test Equipment
4	1.0	G7 - Working in Vicinity of Trolley
4	1.0	M2 - Maintenance/Repair of Surface Production Equipment

(others are less than 1% of the 400 accidents)

TABLE 3.46. Number of accidents vs involved equipment, 1979

# of Accidents	%	Involved Equipment
66	16.5	Cables
65	16.25	Trolley
57	14.25	Underground & Surface Production Equipment
36	9.0	Other/Unknown
33	8.25	Batteries
29	7.25	Circuit Breakers
25	6.25	Miscellaneous (Lighting, Welding, Monitoring Ckts, Rectifiers, Power Hand Tools, Pumps, Beltline)
22	5.5	Uncontrollable Contact
19	4.75	Switches
16	4.0	Motors/Motor Starters
12	3.0	Fuses
11	2.75	Escaping a Hazard
9	2.25	Transformers

TABLE 3.47. Number of accidents vs hazard type, 1979

# of Accidents	%	Hazard	
179	44.75	H7 - None	
90	22.5	H4 - Abnormal Arcs or Sparks	
53	13.25	H8 - Unknown	
32	8.0	H3 - Improper Insulation or Guarding	
19	4.75	H1 - Energized Ground or Frame	
15	3.75	H2 - Energized Conductor Thought Disconnected	
5	1.25	H6 - Putting Power to Loaded Circuit	
4	1.0	H9 - Lightning	
3	0.75	H5 - Defective Tool or Protective Gear	

TABLE 3.48. Number of accidents vs negligence type, 1979

# of Accidents	%	Negligence
112	28.0	NA - No Errors
64	16.0	NB - Unknown
50	12.5	N1 - Not Attempting to Remove Power
42	10.5	N9 - Improper Procedure
34	8.5	N5 - Failure to Maintain Clearance with Nonelec. Equipment
31	7.75	N6 - Failure to Maintain Clearance with Body or Handtool
30	7.5	N7 - Not Wearing Protective Gear
24	6.0	N4 - Incorrect Tool or Improper Use of Equipment
4	1.0	N3 - Failure to Test for Voltage on Conductor
3	.75	N2 - Not Ensuring that Circuit cannot Become Energized
2	.5	N6, N7
1	.25	N8 - Abusing Equipment
1	.25	N1, N4
1	.25	N1, N7
1	.25	N4, N7

TABLE 3.49. Number of accidents vs combined hazard and negligence type, 1979

# of Accidents	%	Hazard	Negligence
69	17.25	H4 - Abnormal Arcs/Sparks	NA - No Errors
49	12.25	H7 - None	N1 - Not Attempting to Remove Power
49	12.25	H8 - Unknown	NB - Unknown Error
34	8.5	H7 - None	N5 - Failure to Maintain Clearance with Nonelec. Equip.
30	7.5	H7 - None	N9 - Improper Procedure
29	7.25	H7 - None	N6 - Failure to Maintain Clearance with Body or Hand Tool
23	5.75	H7 - None	N4 - Incorrect Tool/Improper Use of Equipment
15	3.75	H1 - Energized Ground or Frame	NA - No Errors
15	3.75	H3 - Improper Insulation or Guarding	N7 - Not Wearing Protective Gear
13	3.25	H3 - Improper Insulation or Guarding	NA - No Errors
12	3.0	H4 - Abnormal Arcs or Sparks	N7 - Not Wearing Protective Gear
5	1.25	H2 - Energized Conductor Thought Disconnected	NB - Unknown Error
5	1.25	H4 - Abnormal Arcs or Sparks	N9 - Improper Procedure
4	1.0	H7 - None	NA - No Errors
4	1.0	H9 - Lightning	NA - No Errors

(others are less than 1% of the 400 accidents)

TABLE 3.50 Accident classification by injury type
for 1975, 1978, 1979

Number of Accidents	%	Injury Type	
657	51.90	I3	Flash Burn
279	22.04	I2	Electrical Burn
181	14.30	I1	Shock
55	4.34	I4	Heat Burn
31	2.45	I7	Reaction to Electrical
15	1.18	I5	Explosion
14	1.11	I6	Smoke Inhalation
14	1.11	I8	Other
6	0.48	I1, I7	
3	0.24	I4, I5	
2	0.16	I1, I2	
2	0.16	I3, I7	
1	0.08	I1, I4	
1	0.08	I2, I3	
1	0.08	I3, I5	
1	0.08	I5, I7	
1	0.08	I2, I7	

Table 3.5I. Accident classification by injury degree
for 1975, 1978, 1979

Number of Accidents	%	Injury Degree	
1234	97.472	D3	Non-Disabling
30	2.370	D1	Fatal
2	0.158	D2	Permanent Partial or Total Disability

TABLE 3.52. Accident classification by hazard type
for 1975, 1978, 1979

Number of Accidents	%	Hazard	
583	46.05	H7	None
290	22.91	H4	Abnormal Arcs/sparks
129	10.19	H8	Unknown or Not Classifiable
115	9.08	H3	Improper Insulation
54	4.27	H2	Energized Power Conductor Thought to be Safe
50	3.95	H1	Energized Ground/Frame
31	2.45	H6	Loaded Electrical Circuit Assumed Open
9	0.71	H9	Lightning
4	0.32	H5	Defective Tool or Protective Gear
1	0.08	H3, H5	

TABLE 3.53. Accident classification by negligence type
for 1975, 1978, 1979

Number of Accidents	%	Negligence	
349	27.567	NA	No Errors
215	16.983	N1	Not Removing Power to Circuit Under Repair
171	13.507	N9	Improper Operation
163	12.875	NB	Unknown
93	7.346	N5	Failure to Maintain Clearance with Boom, Truck-bed, etc.
92	7.267	N4	Incorrect Tool
82	6.477	N7	Not Wearing Protective Gear
76	6.003	N6	Failure to Maintain Clearance with Body or Hand Tool
16	1.264	N2	Not Ensuring That the Circuit Cannot Become Energized
5	0.395	N8	Abusing Equipment
4	0.316	N3	Failure to Test for Voltage on Conductor
2	0.16	N6, N7	
1	0.08	N1, N4	
1	0.08	N1, N6	
1	0.08	N1, N7	
1	0.08	N4, N7	

TABLE 3.54. Accident classification by hazard and associated negligence
for 1975, 1978, 1979*

Number of Accidents	%	Hazard - Negligence Pair
218	17.22	H4-NA
209	16.51	H7-N1
122	9.64	H8-NB
92	7.27	H7-N5
92	7.27	H7-N9
88	6.95	H7-N4
69	5.45	H7-N6
55	4.34	H3-NA
44	3.48	H3-N7
41	3.24	H1-NA
30	2.37	H4-N7
26	2.05	H6-N9
21	1.66	H4-N9
21	1.66	H2-N9
15	1.18	H4-NB
14	1.11	H7-NA

* Hazard-Negligence Pairs associated with less than 1% of the accidents are not listed.

TABLE 3.55. Accident classification by job title
for 1975, 1978, 1979*

Number of Accidents	%	Job Title
221	17.457	C5 Mechanic-general underground
157	12.401	C2 Electrician-general underground
93	7.346	B2 Motorman-track worker
89	7.030	C4 Laborer-general underground
62	4.897	A9 Shuttle Car Operator-section worker
60	4.739	A6 Roof Bolter-section worker
58	4.581	D3 Supervisor-non-union
52	4.107	EC2 Surface Electrician
41	3.239	A2 Continuous Miner-section worker
40	3.160	EC5 Surface Mechanic
33	2.607	D2 Section Foreman-non-union
28	2.212	D4 Maintenance Foreman-non-union
25	1.975	E2 Mobile Equipment Operator-surface
24	1.896	C1 Beltman-general underground
22	1.738	A4 Loading Machine Foreman-section worker
20	1.580	E3 Preparation Plant Operator-surface
18	1.422	A7 Scoop Car Operator-section worker
17	1.343	AC Wireman-communication
17	1.343	B4 Trackman
15	1.185	EC4 Surface Laborer
14	1.106	C7 Oiler/Greaser/Pumper

* Job Titles associated with less than 1% of the accidents are not listed.

TABLE 3.56. Accident classification by injured activity
for 1975, 1978, 1979*

Number of Accidents	%	Injured Activity	
105	8.294	T	Other
72	5.687	F4	Pulling/Moving Cable
69	5.450	F5	Splicing Cable
66	5.213	G5	Repair/Inspection of Rail Equipment
62	4.897	G3	Operating Rail Equipment
61	4.818	R	Uncontrollable Contact
56	4.423	N1	Operating Underground Production Equipment
55	4.344	H1	Battery Maintenance/Charging
52	4.107	I1	Operating Circuit Breakers
47	3.712	M1	Maintenance/Repair Underground Production Equipment
43	3.397	G4	Placing/Removing Nip on Trolley
43	3.397	G6	Placing Pole on Trolley
40	3.160	I2	Operating Switches
37	2.923	K6	Maintenance/Repair Fuses
34	2.686	G7	Working in Vicinity of Trolley
32	2.528	K1	Maintenance/Repair Circuit Breakers
31	2.449	K2	Maintenance/Repair Switches
29	2.291	F1	Checking/Inspecting Cable
29	2.291	P	Repairing/Replacing Lighting Circuitry
27	2.133	L1	Inspecting/Troubleshooting Underground Production Equipment
25	1.975	J1	Inspecting/Troubleshooting Circuit Breakers
21	1.659	F3	Making Connection at Power Center
18	1.422	M3	Maintenance/Repair Motor Starters - Motors
17	1.343	G1	Loading/Unloading Supplies
17	1.343	G2	Maintenance on Trolley
16	1.264	F7	Testing Cable with Test Equipment
15	1.185	N2	Operating Surface Production Equipment
15	1.185	O	Escaping a Hazard
15	1.185	S	Welding
14	1.106	M2	Maintenance/Repair of Surface Production Equipment
13	1.027	F2	Hanging Cable
13	1.027	L3	Inspecting/Troubleshooting Motor Starters - Motors

*Injured Activities associated with less than 1% of the accidents are not listed.

TABLE 3.57. Classification by accident location - underground
for 1975, 1978, 1979

Number of Accidents	%	Location
330	32.706	Track
321	31.814	Section/Face
169	16.749	Outby Entry
154	15.263	Power Center
24	2.379	Shop/Office
11	1.090	Other

TABLE 3.58. Classification by accident location - surface
for 1975, 1978, 1979

Number of Accidents	%	Location
55	27.094	Mobile Equipment
54	26.601	Preparation Plant
47	23.153	Distribution
19	9.360	Other
16	7.882	Shop
12	5.911	Track

TABLE 3.59. Injured activity and hazard type interaction
for 1975, 1978, 1979*

#	%	Injured Activity	Hazard Type
52	4.11	G5: Trolley Repair/Inspection of Rail Equipment	H7: None
40	3.16	T: Unknown	H7
39	3.1	T:	H8: Unknown
39	3.1	I1: Energizing/Deenergizing Circuit Breakers	H4: Abnormal Arcs or Sparks
38	3	F4: Pulling/Moving Cable	H3: Improperly Insulated or Guarded
36	2.84	F5: Splicing Cable	H7:
34	2.69	R: Uncontrollable Contact	H4:
34	2.69	G3: Operating Rail Equipment on Trolley	H4:
31	2.45	H1: Battery Maintenance/Charging	H7:
30	2.37	K6: Maintenance/Repair Fuses	H7:
30	2.37	F4: Pulling/Moving Cable	H4:
24	2.29	M1: Maintenance/Repair of Underground Production Equipment	H7:
29	2.29	G6: Placing Pole on Trolley	H7:
27	2.13	K1: Maintenance/Repair Circuit Breaker	H7:
27	2.13	G7: Working in Vicinity of Trolley	H7:
25	1.97	G4: Placing/Removing Nip on Trolley	H6: Putting Power to an Electrical Circuit
21	1.66	P: Repairing/Replacing Lighting Circuit	H7:
19	1.5	N1: Operating Underground Production Equipment	H7:
19	1.5	K2: Maintenance/Repair of Switches	H7:
16	1.26	G3: Operating Rail Equipment on Trolley	H7:
16	1.26	L1: Inspecting/Troubleshooting of Underground Production Equipment	H7:
16	1.26	N1: Operating Underground Production Equipment	H4:
15	1.18	J1: Inspecting/Troubleshooting Circuit Breakers	H7:
15	1.18	F1: Checking/Inspecting Cable	H4:
14	1.11	G1: Loading/Unloading Supplies	H7:
15	1.18	M3: Maintenance/Repair Motor/Starters	H7:
13	1.03	N1: Operating Underground Production Equipment	H1: Energized Frame
13	1.03	F7: Testing Cable with Test Equipment	H7:

* Interactions less than 1% are not listed.

TABLE 3.60. Injured activity and negligence interaction
for 1975, 1978, 1979*

#	%	Injured Activity	Negligence
56	4.42	R : Uncontrollable Contact	NA: None
52	4.11	F4: Pulling/Moving Cable	N7: Not Wearing or Using Protective Gear
49	3.87	G3: Operating Rail Equipment on Trolley	NA:
44	3.48	T : Unknown	NB: Unknown
41	3.24	I1: Energizing/Deenergizing Circuit Breakers	NA:
35	2.76	F5: Splicing Cable	N1: Not Attempting to Remove Power
31	2.45	G4: Placing/Removing Nip on Trolley	N9: Improper Operation
29	2.29	I2: Energizing/Deenergizing Switches	NA:
27	2.13	N1: Operating Underground Production Equipment	NA:
27	2.13	K6: Maintenance/Repair Fuses	N1:
26	2.05	G5: Repair/Inspecting of Rail Equipment	N5: Failure to Maintain Clearance with Boom, Truck-bed
22	1.74	K1: Maintenance/Repair Circuit Breakers	N1:
20	1.58	M1: Maintenance/Repair of Underground Production Equipment	N1:
19	1.5	G6: Placing Pole on Trolley	N9:
19	1.5	T : Unknown	NA:
18	1.42	G7: Working in the Vicinity of Trolley	N5:
16	1.26	N1: Operating Underground Production Equipment	N9:
16	1.26	H1: Battery Maintenance/Charging	NB:
16	1.26	H1:	N9:
16	1.26	G5:	N1:
15	1.18	K2: Maintenance/Repair of Switches	N1:
14	1.11	F5: Splicing Cable	N9:
13	1.03	M3: Maintenance/Repair of Motors/Starters	N1:
13	1.03	G1: Loading/Unloading Supplies	N5:
13	1.03	F7: Testing Cable with Test Equipment	N4:

* Interactions less than 1% are not listed.

CHAPTER IV

RESEARCH CATEGORIES

4.1 INTRODUCTION

One objective of this report is to indicate to the Bureau what effect their out-of-house research funding has had on electrical accidents. A cost/benefit comparison is chosen as this indicator. Research funds expended is the cost, and expected reduction in electrical accidents as a result of the research is the benefit. This analysis is meant to indicate where the Bureau is spending its money most efficiently in terms of potential reduction in electrical accidents. Also, during this investigation, analysis of the accident data can indicate problem areas, based on the number of accidents in those areas where the research is insufficient or nonexistent. Such areas should probably be reviewed by the Bureau to determine if they should allocate more money for research.

4.2 IDENTIFICATION OF ELECTRICAL RESEARCH CONTRACTS

In the effort to assess the impact which Bureau of Mines sponsored research has had on electrical accidents, it was first necessary to determine the nature and quantity of research which they have sponsored. The Minerals Research Contract Review (MRCR), which lists all active and completed contracts granted by the Bureau of Mines from July 1, 1969 through December 31, 1980, was used to generate a list of contracts which seemed to be electrically oriented. This list was based on the contract title. Any title which was even remotely suggestive of electrical research was incorporated into the list. As a result, many contracts were included in the original list which had little to do with electrical research, and a few which did may have been overlooked. In an effort to be as complete as possible, a computer printout was obtained from the Denver Research Center which lists all of the Bureau's contracts and memorandum of agreements involving studies of electrical technology beginning after December, 1974. No in-house research was incorporated in the list.

Once the list of possible electrical contracts was complete, abstracts were obtained for each one to determine its orientation and its content. These abstracts came from three different sources: the report documentation page as copied from the report itself at the USBM library in Pittsburgh, the abstract as it appears in the Open File Report listing of the U. S. Bureau of Mines List of Publications and Articles, or telephone conversations with the contract's Technical Project Officer (TPO). Most of the contracts which were completed and had an Open File Report number were found from the first two sources. The last source served mainly for those contracts which are still active or have not yet been put on open file. All abstracts were reviewed to determine orientation and all those which were not electrically oriented were removed from the list.

To assess the impact of a specific type of research on specific accidents or accident types, it became necessary to assign the research into descriptive categories. This facilitated the cost/benefit analysis

by making it easier to determine the funds spent on a specific type of research as well as the benefits realized from implementation of that research. Thus, the abstracts were read and specific areas and types of research were defined. These areas and types were sorted, evaluated, and combined where possible to form the different categories. Each category was given a title which is descriptive of the nature of the research in it.

4.3 MONEY ASSIGNMENT

Each report or contract abstract was reviewed again to determine with which research topics each one dealt. They were then placed in the appropriate descriptive category. Thus, to allocate funding to each category, the amount spent on each individual report must be determined and then the amount spent on each independent topic in that report must be determined also.

4.3.1 Contract Report Funds

Assignment of funds to the individual contracts was only a problem when there was more than one piece of research under a particular contract number. The total money spent on any contract number was obtained from the "Research Contract Summary Report" supplied by the Denver Research Center. This report covers the period from July 1, 1969 through July 10, 1981 and lists the cumulative funds awarded per contract number for the fiscal years of 1970 through 1977, and then individually for the fiscal years 1978, 1979, 1980, and 1981. The active contracts could usually be assigned money with little trouble using the values listed in this report. Some of the actives had completed reports under the contract number in addition to ongoing research. These could usually be determined by the itemization given in the "Research Contract Summary Report". If not, they underwent the same type of procedure which the completed reports did, as described below.

The number and type of reports filed under a contract number was obtained from the aforementioned MRCR and an updated version of the "Open File Report Listing" obtained from the Denver Research Center. This listing was updated through July 10, 1981. Once the total money spent and the number and types of reports generated for a particular contract number were found, the remaining job was to determine the portion of the total money spent which corresponded to each report. The following example is given for illustration:

Contract # G0133077 Penn State OPR# 75-076

Vol. 0	Mine Electrical Systems Evaluation	501 pp
Vol. 1	Cable Splicing	208 pp
Vol. 2	Explosion-Proofing of Mine Containers	76 pp
Vol. 3	Transient Analysis	42 pp
Vol. 4	Mine Power System Performance	123 pp
Vol. 5	Model Coal Mine Electrical System Specifications	55 pp
Total Money Spent -		\$98,979

The reports under a contract number were first grouped into research periods. The above example is one such period. Usually, each Volume 0 and associated reports were considered as a research period, or if no volume designation was made, each report or group of related reports was considered a research period. The different periods were evaluated to determine the percentage effort they represented in relation to the total research under the contract number. This was done subjectively by considering the time span covered and the number and volume of the reports generated in the period. Once the percentage effort was determined, money was assigned accordingly. Each report within the period was assigned an equal portion of the money allocated to that period. Thus, in the example, assuming that the final report (Vol. 0) was broken into five sections (Vol. 1 - Vol. 5) which were produced also as individual reports, each of the volumes (1 through 5) was assigned one-fifth of the total. An undeterminable error is introduced at this point and should be recognized.

4.3.2 Contract Topics Assigned Money

As noted before, each contract report might cover a variety of research areas or topics. These different areas were placed in different research categories, making it necessary to specify the portion of funds that each topic represented in the report. This was accomplished by determining the percentage effort the topic represented to the whole. This percentage was assigned subjectively, based upon the emphasis given the topic in the abstract or from personal knowledge of the report. Equal weight was given to the topics if there was no indication to the contrary. Money was allotted each topic in proportion to the percentage effort assigned it.

4.4 CATEGORY BREAKDOWN

Each research topic in each report and active contract has an associated dollar figure with it which represents the money spent by the Bureau upon that particular topic in that particular report. All of the topics are organized into the descriptive categories to which they pertain. No single topic is in more than one category. The categories are listed here along with a summary of the research in the category, a list of associated contract numbers, and the total research money spent on the category. The categories are presented in order of contract funding from the most expensive to the least expensive. The cumulative total Bureau spending on all the categories which impact electrical accidents (1 through 24) is shown below.

Bureau of Mines Funding for Research Directly Affecting Electrical Accidents
\$6,311,000

4.4.1 Research Category #1 - Cable Fault Locators

Summary of Research - Development of the Time Domain Reflectometry Micro-computer (TDRM) locator. Design and fabricate prototype cable fault locators. Develop field models of the TDRM. Redesign of the TDR cable fault locator. Evaluate TDR's built by Bendix. Develop alternative means of cable fault locating to the TDR design.

Contract Listing - H0346138 J0377021
 H0122011 H0166082
 H0366020

Bureau Funding - \$873,000

4.4.2 Research Category #2 - Cable Splice Material Improvement

Summary of Research - Improve the quality, dependability, and design of splice kits and shop splices by establishing recommended guidelines and regulations for medium voltage (661-1000 volts). Develop a ground and pilot conductor to improve trailing cable splice performance. Improve the ground and pilot connectors used in splices. Improve the splice connectors for phase conductors. Develop splice testing procedures and evaluation techniques. Determine splice resistance to failure using an environmental simulation machine.

Contract Listing - H0166069 G0199036 J0199106
 H0377042 G0133077
 H0357100 G0101729

Bureau Funding - \$694,000

4.4.3 Research Category #3 - Protective Device Reliability and Coordination

Summary of Research - Reliability and fail-safe assessment of various components of the mine electrical system including the protective system. Evaluation of the suitability of certain protective equipment used in utilities to mine power systems. Investigation of protective device performance characteristics and effectiveness. Development of a cookbook procedure for coordinating the circuit-protection devices in the mine distribution system. Optimize spares and maintenance scheduling for various power system components. Determine the reliability of system components and the resultant reliability of the total system; establish fail-safe functions and distributions. Modeling the reliability of the power system to predict injuries and fatalities from electrical causes.

Contract Listing - G0144137 J0395035
 G0122088 G0188097
 G0101729 J0199119

Bureau Funding - \$673,000

4.4.4 Research Category #4 - DC Circuit Breaker Performance - Withstand Capability

Summary of Research - Define dc system parameters under which protective devices must operate; determine currently available breakers and their adequacy to perform fault interruption, investigate design modifications to improve this ability. Develop a portable calibrator to check the trip settings of dc circuit breakers. Develop a current limiting device for high speed switching of dc circuits. Develop a device to reduce arc energy at the contacts of a dc circuit (a high current bypass for dc circuit breakers).

Contract Listing - H0122058 H0366013
 H0357079 H0395047

Bureau Funding - \$532,000

4.4.5 Research Category #5 - DC Discriminating Circuit Breaker

Summary of Research - New Approach to trolley line fault detection based upon the detection of current difference between feeder and load currents. Investigation of techniques for providing a discriminating control sensitive to low level fault and leakage currents. Verify the practicability of the complete discriminating circuit breaker concept. Detection of low level faults and disconnection from the trolley supply.

Contract Listing - H0242004 H0242064
 H0122058

Bureau Funding - \$451,000

4.4.6 Research Category #6 - Proximity Warning Devices

Summary of Research - Three electrostatic field sensing proximity warning devices tested. Development of warning devices using the electrostatic field around the power lines. Investigation of alternative methods to the detection of the 60 Hz field for providing proximity warning.

Contract Listing - J0188082
 J0318064

Bureau Funding - \$377,000

4.4.7 Research Category #7 - Inter-Machine Arcing - Ignition Hazard

Summary of Research - Analysis of induced voltage and currents in portable trailing cables and their influence on ignition hazard. Analysis of inter-machine arcing. Investigation into the mechanisms causing ignition in the PTB breakflash and the importance of discharge duration in the ignition process. Evaluation of the cadmium disc breakflash and parameters affecting discharge and ignition.

Contract Listing - G0122088 H0111585
 H0155038

Bureau Funding - \$266,000

4.4.8 Research Category #8 - Predicting Incipient Failure

Summary of Research - Development of tests and instrumentation to detect incipient faults. Tests applicable to periodic inspection of mine electrical systems and components to provide early warning of equipment failure. Continuous monitoring. Methods for detecting deteriorating splices are investigated. Detection of deterioration modes is used as a basis for the evaluation of the system's ability to predict incipient failure. Incipient detection by periodic measurement of insulation parameters.

Contract Listing - G0144137 G0144138
 G0155003

Bureau Funding - \$250,000

4.4.9 Research Category #9 - Ground Wire Monitoring

Summary of Research - Provide USBM with a customized wireless ground monitor system. Development of a modular ground wire monitor. Development of an apparatus designed to test commercial monitors. Analysis of audio frequency ground-check techniques applied to very long cables. Development of a combined ground fault-ground check monitoring system.

Contract Listing - H0166034 G0188087
 G0144138 J0199116
 G0122088

Bureau Funding - \$220,000

4.4.10 Research Category #10 - Stray Currents - Generation and Effects

Summary of Research - Investigation of ac and dc ground-wire current generation. Evaluation of the effect of earth currents from dc haulage lines on ground beds, grounding, and ground monitoring. Electrolytic corrosion tests of ground beds. Method of detecting defective trolley line insulators and an investigation into the feasibility of a two-wire trolley system. Development of a technique to detect bad rail bonds and an assessment of grounding techniques for dc face equipment.

Contract Listing - G0144128 J0188083
 G0155003 G0188087

Bureau Funding - \$193,000

4.4.11 Research Category #11 - Improved Trolley Pole Operation

Summary of Research - Concept generation and prototype design of "improved pole tracking", automatic "rapid pole retraction" in the event of de-wirement, and servo-operated "remote pole repositioning" on the trolley wire.

Contract Listing - J0377057

Bureau Funding - \$157,000

4.4.12 Research Category #12 - Low Voltage Shielding for Shock Elimination

Summary of Research - Suggestions for installation, handling, and maintenance plus the investigation of advantages and disadvantages of low-voltage shielded trailing cables. Suitability of utilizing low-voltage shielded trailing cables investigated by laboratory and in-mine testing. An analysis of low-voltage shielded trailing cables was performed to develop a method for calculating the differences in operating costs between shielded and non-shielded cables.

Contract Listing - G0155003 G0188036
 G0155197

Bureau Funding - \$154,000

4.4.13 Research Category #13 - Cable Mechanical Stress Elimination

Summary of Research - Improve cable reel systems for shuttle cars. Design and construct a cable reel control system to significantly reduce cable whip. Cable-stress locations, magnitudes, and frequency of occurrence identified. Cable stress relaxation and reduction in jerk through a better cable reel mechanism.

Contract Listing - J0395102 G0155197

Bureau Funding - \$141,000

4.4.14 Research Category #14 - Sensitive Ground Fault Detection

Summary of Research - Feasibility study of devices to eliminate shock; evaluate the application of GFI for mines.

Contract Listing - J0113009

Bureau Funding - \$138,000

4.4.15 Research Category #15 - Remote Control Trolley Energizing/Deenergizing

Summary of Research - Development of a portable remote control circuit breaker system; features include ability to trip, reset, and adjust remote circuit breaker from a transmitter located on a mine locomotive. Development of a system to remotely energize and deenergize the trolley wire in a section in response to demands from vehicles as they enter and leave the controlled section. Development of a system to provide deenergizing of the trolley when a vehicle's trolley pole is removed.

Contract Listing - H0366029 J0188164
H0166157

Bureau Funding - \$135,000

4.4.16 Research Category #16 - Cable Handling Devices (Underground)

Summary of Research - Design of a separate independently powered tender to serve as a cable handling device for continuous miner cable.

Contract Listing - H0122011

Bureau Funding - \$109,000

4.4.17 Research Category #17 - Elimination of Shuttle Car Trailing Cables

Summary of Research - Investigate alternative power methods for operating shuttle cars.

Contract Listing - H0220004

Bureau Funding - \$103,000

4.4.18 Research Category #18 - DC Ground Fault Interruption

Summary of Research - Evaluation of a Hall-type device for monitoring low-level dc leakage currents in grounding conductors of off-track machines. Developmental use of trippable load-break switches to clear dc ground faults in trailing cables.

Contract Listing - H0242064
G0188097

Bureau Funding - \$92,000

4.4.19 Research Category #19 - Cable Shield Integrity

Summary of Research - Investigation to find a commercial device which could function to detect holes, missing sections, or other defects in the cable shield assuming the semiconducting material underneath is still in satisfactory condition.

Contract Listing - J0188081

Bureau Funding - \$75,000

4.4.20 Research Category #20 - Cable Handling Methods and Devices - Surface

Summary of Research - Investigate cable handling problems in surface mines and the methods used to solve them.

Contract Listing - J0395088

Bureau Funding - \$71,000

4.4.21 Research Category #21 - Battery and Battery-Charger Safety

Summary of Research - Electrical safety research in the area of battery and battery-charger safety. Safety considerations in the use of lead-acid batteries for traction purposes.

Contract Listing - G0155003

Bureau Funding - \$68,000

4.4.22 Research Category #22 - Reduction of Accidental Contact with the
Trolley

Summary of Research - Investigate the feasibility of continuous insulation along the trolley wire.

Contract Listing - J0188083

Bureau Funding - \$54,000

4.4.23 Research Category #23 - Ungrounded Power System Analysis

Summary of Research - An analysis of the performance requirements of isolated systems and design and performance specifications for an isolated system.

Contract Listing - H0111465

Bureau Funding - \$45,000

4.4.24 Research Category #24 - Cable Handling Methods (Underground)

Summary of Research - Recommendations to mine operators include cable-handling suggestions that will increase personnel safety, productivity, and cable life.

Contract Listing - G0155197

Bureau Funding - \$23,000

4.4.25 Research Category #25 - Electrical Research not Directly Affecting Electrical Accidents

All of the research directly affecting electrical accidents has been assigned to the preceding categories. The research in this category has been evaluated and organized into three separate subcategories. Each subcategory has a descriptive title and cumulative total spending along with a total spending for each research area under the subcategory. The total spending for the category, which is the total money spent by the Bureau for research on electrical safety which did not directly affect electrical accidents, is shown below.

Total Bureau Funding - \$14,330,000

4.4.25.1 Electrical Research with Expected Direct Impact on Electrical
Accidents but None Found or No Way to Identify the Affected
Accidents

Total Bureau Funding - \$2,501,000

Research Topic A - Power System Load Flow and Fault Analysis

Summary of Research - Design of optimal mine electrical distribution system including optimized selection of molded case circuit breakers. Computer program to verify the correct settings of haulage circuit breakers. Improve APL Load Flow Program. Computer modelling of mine electrical systems. Presentation of two mine electrical system simulators. Power system design considerations of alternate network topologies, optimum voltage selection, and selection of system components. Interactive mine power simulation model constructed. Development of a physical model of a typical ac-dc coal mine section electrical system. Instrumentation developed to analyze mine electrical systems on a dynamic basis. Load flow and short-circuit analysis on mine power systems. Development of software for programmable calculators that is useful in the analysis and design of mine power systems. Determination of work output of motors on continuous miners.

<u>Contract Listing</u> -	G0144137	G0188097
	G0188035	G0133077
	G0155003	H0111585
	G0101729	J0199060

Bureau Funding - \$1,061,000

Research Topic B - Cable Couplers

Summary of Research - Investigate whether high-and medium-voltage trailing cable couplers must have a metallic shell as required by part 75.805. Develop a permissible high-voltage connector which could be used on underground trailing cables. Develop the mechanism for opening high-voltage connectors under load. Improvements in quality, dependability, and safety of high- and medium-voltage trailing cable couplers in the form of requirements for couplers. Requirement compliance testing of connector assemblies. Failure-mode determination by performance monitoring of high-voltage cable couplers. Effects of corona and methods of prevention.

<u>Contract Listing</u> -	H0166069	H0377043	J0199060
	H0188155	H0110423	
	H0188068	G0188035	

Bureau Funding - \$550,000

Research Topic C - Cable Ampacity and Protection

Summary of Research - Reports on overload and short-circuit protection and cable ampacity -- includes many facts related to circuit breaker settings and cable size. Data on intermittent duty ratings for cables for face equipment and the required protection to prevent damage once the duty rating is known.

Contract Listing - H0377043

Bureau Funding - \$278,000

Research Topic D - Ground Bed Resistance and Continuity

Summary of Research - Development of a continuous ground bed monitor. Ground bed construction and measurement techniques developed. Electrical parameter measurements of finite-layered conducting surfaces. Extensive guide to grounding and bonding procedures for mine surface substations. Evaluation of Xit-rods; investigation of composite ground beds; effect of penetrating the coal seam with a borehole safety ground.

<u>Contract Listing</u> -	G0144137	G0188087
	G0144138	J0199116

Bureau Funding - \$260,000

Research Topic E - Equipment Failures Resulting From Transients

Summary of Research - Digital prediction of electrical transients and testing of suppression devices. Presentation of electrical utility investigations of transient phenomena and a description of a system proposed to record mine power system transients. Elimination of safety hazards created by transients and development of a low-cost peak-detector. Investigation of the effects of repetitive, low-level transients on insulation systems.

Contract Listing - G0144137 G0133077
 G0155003 G0188097

Bureau Funding - \$161,000

Research Topic F - Cable Jacket Integrity

Summary of Research - A cold bend test recommended to be used in conjunction with the flame resisting test to check the integrity of the jacket.

Contract Listing - G0155197

Bureau Fundings - \$67,000

Research Topic G - Gradients - Touch and Step Potentials

Summary of Research - Investigation of gradient determination and studies of touch and step potentials were performed. Development of a prototype potential gradient plotter.

Contract Listing - G0144138

Bureau Funding - \$43,000

Research Topic H - Prep Plant Electrical Classifications

Summary of Research - Recommended uniform guidelines for interpreting NEC as applied to classification of hazardous areas in coal prep plants.

Contract Listing - J0166059

Bureau Funding - \$43,000

Research Topic I - DC Cable Integrity Monitor

Summary of Research - Development of a method of removing power to a dc cable in case of conductor separation.

Contract Listing - J0395012

Bureau Funding - \$38,000

4.4.25.2 Electrical Research with No Expected Direct Impact on Electrical Accidents but with Expected Impact on Nonelectrical Accidents

Total Bureau Funding - \$11,486,000

Research Topic A - Inherently Safe Mining Systems

Summary of Research - Development and demonstration of equipment modification in both conventional and continuous coal mining systems.

Contract Listing - H0111670

Bureau Funding - \$8,472,000

Research Topic B - Explosion-Proof Enclosures

Summary of Research - Examination of the problems associated with the presence of water and organic materials in EPE's. Proposed additions and modifications to EPE design requirements. Suggestions for acceptance criteria of adhesives and sealants for EPE's. Development of quick-opening permissible electric enclosure access cover and flame-path tolerance checking system. Investigation of arcing faults and their interactions with electrical insulating materials within coal-mine power system enclosures. Provision of recommended test and acceptance procedures and criteria for MSHA to use in approving explosion-proof load centers. Development of a permissible pressure vent (ss foam) and a urethane grommet cable entry device. Development of better EPE and better ways to maintain them.

Contract Listing - G0155197 H0308093
 G0133077 H0357107
 H0387009 J0100041
 H0122010 H0377052

Bureau Funding - \$1,899,000

Research Topic C - Automated and Remote Control Machines

Summary of Research - Automated haulage of existing battery-powered equipment to follow a guide-path of electrically excited wires fixed to the mine roof. Feasibility of remote control and development of remote control devices and sensors for shuttle cars and continuous miners.

Contract Listing - H0155103
 J0395012

Bureau Funding - \$387,000

Research Topic D - Intrinsic Safety

Summary of Research - Evaluation in status of standardization of "intrinsic safety". Regulation evaluation and supporting information on intrinsic safety.

Contract Listing - H0111585
 J0177111

Bureau Funding - \$250,000

Research Topic E - Solid State Controls

Summary of Research - General effect that the use of solid state devices might have on the safe operation of underground machines. Application of solid state devices on electrical systems.

Contract Listing - H0111194
J0308035

Bureau Funding - \$213,000

Research Topic F - Lighting

Summary of Research - Development of a power supply operated from dc trolley wires to provide power to flourescent or mercury vapor lamps.

Contract Listing - H0166031

Bureau Funding - \$167,000

Research Topic G - Electrical Detonators

Research Summary - Investigation of electrical and electrostatic effects on detonators.

Contract Listing - J0308113

Bureau Funding - \$98,000

4.4.25.3 Electrical Research with Possible Indirect Impact on Electrical
Accidents

Summary of Research - Development of application-oriented notes to be used by mine electrical engineers. Preparation of a comprehensive report describing all phases of electrical applications in mines. Determination of the relative effect of Bureau electrical research on underground coal electrical accidents.

Contract Listing - J0377065 J010096

Bureau Funding - \$343,000

CHAPTER V

IMPACT OF RESEARCH ON ACCIDENTS

5.1 INTRODUCTION

The objective of this section is to assess the impact of the research categories upon the electrical accidents. The results of this evaluation will be used as the benefits in the benefit/cost analysis at the end of the chapter. The costs were presented in Chapter IV as the total money spent by the Bureau on each category.

5.2 DEFINITION AND SEARCH FOR IMPACTED ACCIDENTS

Initially each category was evaluated as to what type or types of accidents it might impact. This was accomplished by reviewing the type of research done under each category and making certain assumptions about the final outcome or results of the work. These assumptions were evaluated, clarified, and recorded for reference during the assessment stage. Keeping in mind the type of research in each category, particular accidents and accident types were defined as possibly being impacted by that research. These accidents were recorded to be assigned identifiers later. Secondly, a hazard, negligence, injured activity, or combination of the three which would define an occurrence which might be impacted by the research was defined for each category.

All of the accidents were encoded in a standard format and stored in the WVU computing facilities. A retrieval method using specific identifiers from this encoded format was chosen, since a manual search of the 1300 accidents was impractical. Each specific accident or accident type associated with a category was evaluated to determine what entries or combination of entries in the format could be used as identifiers to that particular accident. As it turned out, only five different entries were required, whether separately or in combination, to completely identify the accident or accident type. These entries were: hazard, negligence, injured activity, injury type, and injury location. Definitions of these entries and the format used is given in Chapter II. A combination or several combinations of these identifiers were developed to describe each particular accident associated with a category. The identifiers were fed into the computer which searched the cumulative accident data file. A listing was produced for each category of all the accidents corresponding to that category's identifiers which contained all of the available information about the accidents. Because of the nature of the encoding and retrieval system, many accidents which had nothing to do with the particular category in question were obtained. However, the quantity of these was very much less than the original 1300 accidents. Also, oftentimes the identifiers could be associated with the category without having to specify any particular accident type. This was helpful in assuring that all of the accidents impacted by a category were retrieved.

5.3 LIMITATIONS OF IMPACT ASSESSMENT

When evaluating the impact that a research category might have on a

particular accident, a degree of subjectivity is necessarily introduced. The extent of subjectivity is dependent upon the particular accident and the nature of the research in the category. The accident description is often illegible, insufficient, or worded to hide any violation which might have caused the accident. In these situations, a scenario of the events leading to the accident must be hypothesized in order to evaluate any possible impact. Also, as mentioned before, certain assumptions about the outcome or results of the research must be made in order to have a basis for the impact evaluation. The degree of subjectivity varies proportionally according to these factors.

To avoid making an unfounded decision where there was not sufficient information to develop a sound scenario, an impact level of "possibly impacted" was included. This level includes all of the accidents where, due to the inadequacy of the accident reporting, it is unclear just what device or machine was involved in the accident and how it was involved, but there is a reasonable probability that the actual situation was one which would be impacted by the research. Also, there are certain accidents which may appear on the surface to be impacted by a particular research category, but due to the assumptions about the outcome or the underlying cause of the accident are really not affected. To indicate these accidents, a level of "definitely not impacted" is included. Finally, for those accidents involving a device or procedure which would most surely be affected by the research, a level of "definitely impacted" was included. These three designations help to clarify the evaluation.

No assumption concerning the percentage effectiveness of the research implementation was made. In other words, for those accidents in the definitely impacted and possibly impacted categories, no attempt was made to determine what percentage of these could be eliminated upon implementation of the research results. Each accident has the potential to be eliminated or reduced in severity or it would not be included in the impacted categories, but it is impossible to determine what percentage would actually be eliminated.

5.4 IMPACT EVALUATION

Each category was evaluated as to the types of accidents it might impact and a computer listing of these accidents was generated for each category. Any assumptions about the results of the research were made and the levels of assessment were established. The following represents the evaluation made for each category. The information given about each one includes: the types of accidents expected to be impacted; the identifiers for the accidents; the number and type of accidents definitely and possibly impacted, including an example (Note: The example description is worded as it appears on the computer printout and is the actual or abbreviated description which appeared on the original accident report.); the type of accident which may be thought to be impacted but isn't (if there is any); and finally any assumptions made about the outcome of the research.

5.4.1 Research Category #1 - Cable Fault Locaters

Expected Impact - Shock or burn injuries when people are handling or probing the cable looking for a fault.

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>
		F1	
		F7	
		<u>Number</u>	<u>Days Lost</u> <u>Fatalities</u>
<u>Accidents Definitely Impacted</u>		15	152 0

Type - Employee is shocked or burned when handling, probing, or testing cable while looking for a fault. (Cable is normally energized from the power center but sometimes from a fault locator.) (Example: Cable shorted looking for bursted place in cable and it blew up.)

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Possibly Impacted</u>	15	465	0

Type - Employee was examining or checking (could possibly have been looking for faulted place). (Example: Checking cable; cable grounded and burned in two - flash burned eyes.)

Definitely Not Impacted

Type - Shorted probes or exploding meters while testing for voltage at inby end of cable.

Research Assumptions

Application of this research will produce a locator which will be used on disconnected cables and operate such that the test voltage and current will not be high enough to create any shock or burn hazards.

5.4.2 Research Category #2 - Cable Splice Material Improvement

Expected Impact - Accidents where employee touches or picks up cable in vicinity of a splice and is shocked - Splice blows up burning, shocking or creating a reaction and accidents where the splice heats up enough to create a burn hazard.

Accident Identifiers

<u>Hazards</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>
H3	N7	Fx	
H3	NA	Fx	
H4	N7	Fx	
H4	NA	Fx	
H4	NA	R	

<u>Accidents Definitely Impacted</u>	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
	16	131	0

Type - Employee is burned, shocked, or injured by his reaction to a splice blowing up. Employee is shocked at or near a splice due to the failure of the splice insulation. (Example: Feeding rockduster and splice in cable blew, burning right wrist.)

<u>Accidents Possibly Impacted</u>	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
	71	673	0

Type - Any cable handling shock, burn, or reaction to, in which no specific cause is detailed (i.e. a splice is not indicated as the problem source but there is reason to believe it may be.) (Example: Anchoring buggy cable; drill cable blew up in face.)

Definitely Not Impacted

Type - Any cable accident which can be determined not to be at a splice.

Research Assumptions

Application of this research will eliminate catastrophic failure and insulation breakdown in cable splices.

5.4.3 Research Category #3 - Protective Device Reliability and Coordination

Expected Impact - Catastrophic failure of protective equipment.

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>
H4		I1	
H4		H2	
H4		R	

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Definitely Impacted</u>	51	562	0

Type - Injuries resulting from the explosion of system circuit breakers and switches when there is no indication that the employee did anything other than operate the device. (Example: Putting breaker in, hole was blown through bottom of box burning hands.)

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Possibly Impacted</u>	10	107	0

Type - Breaker or switch blows up, on operation, injuring the employee and it is indicated that he had just performed some type of maintenance on the device (i.e. he may have caused the explosion by improper maintenance.)
Accidents resulting from an arc occurring at the connecting plugs, probably caused by contamination. Accidents where it is unclear whether it is the breaker or switch which arcs or something else. (Example: Had replaced breaker in load circuit, activated switch on breaker and a short occurred.)

Definitely Not Impacted

Type - Accidents resulting from an arc in a breaker when the cover of the breaker has been removed.

Research Assumptions

Application of this research would result in established maintenance schedules and guidelines for power system components and provide more reliable and fail-safe replacement components.

5.4.4 Research Category #4 - DC Circuit Breaker Performance - Withstand Capability

Expected Impact - Accidents resulting from dc circuit breakers blowing up when people are energizing or deenergizing them or simply standing in the vicinity when one blows up.

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>		
H4		I1			
		J1			
		K1			
		H2			
		<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>	
Accidents Definitely Impacted		2	6	0	

Accidents Definitely Impacted

Type - Employee is injured by a dc circuit breaker explosion when he attempts to energize or deenergize it or he is simply standing in the vicinity when it blows. (Example: Injured was pulling breaker without removing fuse nip).

<u>Accidents Possibly Impacted</u>	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
	28	529	0

Type - Injuries resulting from circuit breaker explosions when it is not possible to determine whether it is an ac or dc application. Injuries occurring while the cover is off of the breaker and it is not evident that the arc is generated by breaker failure. (Example: Resetting a breaker and it exploded, burning eyes.)

Definitely Not Impacted

Type - Accidents occurring where ac systems can be specifically identified.

Research Assumptions

Application of this research would produce improved dc circuit breakers with higher interrupting capacity and more ability to contain any internal arcs which occur.

5.4.5 Research Category #5 - DC Discriminating Circuit Breaker

Expected Impact - Accidents involving the trolley line, which result from an arc, short circuit, or low-current fault which create a burn or shock hazard.

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>
	NA	G3	
	NA	R	
	N5	G7	

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Definitely Impacted</u>	11	153	0

Type - Employee is shocked or burned when track or production equipment contacts the trolley wire. Accidents where an employee contacts the trolley wire and the track with some device thereby creating a high-resistance or direct short. (Example: A piece of trolley wire fell on motor.)

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Possibly Impacted</u>	20	134	0

Type - Shock or burn accidents occurring from accidental contact with a conductive device to the trolley where it is doubtful that the resulting current level could be detected by the discriminating breaker. (Example: Working on crossover when pipe flipped and contacted trolley wire.)

Definitely Not Impacted

Type - Accidents resulting from faults on-board track equipment (the protective devices on-board are responsible for removing all faults on the equipment.) Accidents involving the arc which occurs when the pole jumps off the trolley.

Research Assumptions

Application of this research would provide a discriminating dc breaker which could detect low-level fault currents on the trolley, but a screening device would shield faults occurring in track equipment and would be located between the harp and fuse on the trolley pole.

5.4.6 Research Category #6 - Proximity Warning Devices

Expected Impact - Burn and shock accidents resulting from equipment contacting bare overhead energized conductors.

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>
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N5

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Definitely Impacted</u>	10	3915	6

Type - Employee is shocked or burned when he contacts overhead high voltage lines with his piece of equipment. (Example: Raised drill boom and contacted wires.) (Fatality: Injured raised his truck bed into power lines.)

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Possibly Impacted</u>	1	999	0

Type - Accidents where it is unclear whether a machine which would have a proximity warning device on it is involved. (Example: Lifting piece of scaffolding, handrail came in contact with high voltage line.)

Definitely Not Impacted

Type - Accidents involving the trolley wire.

Research Assumptions

Application of this research would provide devices, whether installed on the equipment or on the lines, which would detect the proximity of a piece of equipment to an overhead electric line and alert the operator of such proximity.

5.4.7 Research Category #7 - Inter-Machine Arcing-Ignition Hazard

Expected Impact - Fire and explosion resulting from arcing and shocks resulting from voltage differences between machines.

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>
H1	NA		

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Definitely Impacted</u>	3	18	0

Type - Shocks occurring due to a potential difference between the frames of two pieces of equipment and due to a potential on the frame of a shuttle car (assuming the protective and monitoring devices involved are functional). (Example: Touched rock duster and mine car and received an electric shock.)

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Possibly Impacted</u>	4	24	0

Type - Accidents where personnel are shocked but it is unclear whether it is from a potential on a frame or other source. (Example: Operator was turning shuttle car on and was shocked.)

Definitely Not Impacted

Type - Shock hazards not generated by stray or unbalanced currents on equipment frames.

Research Assumptions

Application of this research would eliminate the ignition hazard associated with inter-machine arcing and a byproduct of this effect would reduce voltage differences on machines, reducing the shock hazard to personnel.

5.4.8 Research Category #8 - Predicting Incipient Failure

Expected Impact - Shock, fire and explosion accidents resulting from insulation failure.

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>
H4	NA		
H3	NA		

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Definitely Impacted</u>	6	44	0

Type - Accidents where it is apparent that the insulation may have been deteriorating for some time. (Example: Operating loader when cable caught fire.)

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Possibly Impacted</u>	57	653	0

Type - Cable explosions which could have been a result of insulation failure or mechanical damage and shorted leads and cables which could have resulted from the same. (Example: Applying power to a trailing cable when nearby splice blew up.)

Definitely Not Impacted

Type - Accidents resulting from grounded leads on track equipment and those involving cables and components which would not be expected to be tested for insulation failure.

Research Assumptions

Application of this research would detect deteriorating insulation in cables, motors, and transformers.

5.4.9 Research Category #9 - Ground Wire Monitoring

Expected Impact - Shock hazards due to energized machine frames. (Note! Ground check monitors have been required by law and enforced by MSHA since December 31, 1977.)

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>
H1			

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Definitely Impacted</u>	4	16	0

Type - Shock injuries which result from an energized frame of an ac or three-wire grounded dc machine due to continuity loss in the ground conductor. (Example: Back over loader cable causing loader to become energized.)

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Possibly Impacted</u>	16	139	1

Type - Accidents occurring from an energized shuttle car frame (could be ac or dc). Accidents where it is unclear whether the machine frame is energized or the injury results from some other source. (Example: Worker picked up a can of welding rods while sitting in his shuttle car.)

Definitely Not Impacted

Type - Accidents occurring on ungrounded dc equipment.

Research Assumptions

Application of this research will eliminate energized machine frames which occur during phase-to-frame faults and are a result of a noncontinuous ground conductor.

5.4.10 Research Category #10 - Stray Currents - Generation and Effects

Expected Impact - Shock and fire accidents resulting from voltage differences on equipment frames - Accidents resulting from ground bed continuity loss by deterioration - Elimination of corrosion of water and communication lines in the vicinity of the haulage track and reduction in false tripping of ground monitors and improved relay coordination.

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>
H1			

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Definitely Impacted</u>	0	0	0

Type - Shocks from machine frames which are energized by stray currents flowing in their ground conductors.

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Possibly Impacted</u>	8	47	0

Type - Shocks occurring from machine frames which may have been energized by stray currents. (Example: Touched rock duster and mine car and received an electric shock.)

Definitely Not Impacted

Type - Shock injuries from machine frames when it is evident that a fault was the source of energization.

Research Assumptions

Application of this research would eliminate the stray dc currents on ground wires generated by track vehicles.

5.4.11 Research Category #11 - Improved Trolley Pole Operation

Expected Impact - Shock or burn injuries due to setting, resetting, removing, or reversing of the trolley pole.

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>
		G6	
H7	N9	G3	
H7	NA	G3	

<u>Accidents Definitely Impacted</u>	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
	24	256	1

Type - Shock or burn injuries caused by exposure to live conductors or proximity to arcs, while turning, placing, or removing the pole. (Example: Put pole on trolley wire, had hand on leads and they grounded out.) (Fatality: Putting trolley pole back on wire and evidently stumbled lodging between wire and roof.)

<u>Accidents Possibly Impacted</u>	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
	16	64	0

Type - Eye injuries resulting from looking at the arc which occurs when placing the pole on the trolley (employee may still look at it but he will not be as close to it). Accidents involving the trolley pole which are suspected to be as described above but the descriptions are too vague to be certain. (Example: Put motor pole on trolley wire causing an arc burning both eyes.)

Definitely Not Impacted

Type - Injuries occurring to the eyes when an arc is produced as the pole jumps off the trolley wire.

Research Assumptions

Application of this research would provide a means so that the operator is remote from the pole during setting, resetting, removing and reversing of the pole.

5.4.12 Research Category #12 - Low-Voltage Shielding for Shock Elimination

Expected Impact - Cable handling shock on trailing cables and cable tapping or accidental abuse - Possibly reduce significance of faulty repair accidents.

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>
H3	NA	Fx	
H3	N7	Fx	
H7	NA	Fx	
H7	N8	N1	
H7	N9	N1	

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Definitely Impacted</u>	45	646	0

Type - Employee is shocked or burned while handling trailing cable and contacts exposed conductor on weak insulation. (Including dc and reeled applications.) Employee is shocked or burned from a normally noncurrent-carrying article or structure which has been energized by contact with an exposed trailing cable conductor. (Example: Moving excess trailing cable out of roadway when he contacted an exposed conductor.)

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Possibly Impacted</u>	6	81	0

Type - Injuries resulting from cable explosions (phase-to-phase faults). (Type of shielding (SHD or SHC) will determine impact on these accidents). (Example: Injured got in canopy of miner to move it, pinched miner cable causing flash.)

Definitely Not Impacted

Type - Accidents resulting from arcs which occur when a cable is torn or cut in two.

Research Assumptions

Application of this research will result in total shielding of all low-voltage trailing cables, including reeled situations.

5.4.13 Research Category #13 - Cable Mechanical Stress Elimination

Expected Impact - Shock or burn hazards resulting from mechanical cable damage scrape, tear, conductor parting, etc.

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>
H3		F1	
H3		F2	
H3		F4	
H3		R	
H4		F1	
H4		F2	
H4		F4	
H4		R	

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Definitely Impacted</u>	0	0	0

Type - Employee is injured by an explosion or arc resulting from conductor separation, due to high stress or whip in a reeled-cable application. (Also includes splice separation)

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Possibly Impacted</u>	73	1117	0

Type - Shock or burn injuries resulting from mechanical cable damage (i.e. scrape, tear, etc.) on reeled cables. Also cable handling injuries where it is not possible to determine whether or not it was in a reeled application and cable explosions which may have been generated by conductor separation but cannot be specifically determined. (Example: Holding shuttle car anchor when trailing cable blew up.)

Definitely Not Impacted

Type - Accidents specifying nonreeled applications.

Research Assumptions

Application of this research will produce an improved cable reel which would eliminate the jerk and alleviate most of the tension stress on reeled cables.

5.4.14 Research Category #14 - Sensitive Ground Fault Detection

Expected Impact - Shock from exposed ac conductors (cables or in a power center).

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>
H1			
H2			
H3			
H7	N1		
H7	N2		
H7	N3		
H7	N6		
H8	N1		
H8	N2		
H8	N3		
H8	N6		

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Definitely Impacted</u>	147	2653	2

Type - Employee is shocked from an exposed conductor in a cable (assuming the cable is ac if not specified). Accidents involving a line-to-ground fault, not on a cable, which are obviously on the load side of the circuit. Employee cuts into an energized cable and receives a shock or he is handling the cable at a splice and receives a shock. (Example: Moving cable when his hand contacted damaged place in outer insulation.) (Fatality: Attempting to splice cable and contacted live wire.)

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Possibly Impacted</u>	114	2071	5

Type - Shocks occurring on shuttle car and bolter cables (could be either ac or dc) and accidents involving the circuit breaker where it cannot be determined whether it is on the line or load side. Accidents which are unclear as to whether they are line-to-line or line-to-ground faults. (Example: Attempting to deenergize breaker with fingers, contacted power leads.) (Fatality: Splicing buggy cable without unplugging it.)

Definitely Not Impacted

Type - Shock accidents which occur on dc or high-voltage systems.

Research Assumptions

Application of this research would eliminate the low-level fault current that flows in a high-resistance line-to-ground fault on low-voltage load and control circuits.

5.4.15 Research Category #15 - Remote Control Trolley Energizing/Deenergizing

Expected Impact - Accidents occurring when off-track equipment is moved under and contacts a live trolley and also those injuries resulting from contact with the trolley when men are working around or near a live trolley wire (i.e. loading and unloading supplies, etc.)

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>
		0	
H7	N1	Gx	
H7	N5	Gx	
H7	N6	Gx	
H7	N9	Gx	

<u>Accidents Definitely Impacted</u>	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
	85	825	0

Type - Injuries resulting from accidental contact of body or object with the trolley wire. (Assuming only one vehicle per track section at a time and all poles are removed from the trolley wire when the vehicle is not moving or preparing to move.) Employee is injured by the arc which occurs when the trolley pole is placed on the wire. (Example: While jacking supply onto the track, jack handle hit trolley wire.)

<u>Accidents Possibly Impacted</u>	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
	15	172	1

Type - Accidents occurring around or involved with a track vehicle when it is unclear whether the pole should be off the trolley wire or not. (Example: Door on tool car contacted trolley wire, the car moved as he was closing the door.)

Definitely Not Impacted

Type - Accidents involving the arc which occurs when the pole is removed or jumps from the trolley wire. Accidents occurring while pole is on the trolley wire.

Research Assumptions

Application of the research in this category would mean that no trolley section would be energized except when there was specific demand for it to be. Assume a slight delay is introduced before the trolley is energized when the pole is being put on (thus no arc occurs when putting on under load).

5.4.16 Research Category #16 - Cable Handling Devices (Underground)

Expected Impact - Shock or burn accidents resulting from the handling of energized miner cable.

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>
		F1	
		F2	
		F4	

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Definitely Impacted</u>	7	26	0

Type - Employee is shocked or burned as a result of handling energized continuous miner cable. (Example: Dragging miner cable when cable made contact with legs.)

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Possibly Impacted</u>	28	378	0

Type - Cable handling accidents which cannot be determined whether or not they are involved with continuous miner cable. (Example: Moving cable and received electrical shock.)

Definitely Not Impacted

Type - Accidents occurring while hanging or checking or inspecting cable.

Research Assumptions

Application of this research would produce a device to handle the energized miner cable so that the employee would not have to touch the cable very often and also reduce his proximity to the cable during normal operation.

5.4.17 Research Category #17 - Elimination of Shuttle Car Trailing Cable

Expected Impact - All accidents dealing with the shuttle car trailing cable.

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>
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Fx

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Definitely Impacted</u>	37	565	1

Type - Cable accidents which specifically indicate that they involve shuttle car trailing cable. (Example: Injured was taking a shuttle car cable off a crossover when cable shorted and blew up.)

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Possibly Impacted</u>	111	1806	1

Type - Cables accidents where it cannot be determined whether it is a shuttle car cable or not. (Example: Attempting to tape a cable and contacted electric power.)

Definitely Not Impacted

Type - Accidents involving cables which are specified as non-shuttle car trailing cables.

Research Assumptions

Application of this research would provide a method of power supply to shuttle cars other than by a trailing cable.

5.4.18 Research Category #18 - DC Ground Fault Interruption

Expected Impact - Elimination of shock and fire hazards occurring in off-track dc machines.

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>
H1	NA	N1	
H1	NA	R	

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Definitely Impacted</u>	0	0	0

Type - Accidents resulting from a ground fault on a dc circuit.

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Possibly Impacted</u>	7	24	0

Type - Ground fault accidents which cannot be determined as to whether they are ac or dc systems. (Example: Contacted energized frame while getting in or out of shuttle car.)

Definitely Not Impacted

Type - Accidents which can be identified as being on ac circuits.

Research Assumptions

Application of this research would detect and interrupt low level dc ground faults in off-track dc machines.

5.4.19 Research Category #19 - Cable Shield Integrity

Expected Impact - Shock hazard elimination on shielded cables.

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>
H3			Fx

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Definitely Impacted</u>	2	37	0

Type - Shocks from surface cables which are expected to be shielded. (Example: Employee stated he received an electrical shock to his leg when he moved the cable.)

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Possibly Impacted</u>	12	98	0

Type - Employee is shocked while handling cable but it cannot be determined whether it is shielded cable or not. (Example: Hanging cable barehanded and touched split place in the cable and received shock.)

Definitely Not Impacted

Type - Cable accidents which can be determined to be non-shielded low-voltage trailing cables.

Research Assumptions

Application of this research will eliminate the possibility of receiving a shock while handling shielded cable.

5.4.20 Research Category #20 - Cable Handling Methods and Devices - Surface

Expected Impact - Accidents dealing with cable handling in surface mines.

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>	<u>Accident Location</u>
		Fx		Surface

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Definitely Impacted</u>	2	37	0

Type - Employee is injured while handling surface cables. (Example: Handled cable near splice while moving machine.)

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Possibly Impacted</u>	0	0	0

Type -

Definitely Not Impacted

Type - Accidents involving underground cables.

Research Assumptions

Application of this research will provide means and methods to handle energized surface cables without presenting a hazard to personnel.

5.4.21 Research Category #21 - Battery and Battery Charger Safety

Expected Impact - Shock, fire, or explosion accidents dealing with batteries and battery charging.

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>	
		H1	I5	
		H2	I5	
		R		
		<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
Accidents Definitely Impacted		42	150	1

Type - Accidents in which an improper procedure or ignorance creates an explosion, arc, or shock hazard while working with or around batteries or battery chargers. (Example: Charging battery, crossed terminals on wrong post; battery blew up.)

		<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Possibly Impacted</u>		0	0	0

Type -

Definitely Not Impacted

Type - Accidents involving maintenance, by maintenance people, on the battery charger.

Research Assumptions

Application of this research would result in better training programs and a set of guidelines to follow in nearly all situations in which batteries and battery charging are involved.

5.4.22 Research Category #22 - Reduction of Accidental Contact with the Trolley

Expected Impact - Shock or burn accidents resulting from contact with the trolley - flash burns occurring from arcs generated by contact of equipment or devices with the trolley (not including trolley pole).

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>
H3	N5	Gx	
H3	N6	Gx	
H3	NA	Gx	
H3	N5	Gx	
H7	N6	Gx	
H7			

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Definitely Impacted</u>	82	701	2

Type - Accidents resulting from accidental contact of the body or some device with the trolley wire. Accidents involving an arc which occurs after the trolley pole has jumped off the wire and then contacts it with some part of its conductive structure or wiring. (Example: Was talking to foreman and took hold of trolley wire.)

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Possibly Impacted</u>	7	29	0

Type - Accidents where the employee is working on the wire and accidentally creates a ground and those where the trolley wire falls contacting a piece of equipment. (Example: Injured was operating locomotive when trolley wire fell and arced, burning eyes.)

Definitely Not Impacted

Type - Accidents involving the arc which occurs when the pole jumps off or is removed under load from the wire and those involving arcs which occur at section switches during switching.

Research Assumptions

Application of this research would provide continuous insulation along the trolley and redesign of the trolley shoe such that the insulation could nearly enclose the wire, making accidental contact with the live conductor very unlikely.

5.4.23 Research Category #23 - Ungrounded Power System Analysis

Expected Impact - Accidents occurring when people are working in a power center or electrical enclosure and contact phase to ground.

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>
	N1	Jx	
	N1	Kx	
	N1	Lx	
	N2	Jx	
	N2	Kx	
	N2	Lx	
	N6	Jx	
	N6	Kx	
	N6	Lx	
	N7	Jx	
	N7	Kx	
	N7	Lx	

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Definitely Impacted</u>	9	112	0

Type - Employee is working on a live circuit and inadvertently grounds a phase creating a flash. (Example: Changing out feeder breaker, allen wrench touched distribution box frame and burnt hand.)

	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
<u>Accidents Possibly Impacted</u>	30	493	0

Type - Accidents where it is suspected that the employee created a short but the description is not definite or specific. Accidents where it is unclear whether a phase-to-ground fault or a phase-to-phase fault occurred. (Example: Wrench fell on electrical device causing flash.)

Definitely Not Impacted

Type - Employee is shocked by grounding a phase (i.e. there is enough stray capacitance to ground in an ungrounded system to still allow enough current to flow to produce a shock hazard but not enough to produce a substantial arc).

Research Assumptions

Application of this research would provide ungrounded power systems but the ground wire connecting all equipment frames would still be present.

5.4.24 Research Category #24 - Cable Handling Methods (Underground)

Expected Impact - Shock or burn accidents resulting from the handling of energized cable.

Accident Identifiers

<u>Hazard</u>	<u>Negligence</u>	<u>Injured Activity</u>	<u>Injury Type</u>
		F1	
		F2	
		F4	

<u>Accidents Definitely Impacted</u>	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
	52	677	0

Type - Employee is shocked or burned while handling energized cable. (Example: Moving cable when his hand contacted damaged place in outer insulation.)

<u>Accidents Possibly Impacted</u>	<u>Number</u>	<u>Days Lost</u>	<u>Fatalities</u>
	38	864	0

Type - Hand injuries resulting from explosions while handling energized cable. Injuries occurring while checking, inspecting, or examining energized cable. (Example: Examining shuttle car cable and cable exploded causing flash burns to eyes.)

Definitely Not Impacted

Type - Injuries resulting from cable explosions which are to parts of the body other than the hands.

Research Assumptions

Application of this research would provide methods and guidelines for handling underground energized cables which if applied correctly would significantly reduce the injury hazards associated with such handling.

5.5 COST/BENEFIT TO THE BUREAU

A typical cost/benefit analysis refers the costs and benefits to some standard unit, normally money. In order to do that for this analysis, a monetary value would have to be assigned to an accident, a day away from work, or to a fatality. To evaluate the price of an accident to the government or to society is certainly beyond the scope of this report and no attempt will be made to do so. The expected benefits and the cost is presented in Table 5.5.1 for the reader's inspection and anyone desiring to do a standard cost/benefit analysis may assign their own figures to the accidents and go from there. The table contains the following information for each category: total funding cost; number of accidents definitely and possibly impacted; number of associated days lost; and the number of fatalities definitely and possibly impacted.

5.6 AREAS WHERE MORE RESEARCH IS NEEDED

An analysis of electrical accidents and research areas shows that Bureau research has been carried out with respect to nearly every type of accident. There are several areas in which future research appears to be highly desirable in terms of reducing electrical accidents. The items listed here are not ranked in order of importance. Some of them are extremely simple, and are really suggestions for alterations in equipment design. Others would require a great deal of work. It is quite likely that a few are already underway.

A. A sensitive ground fault interrupter, that would work on 480 V 3-phase systems to drastically reduce arcing and sparking when a high-resistance ground fault occurs. Care must be taken to assure that this system is not prone to false trips.

B. A study to determine the costs and benefits (safety and monetary) of such practices as monthly visual inspections of circuit breakers.

C. A simple cable fault locator that could be located in every mining section.

D. Design of control circuits, breakers, and other pieces of equipment with diagnostic sockets so that they may be tested without taking them apart or entering energized cabinets. An extension of this would be to design self-diagnostic control circuitry.

E. Methods by which workers could be easily warned of the dangers of energized conductors. This might take the form of some sort of visual indication by the insulation that a field was present, indicating lights on breakers and catheads to show that conductors are energized, or small sensors in screwdrivers and cable skinning knives to warn that a field was present.

F. Design of all sizes of fuses to provide a clear visual indication that they are blown.

G. Design of special tools for electrical work. These would include a goof-proof multimeter and probe arrangement, and insulated or non-conducting screwdrivers and wrenches. They should have special configurations to mate with electrical connectors such that their use would be encouraged.

H. Design of switches and breakers that do not flash or eject material under any condition. An alternative would be to develop solenoid-operated devices which could be operated remotely by low-power control circuits.

I. Design of fuse boxes and breakers so that access is prevented while the power is on. Design of reliable (probably mechanical) interlocks for small boxes, panels, etc.

J. Redesign of molded case circuit breakers to prevent accumulations of dirt on terminals from initiating phase-to-phase faults and to prevent the operator from contacting any live parts by slipping off the handle.

K. Design of control circuits to prevent arcs at trolley poles and nips that result from making and breaking these contacts under load.

L. Redesign of batteries and battery connections. Use of incompatible + and - terminals to prevent crossed connections. Use of recessed battery terminals to prevent accidental contact. Use of a battery cable connector that would provide no exposed energized conductor when attached to a battery. Use of completely insulated battery tops.

M. Control circuitry for battery chargers which will deenergize charger when no battery is present to be charged.

N. Design breakers and fuses so that inadequate interrupting capacity devices are physically incompatible with the mount or bracket.

O. Addition of insulators on top of jeeps and locomotives to "catch" any trolley wire that falls or sags down into contact with the vehicle.

P. Redesign the trolley wire to provide better inherent protection from accidental contact. Redesign trolley pole so that the energized lead is completely inaccessible to a person handling the pole.

Q. Develop a control circuit to deenergize all portions of a locomotive except the lights and radio whenever the vehicle is not moving.

R. Develop plastic-coated light bulbs that will not explode if defective or abused, such as the coating for camera flash bulbs. Make base design of bulbs for different voltage levels incompatible.

TABLE 5.5.1. Category costs and benefits

Research Category	Electrical Accidents Definitely Impacted				Electrical Accidents Possibly Impacted			
	No.	Lost Days	Fatals		No.	Lost Days	Fatals	Funding
Cable Fault Locators (#1)	15	152	0		15	465	0	\$873,000
Cable Splice Material Improvement (#2)	16	131	0		71	673	0	\$694,000
Protective Device Reliability and Coordination (#3)	51	562	0		10	107	0	\$673,000
DC Circuit Breaker Performance-Withstand Capability (#4)	2	6	0		28	529	0	\$532,000
DC Discriminating Circuit Breaker (#5)	11	153	0		20	134	0	\$451,000
Proximity Warning Devices (#6)	10	3915	6		1	999	0	\$377,000
Intermachine Arcing - Ignition Hazard (#7)	3	18	0		4	24	0	\$266,000
Predicting Incipient Failure (#8)	6	44	0		57	653	0	\$250,000

TABLE 5.5.1. Category costs and benefits (continued)

Research Category	Electrical Accidents Definitely Impacted			Electrical Accidents Possibly Impacted			Funding
	No.	Lost Days	Fatals	No.	Lost Days	Fatals	
Ground Wire Monitoring (#9)	4	16	0	16	139	1	\$220,000
Stray Currents - Generation and Effects (#10)	0	0	0	8	47	0	\$193,000
Improved Trolley Pole Operation (#11)	24	256	1	16	64	0	\$157,000
Low-Voltage Shielding for Shock Elimination (#12)	45	646	0	6	81	0	\$154,000
Cable Mechanical Stress Elimination (#13)	0	0	0	73	1117	0	\$141,000
Sensitive Ground Fault Detection (#14)	147	2653	2	114	2071	5	\$138,000
Remote Control Trolley Energizing/Deenergizing (#15)	85	825	0	15	172	1	\$135,000
Cable Handling Devices (Underground) (#16)	7	26	0	28	378	0	\$109,000

TABLE 5.5.1 Category costs and benefits (continued)

Research Category	Electrical Accidents Definitely Impacted		Electrical Accidents Possibly Impacted		Funding		
	No.	Days Lost	Fatals	No.		Lost Days	
Elimination of Shuttle Car Trailing Cables (#17)	37	565	1	111	1806	1	\$103,000
DC Ground Fault Interruption (#18)	0	0	0	7	24	0	\$ 92,000
Cable Shield Integrity (#19)	2	37	0	12	98	0	\$ 75,000
Cable Handling Methods and Devices - Surface (#20)	2	37	0	0	0	0	\$ 71,000
Battery and Battery-Charger Safety (#21)	42	150	1	0	0	0	\$ 68,000
Reduction of Accidental Contact with the Trolley (#22)	82	701	2	7	29	0	\$ 54,000
Ungrounded Power System Analysis (#23)	9	112	0	30	493	0	\$ 45,000
Cable Handling Methods (Underground) (#24)	52	677	0	38	864	0	\$ 23,000

CHAPTER VI

DEVELOPMENT OF MODEL MINES

6.1 INTRODUCTION

Power system models for a surface and underground coal mine were developed as a foundation for the assessment of the relative economic impact which implementation of the various research results would have on the coal industry. The models were constructed from information gathered during mine visits, from personal interviews, from commercial and educational literature, and from previous coal mining experience. During the visits, active working power systems were observed from the utility supply point to utilization by the various pieces of mining equipment. Many of the companies visited supplied one-line diagrams of their substations, power centers, rectifiers, and distribution systems in addition to granting personal interviews with their electrical people. Also, interviews were held with MSHA inspectors and directors concerning prevalent practices and applications of coal mine power systems. Commercial and educational literature on power system design and components generated a good basis for development of the models and additional telephone consultations, clarifying specific questions which arose during the actual construction of the models, were made with both industry and educational people experienced in the field of power system design and construction.

6.2 MODEL SIZE DETERMINATION

The underground model is considered as representative and not necessarily average. It presents a four-section mine of 150 employees, while the statistical average mine, based on the Quarterly Employment and Coal Production Reports, MSHA Form 7000-2, which mine operators submitted to MSHA Health and Safety Analysis Center in Denver four quarters of 1979, has an employment level of 64 persons, working 115,000 man-hours annually and producing 136,000 tons of clean coal. The inclusion of the small punch mines and one-section mines in the calculation of the statistically "average" mine significantly reduces its size. Thus, considering the necessity of mine size and production capacity in evaluating the relative cost of power system alterations, the larger four-section mine was chosen as more representative in terms of economic impact.

The statistically "average" surface mine was chosen to be "representative" after several conversations with knowledgeable industry and MSHA personnel. The model presents a single-pit operation, which is considered the most common type of surface mine. Based upon the employment and production reports as described above, the surface model represents the "average" mine, which employs 24 persons who work on the average of 50,000 man-hours per year and produce 166,000 tons of clean coal annually.

6.3 MINE MODELS

The models were developed for the purpose of a cost analysis tool and as such they do not contain every intricate detail of a mine power system,

but only those necessary to facilitate the safety changes and produce continuity and completeness of concept. Each model is presented separately and as a complete entity, containing statement of intended purpose, size, and mining method determination and justification. This facilitates any external usage which might be found for them and ensures that no misunderstanding concerning the technical extent or design of the models occurs if the model is removed from this text and applied in another situation.

6.3.1 Power System Model for Underground Coal Mine

The following model of an underground coal mine power system concentrates its detail primarily in the main substation and underground portion of the power system. This is a result of accident data analysis which indicates these to be the primary areas involving electrical accidents. This model is developed for the use of relative cost-benefit analysis of certain safety-related changes and should be viewed in that sense. This model is not intended as a guide for power system design or as a representation of state-of-the-art technology and practice. It is made to represent present practice and is to be used as an instructive tool to show mine owners and operators the relative advantage of certain procedural and component changes. Being primarily a cost analysis tool it does not delve into all the intricacies of an actual mine power system.

The model contains the locations and equipment most frequently involved in electrical accidents with enough specifications to handle the proposed safety changes. The particular configuration and components used are a result of several mine visitations and past experience. They represent as closely as possible a power system layout and size corresponding to an underground mine of representative size and production capacity. This mine employs 150 persons who work a total of 270,000 man-hours annually and produce 200,000 tons of clean coal.

The mine modeled is a four-section operation employing belt haulage of coal and track haulage of men and supplies. Only the conventional and continuous mining methods are represented because together they constitute over 91 percent of all coal produced underground in the United States as of 1978, with the conventional and continuous methods responsible for approximately 25 and 66 percent, respectively. Thus the model includes three continuous sections and one conventional section. The model does not incorporate any special situations which might be present in some specific situations such as very low coal.

A block diagram of the model is given in Figure 6.1. It contains a single primary substation through which power enters the system from the utility supply. The voltage is transformed down to the company's surface distribution level and transmitted to branch substations via four-wire overhead distribution lines. These lines consist of three phase conductors and a static line mounted above the phase conductors for lightning protection. The main and peripheral substations are all owned and maintained by the company. The surface loads are shown only for completeness and except for the borehole substation will not be considered further in the model. Power enters the underground section directly from the main substation through the portal and indirectly through a remote borehole. This configuration represents an expanded radial system.

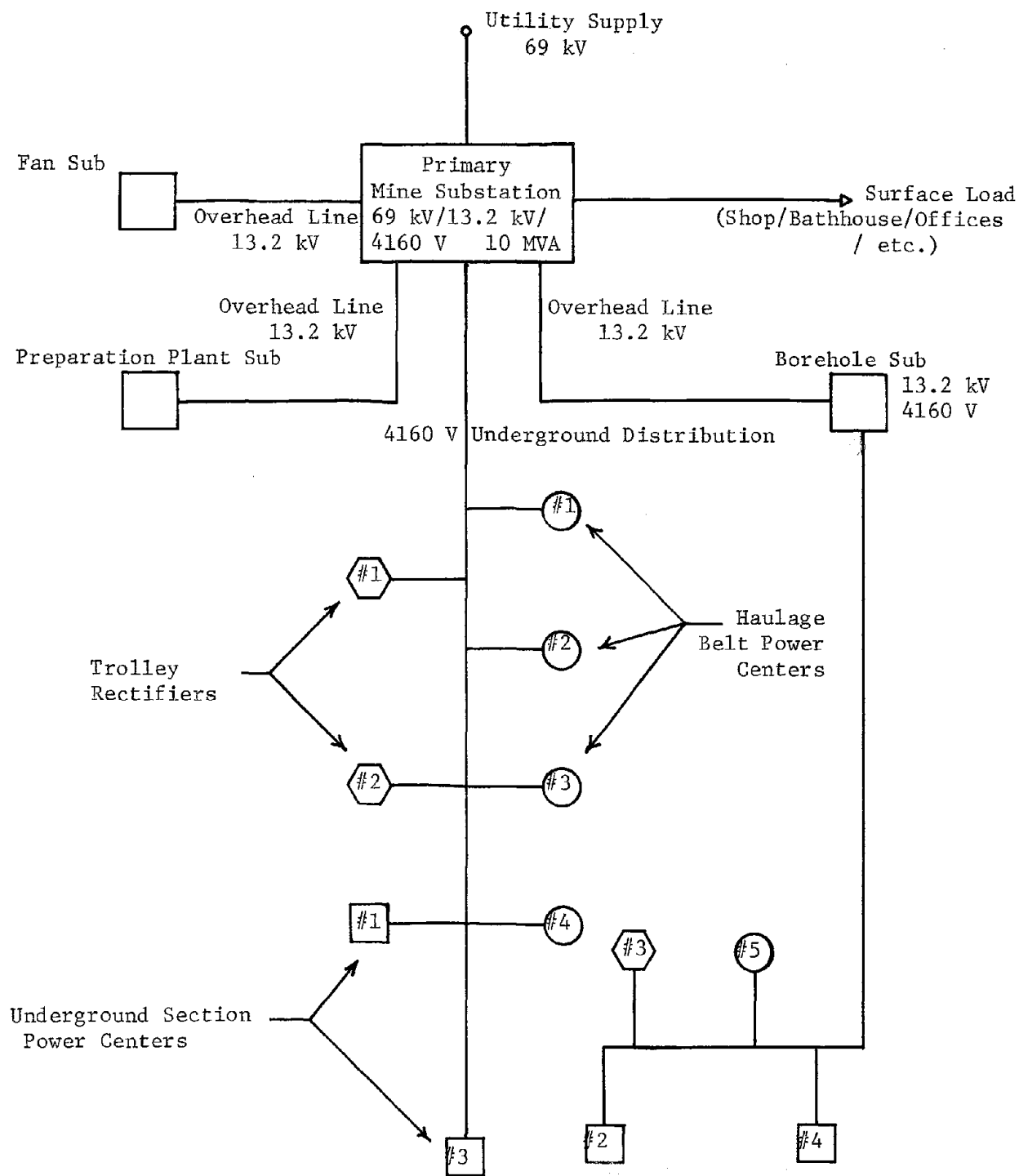


FIGURE 6.1. Block diagram of underground coal mine power system.

Figure 6.2 illustrates the configuration of the main substation. Power enters the station at 69 kV through a visible air disconnect and then into the two transformers through fused switches. Surge arrestors are shown immediately after the air disconnect, on both sides of the transformers, and on outgoing overhead distribution lines to provide lightning protection. These arrestors are connected to the substation ground bed along with all supporting structure, containers, enclosers, and the surrounding fence. The 7500 kVA 69/13.2 kV (delta-delta) transformer supplies all of the surface load including the borehole substation. Both oil and vacuum circuit breakers are used in the substations because of their predominant application throughout the industry. The breakers protecting these overhead lines contain basic overload and short circuit protection with the one supplying the fan also containing reverse phase protection. The 2500 kVA 69 kV/4160 V (delta-wye) transformer is strictly for underground power use except for the control transformer. The neutral of the wye is grounded through a power resistor to limit fault current to 25 amperes. This ground is remote from the substation ground to provide personnel protection from energized frames resulting from short circuits or surges. The circuit breaker protecting this circuit contains undervoltage and ground-fault protection as well as overload and short-circuit protection. Resistance monitors of the pilot-wire type maintain ground continuity monitoring of the 8 kV 4/0 SHD-GC underground distribution cable leaving the substation.

Figure 6.3 is a one-line diagram of the borehole substation. It is very similar to the underground supply section of the main substation. The secondary of the transformer is grounded through a resistance to limit fault current and undervoltage, overload, short-circuit, and ground fault protection are provided. Monitoring is of the pilot-wire type and surge arrestors are placed above the borehole for lightning protection.

Figure 6.4 is a block diagram of the underground distribution circuit. The modules providing branching capabilities and the respective branches are labeled for easy reference. This diagram follows the basic outline given in Figure 6.1. A module, as used here, is a skid-or tire-mounted enclosure containing electrical components constructed and packaged to provide durability and portability in an underground environment. Specific details and diagrams of each module will be discussed as the need arises.

Figure 6.4 shows that the underground circuit is bordered by a dual load-break switch (LBS) module at the bottom of the slope and by a Vacuum circuit breaker (VCB) module at the bottom of the borehole. These two modules provide the means of visible disconnection from the incoming power supplies required by Part 75.802 paragraph (c) of Title 30 of the Code of Federal Regulations. They also contain the ground monitoring circuits which maintain ground continuity in the primary distribution cable, excluding branch circuits. All of the 4160 volt distribution is by means of a 4/0 SHD-GC 8 kV cable. The SHD-GC cable is a shielded cable containing three phase conductors, two ground conductors, and a pilot wire used for ground continuity monitoring. Connections in this distribution cable are made using high-voltage couplers designed such that the pilot wire is broken first and the ground conductors broken last when the coupler is being uncoupled. All exposed conducting material on the couplers is connected to the ground wire in the cable.

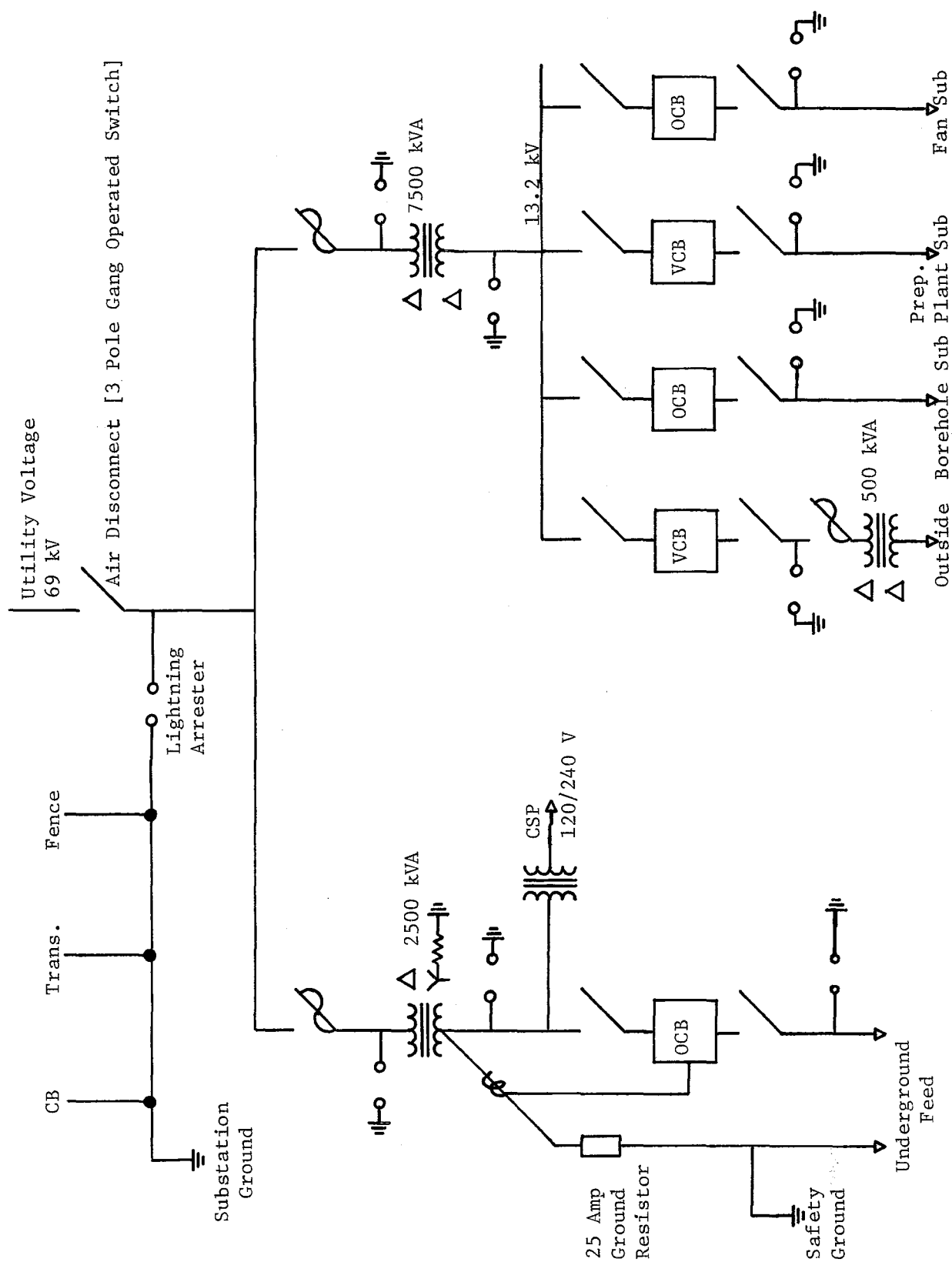


FIGURE 6.2. Underground mine surface substation.

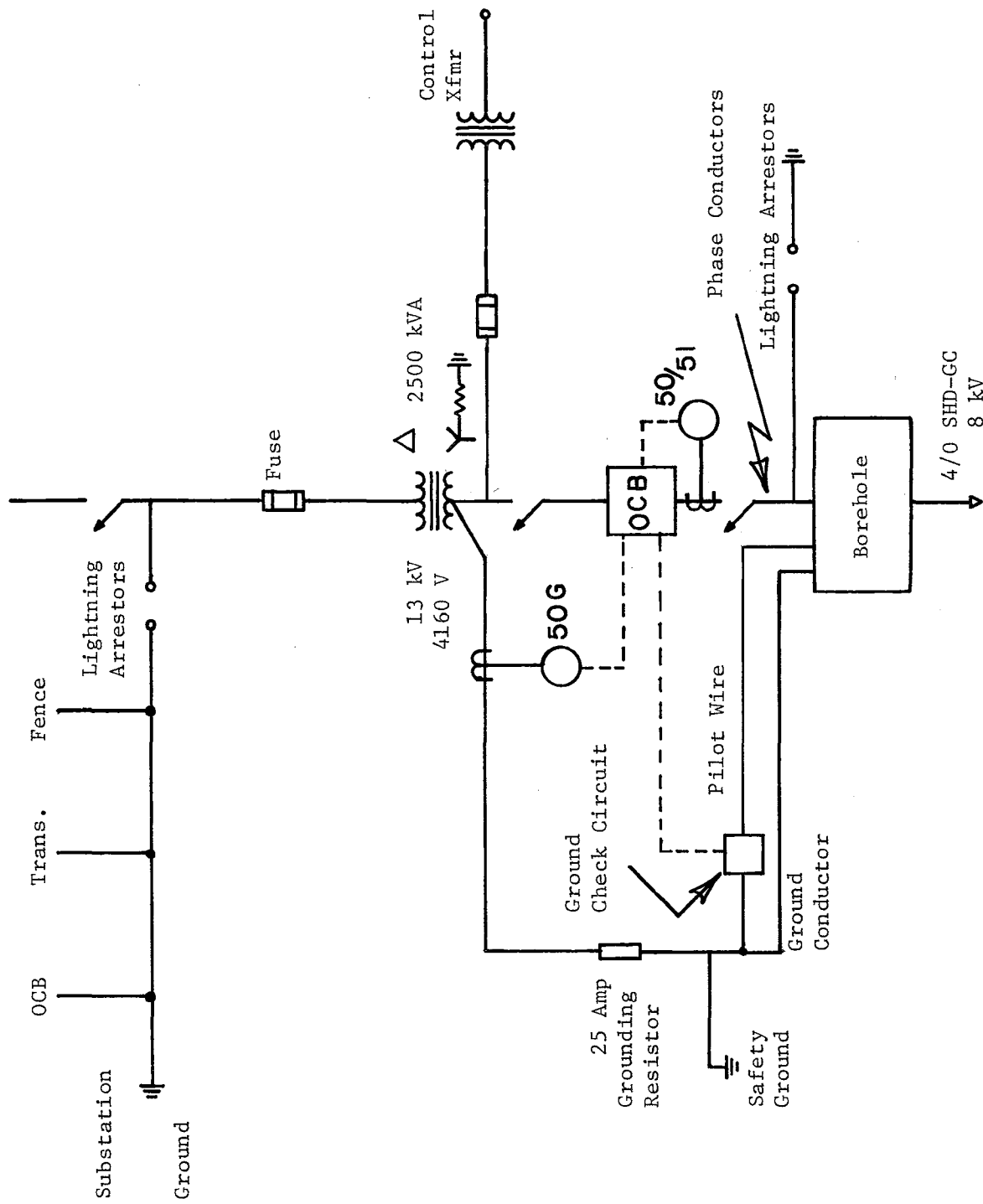


FIGURE 6.3. Borehole substation.

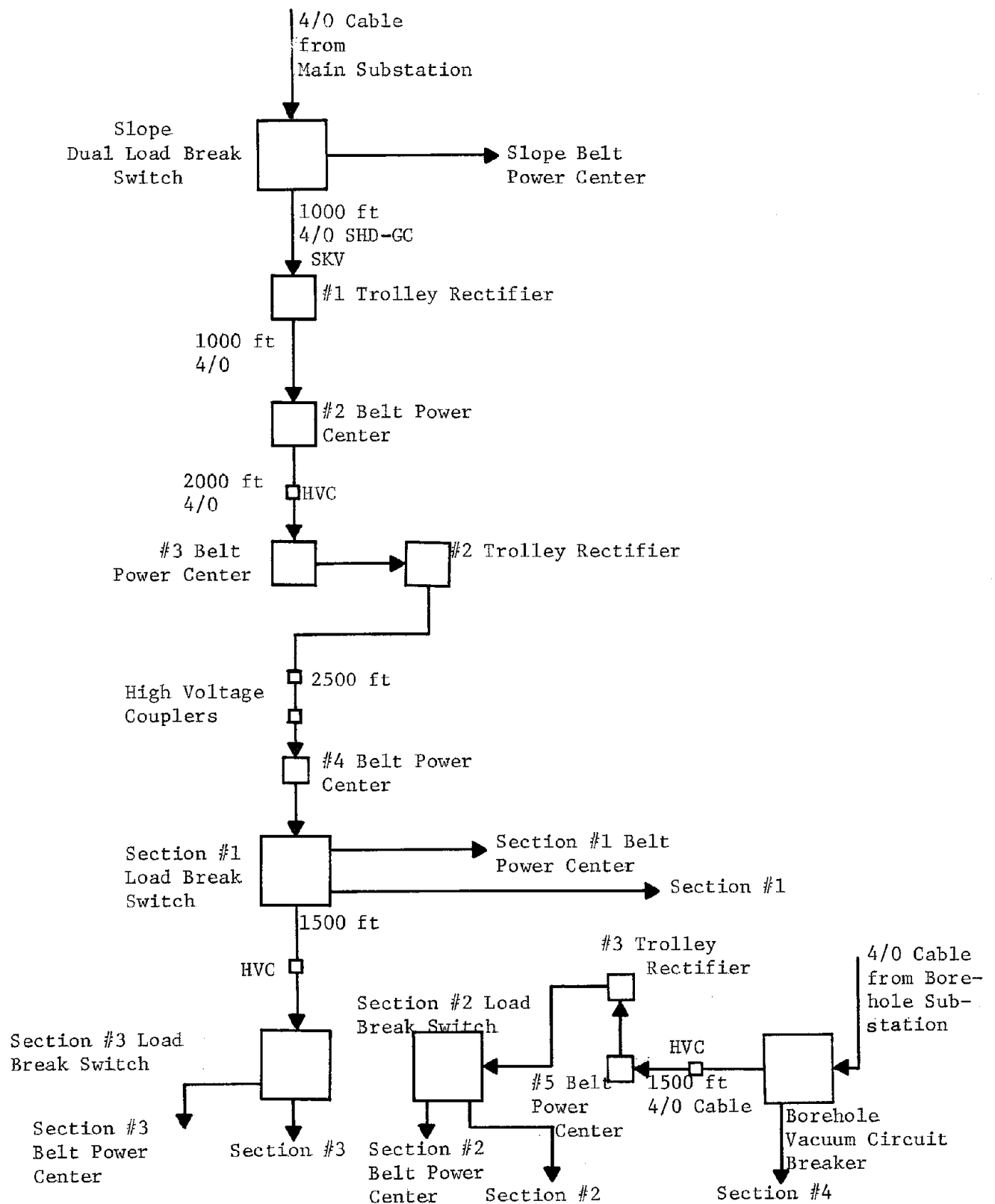


FIGURE 6.4. Distribution branching circuit block diagram.

The primary distribution circuit directly powers the trolley rectifiers and mainline belt power centers. This eliminates the need for additional sectionalizing equipment and is facilitated by running the distribution cable and trolley in the same heading and the beltline either in the same heading or an adjoining heading. The monitoring circuit is not interrupted because of the direct feed-through feature of the rectifiers and power centers.

Each operating section has an associated sectionalizing module. These modules provide a means of disconnecting power to the section without interrupting service to the rest of the mine. This is an essential capability due to the frequent advancing or retreating of section operations. Figure 6.4 shows three sections using single load-break switch modules which incorporate the feed-through feature while Section #4 is fed directly from the borehole VCB. Now that general application has been defined the modules can be described and understood more fully.

The slope dual load-break switch is shown in Figure 6.5. It provides two monitored and protected output circuits from the single input supply. The monitoring circuit in the substation is terminated in this module and separate monitoring circuits are established for the two output feeds. The separate feeds are obtained by means of two fused load-break switches. Visible disconnection is provided through a "sight window" in the side of the enclosing structure. The switches are three-pole, gang-operated with safety electrical interlocks on high-voltage compartment doors and covers. They can be operated manually and will operate automatically for any fuse failure or opening of any electrical interlock. The unit contains an "emergency stop" push button, which is connected to the incoming ground monitoring circuit, and a remote surface circuit breaker control complete with indicating lights. Ground fault and ground monitoring systems are incorporated in both outgoing feeds.

The borehole vacuum circuit breaker, shown in Figure 6.6, operates similarly to the dual LBS. The only real difference is that this unit replaced the fuses with vacuum breakers. Of course, protection can be more versatile and accurate due to the capabilities of modern relays. This module serves as Section #4's sectionalizer as well as a disconnect and monitoring unit. This unit must be located within 100 feet of the borehole entrance.

Figure 6.7 shows the single LBS module which is used as a sectionalizer for Sections #1, #2, and #3. This unit contains the "emergency stop" push button, "sight window", and control transformer of the dual LBS. It also contains a high voltage feed-through which does not interrupt the ground monitor circuit. The single fused load-break switch is the same three-pole, gang-operated switch with safety interlocks as before. However, this unit outputs two branch circuits off the same LBS and ground fault monitor. The ground check circuits are separated for each branch feed. Branch line #1 is for the section feed and #2 is for the section belt power center.

The trolley rectifier is shown in Figure 6.8. The feed-through feature, safety interlocks on high voltage compartment doors and covers, and the "emergency stop" push button in the incoming ground monitor circuit are standard in most of the underground modules and have been previously described.

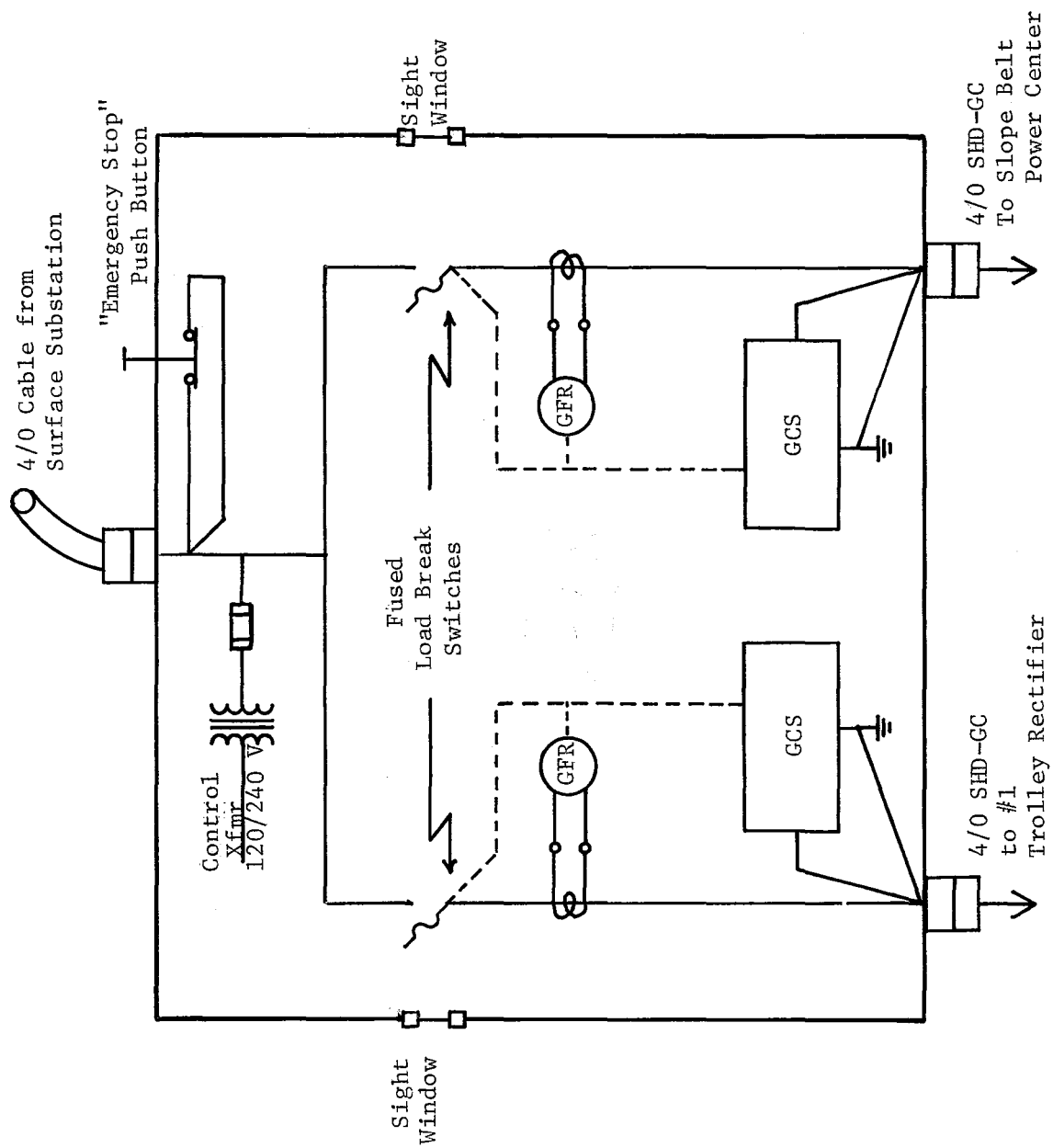


FIGURE 6.5. Slope dual load break switch.

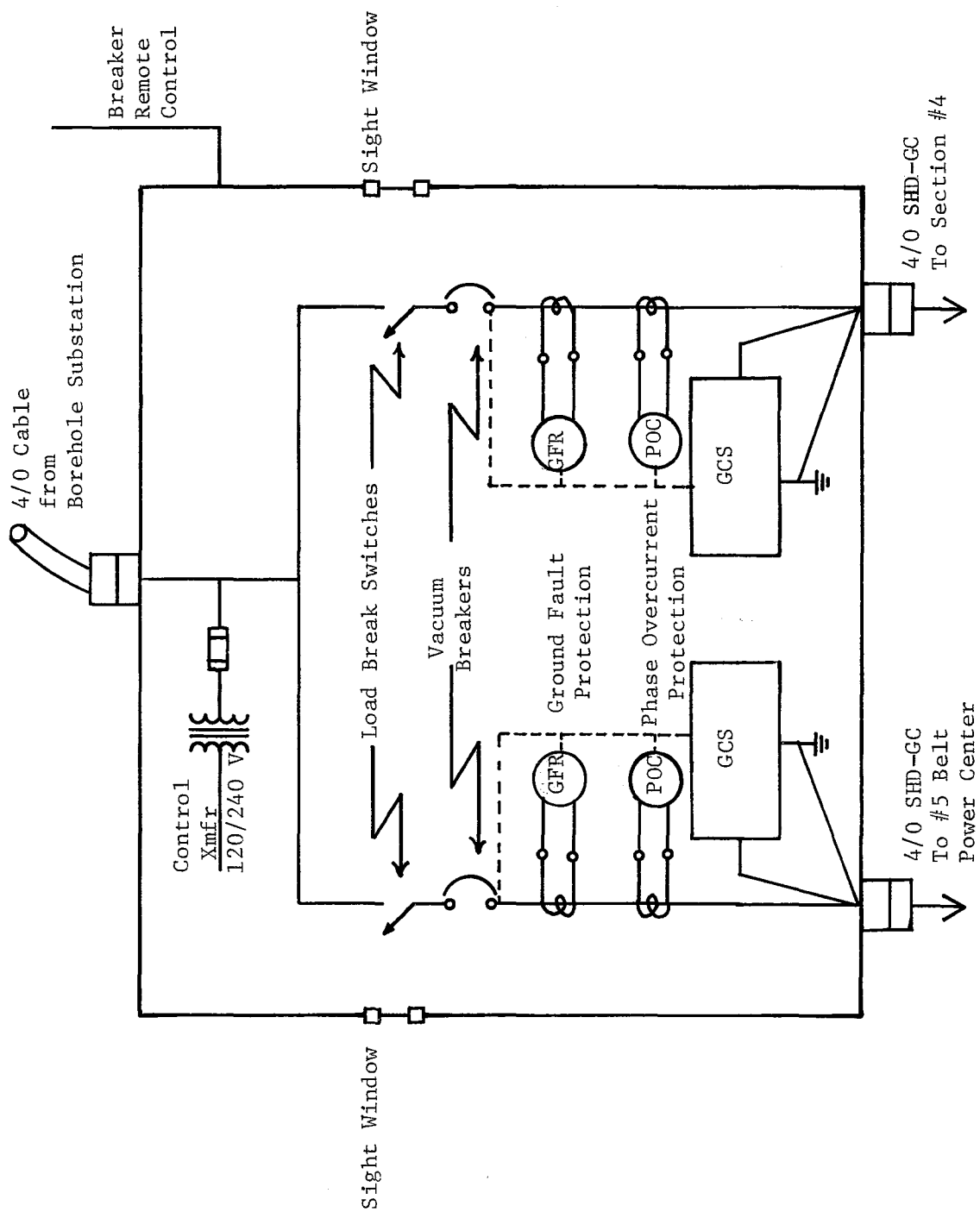


FIGURE 6.6. Borehole vacuum circuit breaker.

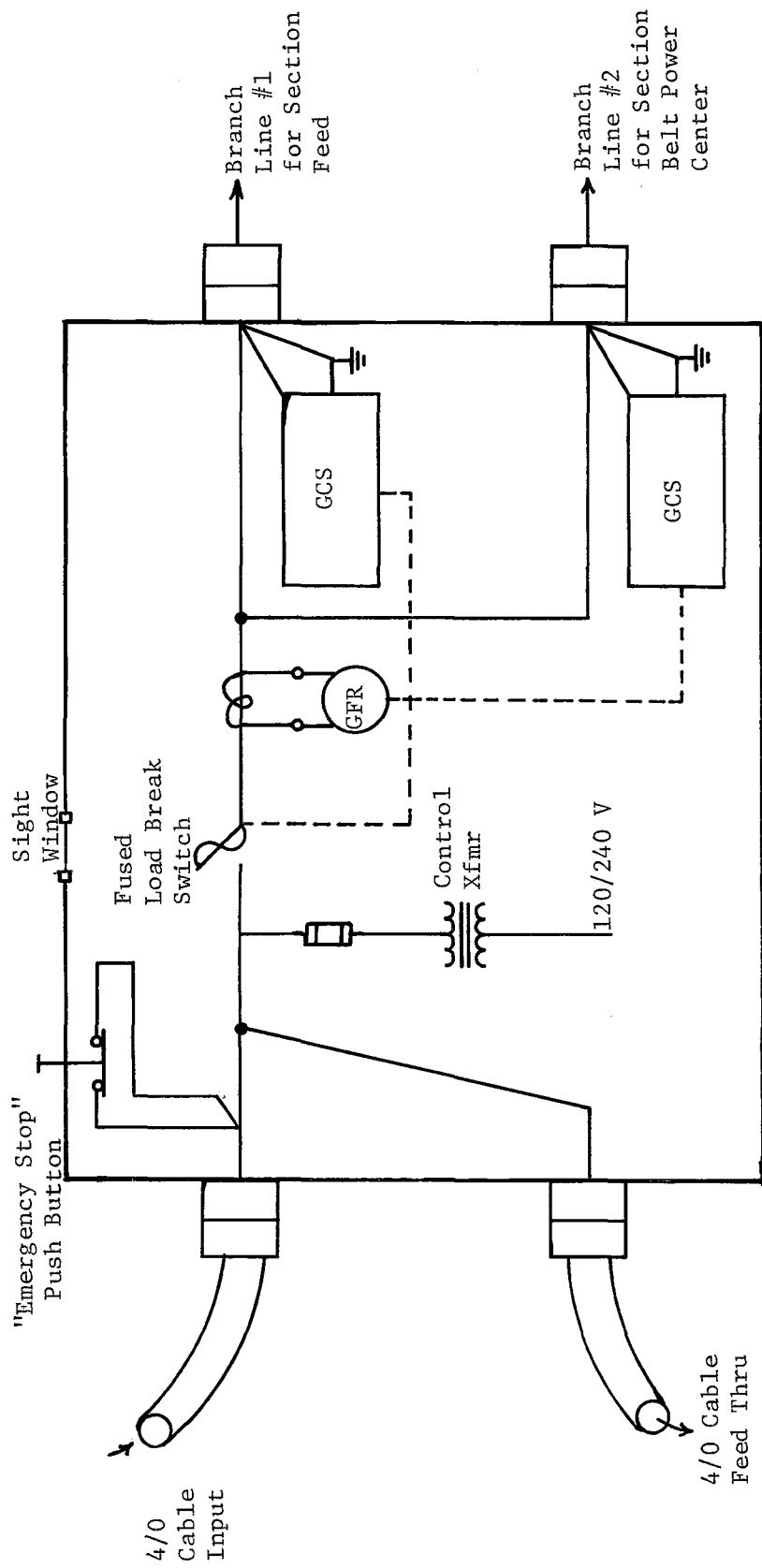


FIGURE 6.7. Section single load break switch.

Another standard safety feature is the inclusion of a pilot-ground shorting bar in the dust covers. This eliminates the possibility of any energized conductors being exposed when the dust cover or other half of the coupler is not connected. This feature is incorporated in both high-and low-voltage couplers. The "sight window" and disconnecting switch are the last features to be mentioned which are standard in all of the underground modules. These features will be shown on all remaining module diagrams but will not be included further in the description.

The fused LBS shown in Figure 6.8 serves as protection for the transformer primary as well as a means of visible disconnection. The lightning arrestors provide surge protection for the transformer which is a ventilated dry-type, three phase, 60 Hertz unit. It is a 4160/220 V (delta-delta) arrangement with 2 1/2% full capacity taps above and below normal voltage. The transformer has an overload rating of 100% full-load continuous, 150% full load for two hours following a 100% full load and 200% full load for one minute following a 100% full load. This type of rating is considered to be a standard mine-type rating. The three-phase, full-wave rectifier bridge is protected by a three-pole, molded-case circuit breaker. The rectifier supplies a 300 volt dc output which is used in the grounded-negative configuration. An auxiliary circuit is provided and is protected separately by a two-pole, molded-case circuit breaker. The primary outputs which supply the trolley are protected by the rectifier breaker. As mentioned before, this unit operates in the grounded-negative configuration. This means that the trolley wire is connected to the positive supply and the rail serves as the negative or ground return.

The mainline belt power centers are diagramed in Figure 6.9. This ac power center is a 400 kVA, 4160/480 V (delta-wye) unit containing power factor correcting capacitors. The transformer neutral is grounded through a resistor to limit ground fault current to a maximum of 15 amperes. The 480 V dual belt feed circuit is protected by a 600 ampere, three-pole, 600 volt, molded case circuit breaker and the auxiliary circuit is protected by a smaller 100 ampere breaker. Both circuits incorporate ground-fault and ground-continuity protection. A separate utility transformer provides convenience outlets for power hand tools or lighting.

Associated with each of these power centers is a motor starter-belthead combination. The belthead consists of two 150 Hp squirrel-cage induction motors, drive rollers, and the supporting framework. The motors represent the bulk of the power needs associated with operating a section of the 48" mainline belt. A solid-state motor starter incorporates the remaining power requirements. The solid-state starters, by using reduced-voltage motor starting, provide controlled motor acceleration which reduces belt wear, slippage, and maintenance, while increasing motor life. The starter units also include certain monitoring and control features. Motor overload protection is normally provided by thermal overload relays. Belt slippage and sequence monitoring is included in the starter and means for interruption of the ground monitor circuit of the belt power center is provided. A separate supply is built into the starter to support a control line, running the length of belt section, which provides local and remote start-stop capability. Additionally, at every belthead a centrifugal switch is incorporated into the control circuitry of the belthead which monitors the outby belt. This is needed to prevent the spillage which would occur

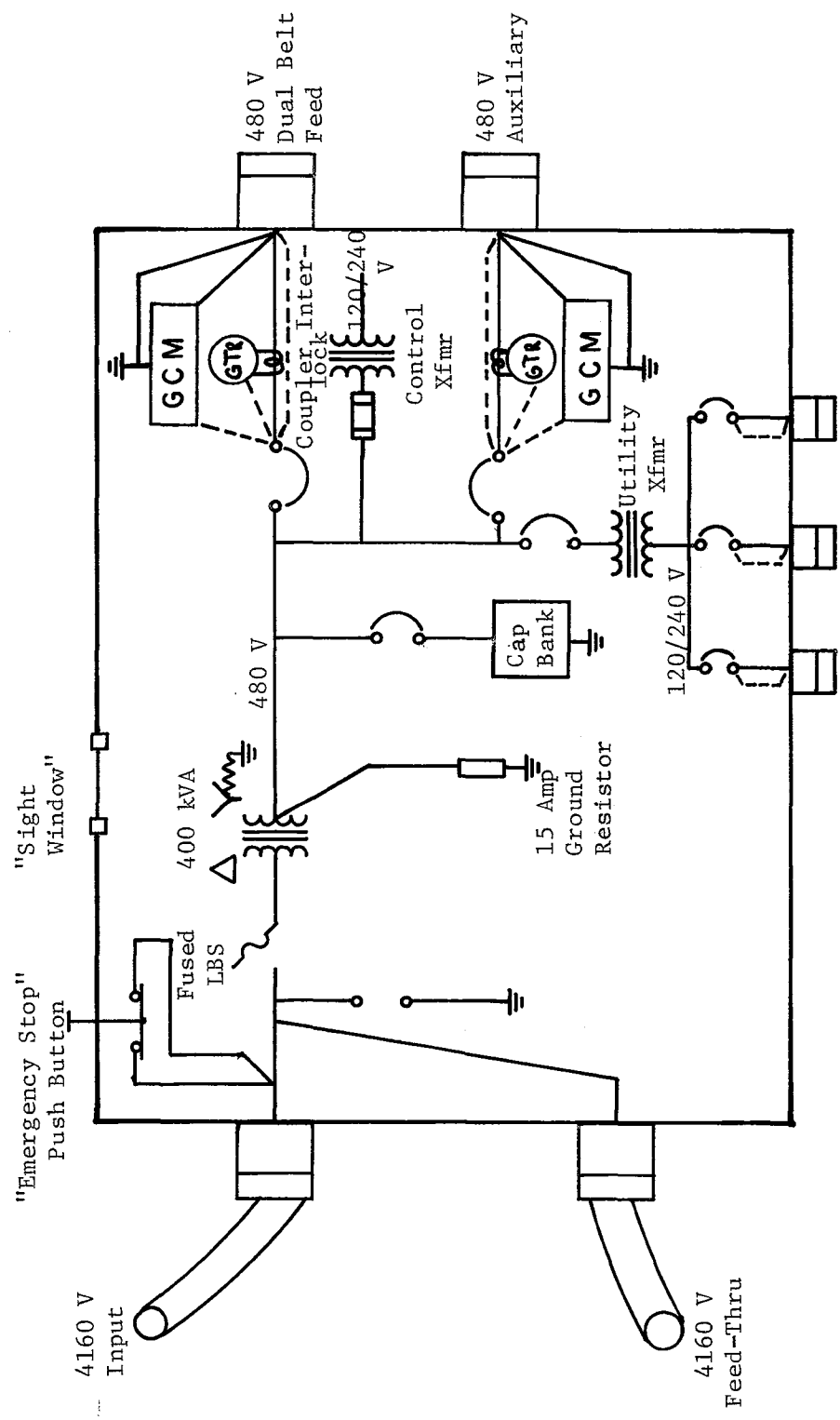


FIGURE 6.9. Dual mainline belt power center.

if an inby belt continued to dump coal on a non-moving outby belt.

Figure 6.10 gives the configuration of the section belt power center. This 225 kVA unit operates in the same manner as the mainline belt module. In this case, the transformer is connected delta-delta and a neutral is derived using a zig-zag transformer. This is also a common practice in the mining industry. The belthead associated with this power center drives the 36" section belt with a single 150 Hp motor. The motor starter and operating characteristics are similar to those associated with the mainline belt just described.

All of the underground power system indicated by Figure 6.4 has now been discussed. The section power system is the only remaining portion to be covered. Sections #2, 3, and 4 employ the continuous mining method and have the same power system. Thus, discussion of one will be sufficient to cover all three. Section #1 uses conventional mining machines and is set up slightly different from the continuous sections. The difference in application methods is mainly for representation purposes since there are many power system variations in section utilization. Only two of the more common methods are chosen for practicality.

Figure 6.11 gives the outline of section #1's ac power center. This unit in conjunction with the face rectifier of Figure 6.12 comprise the conventional section's power system modules. This power center has the same major components as the belt power centers but is of much larger capacity and has several more output circuits. Each circuit is protected by a molded-case circuit breaker and incorporates the required ground-fault and ground-check monitoring. The circuit breaker case sizes are shown in the drawing to indicate the approximate load that each piece of machinery represents. Each different size output feed has a spare receptacle in case of failure of the breaker or monitoring circuit associated with one of the designated feeds. The exception to this is the 100 A circuit. It has only one feed because a temporary loss of this circuit would not greatly interfere with the normal section operation. The power center directly supplies the cutting machine, face drill, loading machine, roof bolter, and 150 Hp crusher/feeder. It also supplies the 150 kW face rectifier which produces the 300 V dc needed to operate the shuttle cars. This rectifier produces the dc voltage in the same manner as the trolley rectifier. The output circuits shown are protected by a dc contactor in the positive lead. A separate wire connected to the machine frames and the ac ground provides the grounding method. This third wire is also connected to the negative lead, thus ground fault protection is accomplished by the overcurrent device.

The continuous sections replace the separate ac and dc power modules of the conventional section with a single ac power center as shown in Figure 6.13. All of the mining equipment require 480 V ac power supply inputs. Any required dc voltage is transformed on board the equipment. The continuous miner singularly replaces the cutting, drilling, blasting, and loading operations of the conventional method. Two 800 A circuits are provided for the "miner" and "miner spare". Three-pole, molded-case circuit breakers equipped with thermal and magnetic trip units and 120 volt undervoltage releases protect the output feeds of this power center. Ground-fault and ground monitoring are

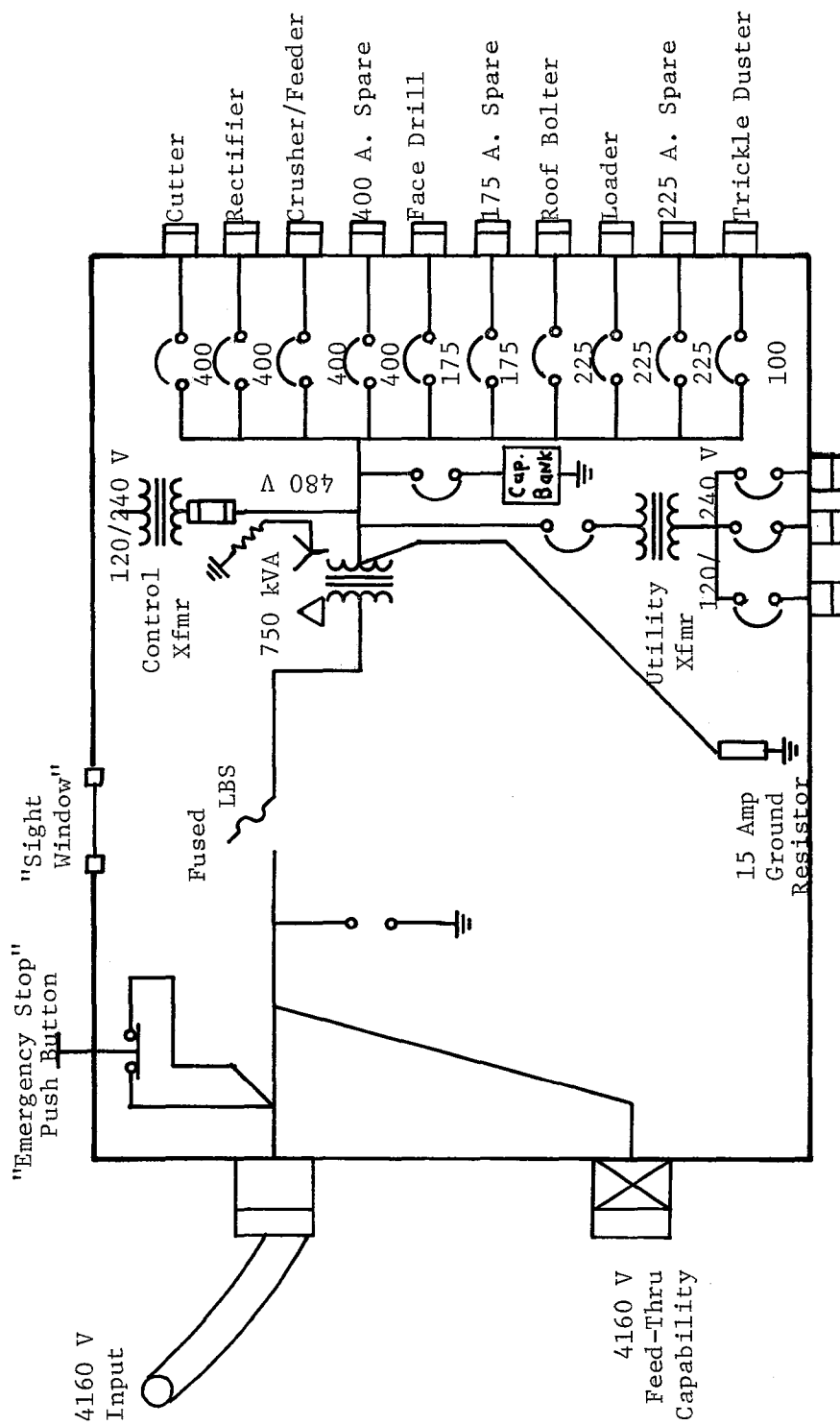


FIGURE 6.11. Conventional section power center.

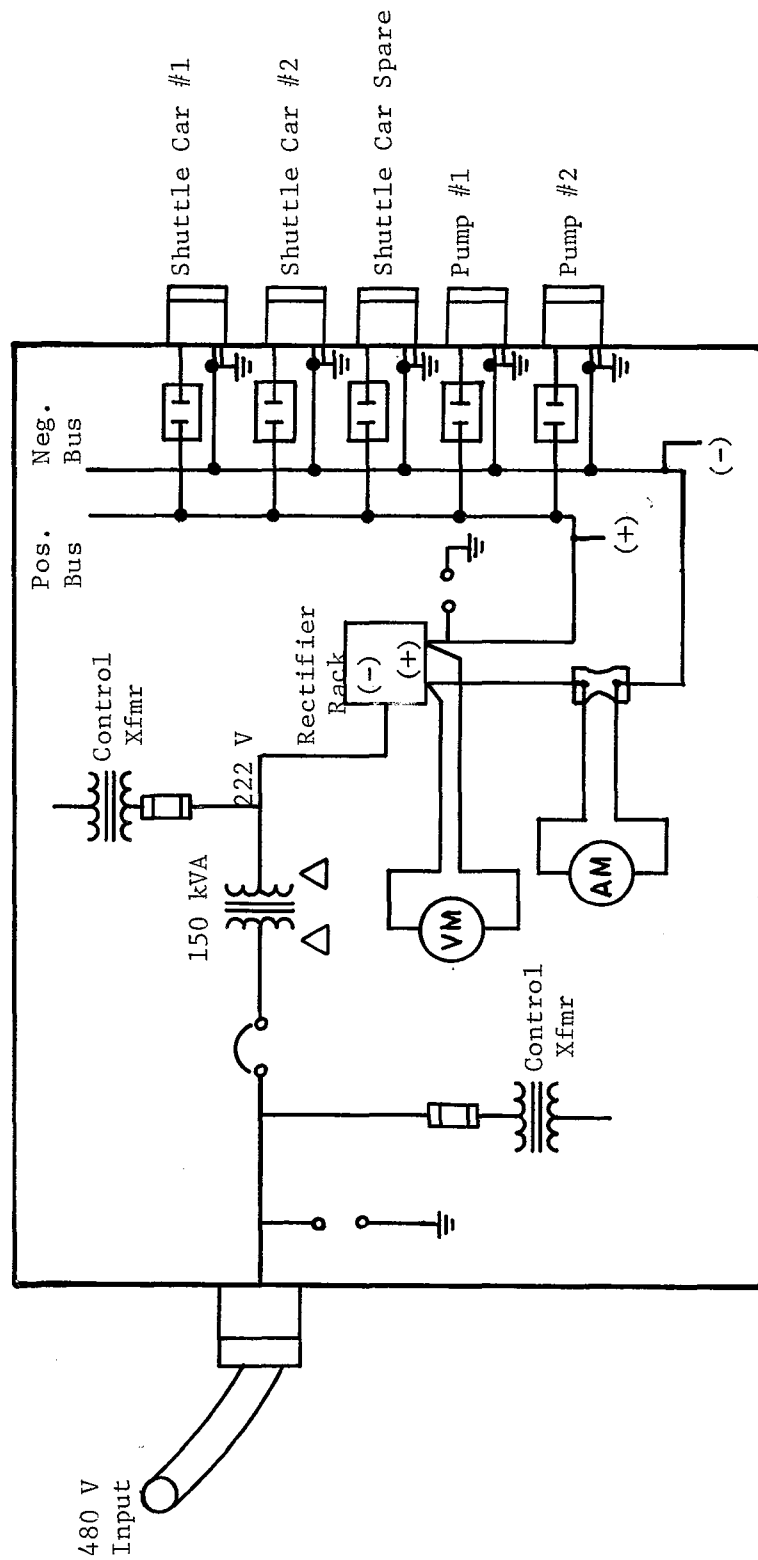


FIGURE 6.12. 150 kW face rectifier.

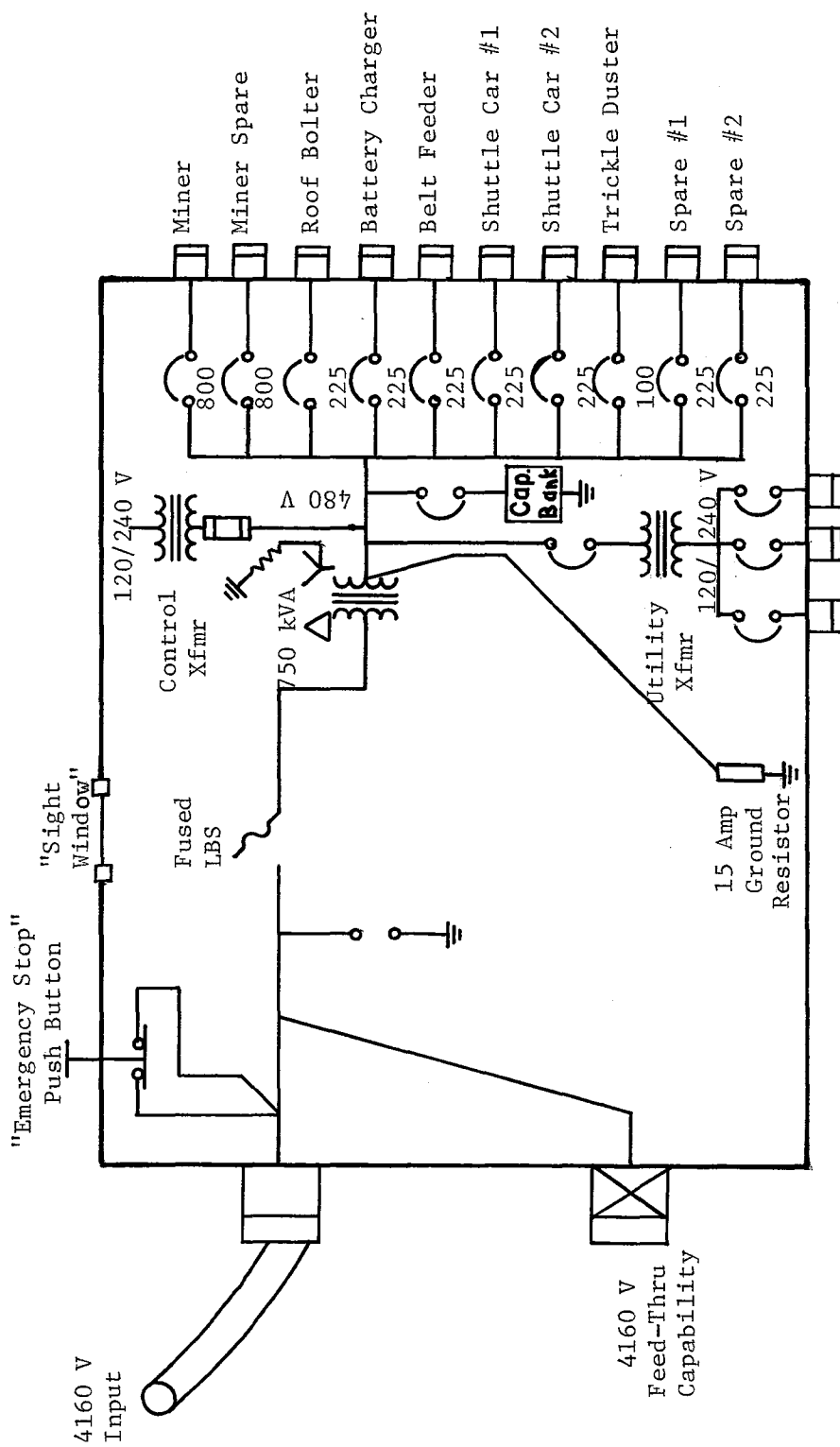


FIGURE 6.13. Continuous miner section power center.

also included in each circuit. The remaining circuits supply the roof bolter, belt feeder, battery charger, and shuttle cars. Two spare circuits are provided in case the designated outputs malfunction.

All trailing cable lengths are 500 feet but may be extended if the provisions of Part 18.35 paragraph (5) of Title 30 are met. The miner trailing cable is a 4/0 G-GC cable and the belt feeder cable is a #1 G-GC cable. The bolter and shuttle car cables are #4 G-GC cables.

The battery charger is a tapered charge-rate control device which is included to maintain the service of a battery-powered scoop. The scoop is used for supply haulage, maintaining road conditions, and as a tractor during advance and retreat.

6.3.2 Power System Model for Surface Coal Mine

The following model of a surface coal mine power system is developed for use as a cost-analysis tool and is not intended as a guide for power system design or as a representation of state-of-the-art technology in the mining industry. The model includes and describes the equipment and devices which are used in the particular stripping method modeled and does not suggest or claim this to be the best or most prevalent application. Also, the detail and specifications of the components presented are only as intricate as the intended purpose of the model dictates. The statistics given are developed from employment and production reports filed by surface operators and are not necessarily representative of any particular mine.

The mine modeled is a small strip mining operation consisting of a single pit, a small crusher and tipple, a shop, and associated offices. This arrangement corresponds to the "average" mine size of approximately 24 employees who work an average of 50,000 man-hours per year and produce 166,000 tons of clean coal annually. (Many mines are substantially larger than those figures denote, but modeling such a mine would produce unnecessary duplication). These small mines usually transport their coal by truck or rail depending upon the area and distance involved to a nearby preparation plant if washing is necessary. These plants may or may not be company-owned facilities. The shop and offices may be combined in a building complex, but oftentimes the office facilities consist of two or three converted mobile homes located right on the job.

Surface mining consists of overburden removal, coal loading, haulage, and reclamation. For the purposes of this model only the overburden removal and coal loading processes will be discussed. Overburden is the material overlying the coal seam. This is first fragmented by drilling and blasting and then removed by a dragline. Assuming a single coal seam, one or two blast-hole drills will be used depending upon overburden composition and depth and the size of the dragline. Dragline size may vary from 15 yd³ to over 150 yd³. This model will consider a dragline of approximately 30 yd³ and one associated drill. These machines operate on the bench above the pit while the production shovel operates in the pit. This shovel handles the coal loading operation once the coal seam has been exposed by the overburden removal process. All three of these pieces of

equipment are electrically powered and require a trailing cable supply because they advance along the pit as they operate.

Cables and portable components provide flexibility and mobility in the pit power system. This is an essential feature considering the constant movement along the pit of each mining machine and the continued movement of the pit away from the mined-out area. This constant motion creates several problems involving the power system. Initially, system and component design engineering is increased in an effort to provide the needed mobility. Secondly, coordination must be simpler because of constant parameter variation, and the necessity of large cable lengths increases monitoring difficulties. Finally, cable handling becomes significantly important to the operation of the mine. Various techniques have been implemented to alleviate these difficulties and one such method is shown in Figure 6.14.

Figure 6.14 is a block diagram of the model. It contains a primary switchyard through which power is fed from the utility supply to the various load centers of the mine. This distribution is via company-owned and maintained overhead lines. The pit substation furnishes all of the power requirements associated with the actual mining of the coal. A "baseline" is established which runs parallel to the pit and effectively acts as a 23 kV bus. The baseline is composed of 1500 foot lengths of shielded cable interconnected by switchhouses. The switchhouses serve as local bus connections for the breaker skids and portable substations which supply the various mining equipment. The portable subs transform the baseline voltage and provide branch circuits to support the drill, production shovel, and pump circuits. The breaker skids serve as a protection and disconnect point for the dragline. The pit tower provides a local connection for the shovel and supports the pumping network in the pit.

Figure 6.15 is a one-line diagram of the switchyard. The switchyard is a permanent installation of high-voltage switching apparatus located in a position normally remote from the mining operation. The choice of a switchyard or a primary substation is dependent upon the voltage level and tap-in point available from the utility and by the dispersion of the load centers. Utility metering occurs at or before the switchyard which serves as a termination point for the utility supply and affords branching to the various load centers in the mine. The branch circuits are fed through high-voltage circuit breakers to protect the transmission lines and the utility's system. A switchyard ground is established to which is connected the utility ground, lightning arrestors, support structure, device enclosures, and the static wires of the outgoing distribution lines.

The physical construction of the pole lines is shown in Figure 6.16. This single-pole structure carries the static wire above the phase conductors to provide a measure of lightning protection. This is accomplished by the shielding effect of the ground wire and by the reduction of induced potentials on the phase conductors. This potential reduction occurs because the impulse travels in both directions from the strike point, thus halving the surge current. Also, minimum induced voltages are realized by conducting the surge current to ground as quickly as possible. This translates to adequately grounding the static wire at every pole (or every other pole, depending upon conditions). Grounding is accomplished by running a conductor

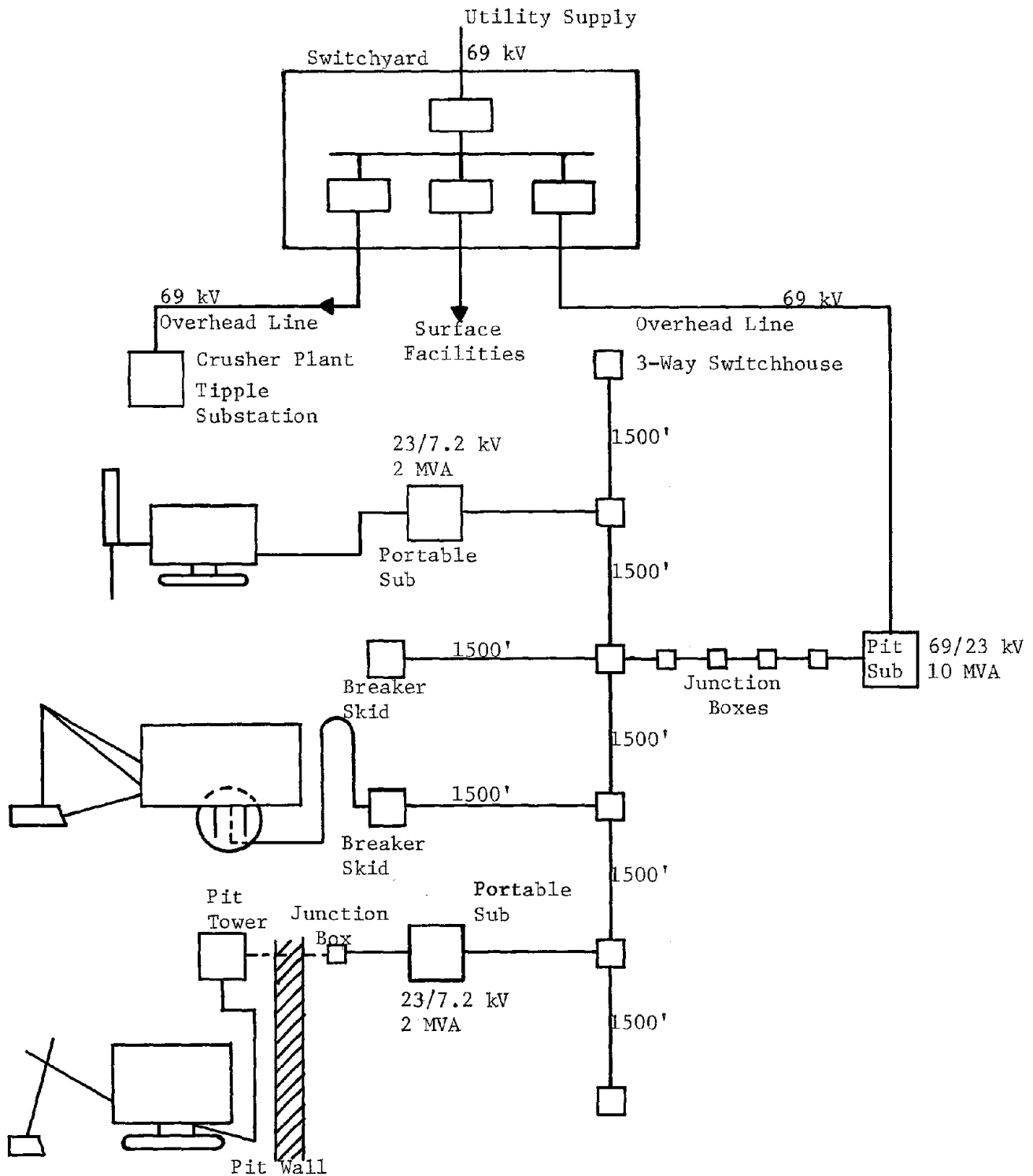


FIGURE 6.14. Block diagram of surface coal mine.

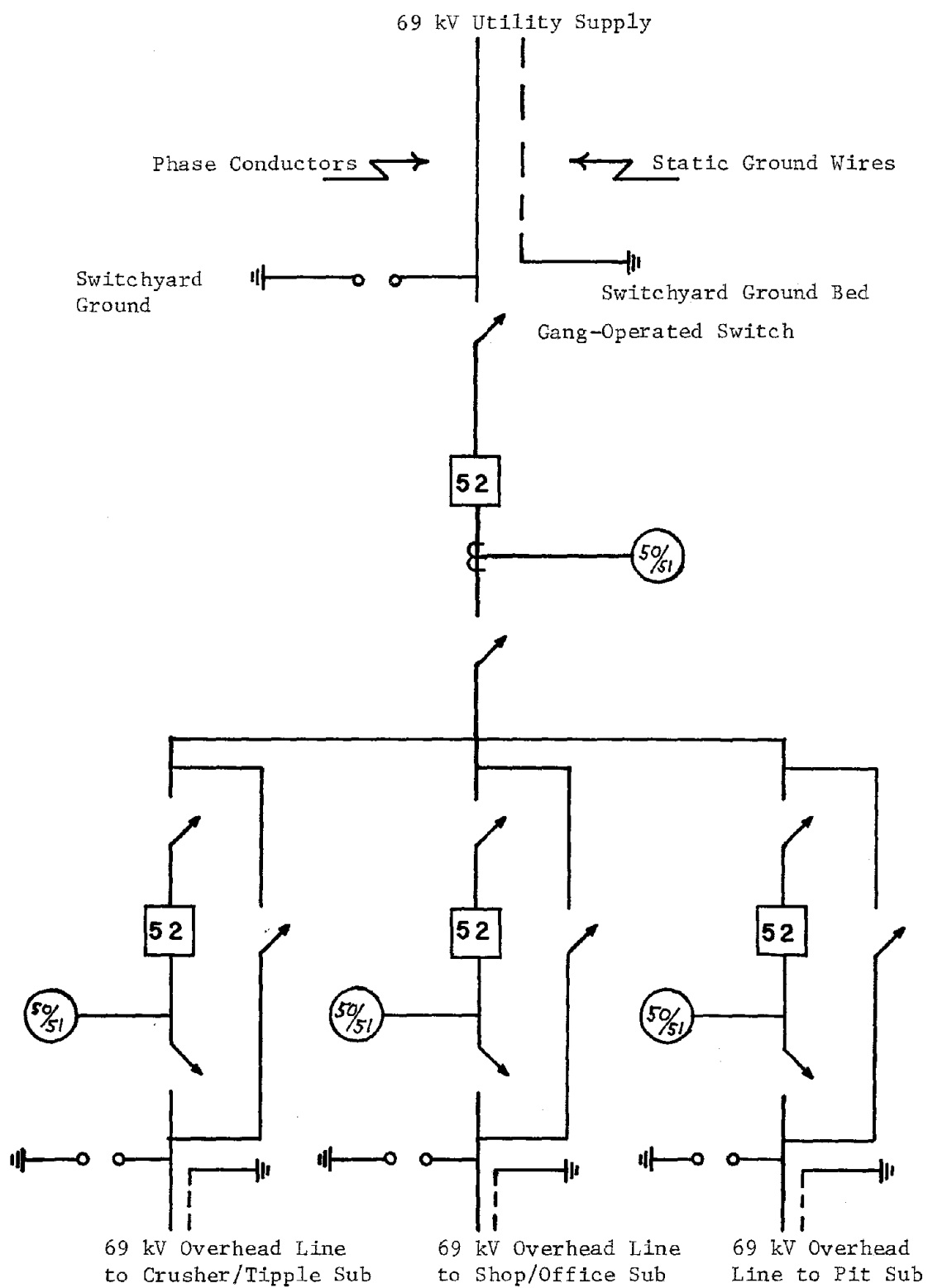


FIGURE 6.15. Surface switchyard.

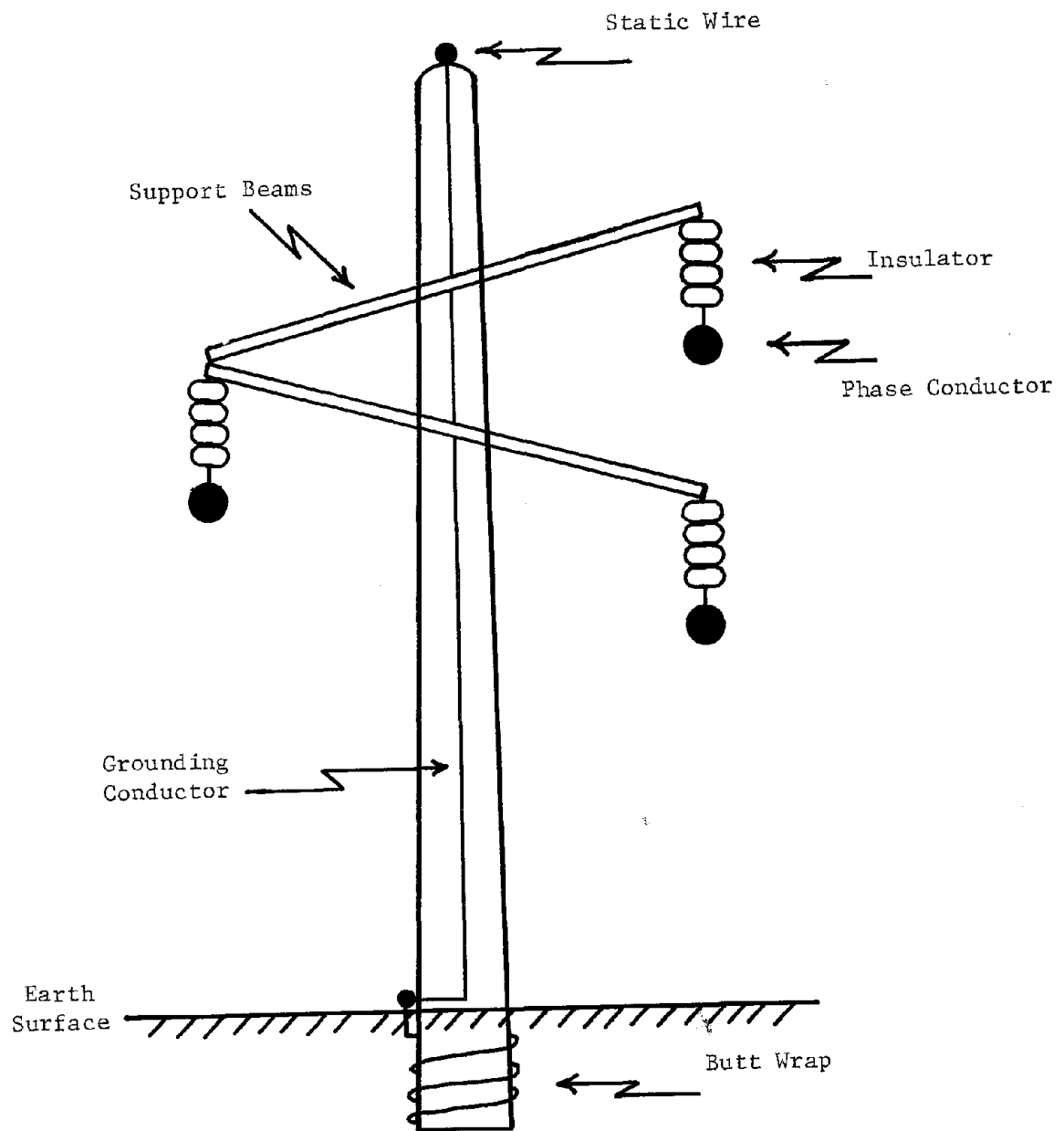


FIGURE 6.16. Pole line support structure and conductor arrangement.

from the static wire and attaching it to some type of grounding electrode. Figure 6.16 shows a "butt wrap" ground which is simply bare wire wrapped around the bottom of the pole before it is installed. This method, ground rods, a "counterpoise", or a combination of these will be used as the ground electrode depending upon soil resistivity and desired resistance level.

The only load center supplied by the pole lines which is of interest in this model is the pit. Figure 6.17 gives the one-line diagram of the pit substation. This station supplies all of the power requirements associated with the actual mining of the coal. The "safety ground" which is carried to all machine frames is established here. This ground is normally implemented by drilling a hole through the watertable and coal seam, lowering a bare ground conductor, and refilling the hole with coal slurry, salt, or some other conductive material. This normally provides a low ground-resistance even in some very high-resistivity soils.

The substation transformer is a 10 MVA, 69/23 kV (delta-wye), oil-filled unit. On the high side of the transformer are lightning arrestors, fuses, and a gang-operated air-disconnect switch. The pole line static wire is connected to the substation ground bed along with all supporting structure, component containers and enclosures, and the surrounding fence. This substation may or may not be skid-mounted. A location is selected before installation such that, hopefully, it will not need to be moved within at least a ten-year period. The secondary of the transformer is connected to the safety ground through a 25 ampere neutral-grounding resistor. The vacuum circuit breaker protecting the 23 kV output is equipped with time- and instantaneous-overcurrent, undervoltage, and ground-fault relaying. The ground-fault protection is furnished by both potential and current relaying.

The output of this substation is carried on a 25 kV 4/0 SHD-GC cable which contains three phase conductors, two ground conductors and a pilot wire. The pilot wire is used in conjunction with the impedance-type ground check monitor which ensures the ground continuity of the cable. This monitor is interconnected with the circuit breaker so that loss of continuity will automatically trip the breaker. The 1500-foot sections of cable are joined together by junction boxes to bring the power from the substation to the baseline (see Figure 6.14). Junction boxes (or dry boxes) are small skid-mounted enclosures which serve only to connect sections of cable together.

Figure 6.18 shows the heart of the baseline. The 3-way switchhouse serves as a junction and monitoring point for cable sections and as a tap-in point to the baseline bus network. The switchhouse is a skid-mounted metal enclosure with the skid having either a flat bottom or fabricated runners, depending upon the local bearing pressure. A means of visible disconnection is provided by side windows in the housing shell. Figure 6.18 shows that a bus is constructed from which three individual circuits are created. Each circuit has its own gang-operated, load-break switch and associated "sight window". Each branch also has a separate ground-check monitor (GCM) which is connected to a contact in series with the ground-check circuitry of the supplying cable. A ground-continuity loss in any cable leaving the switchhouse will trip the GCM of the supplying cable which in turn

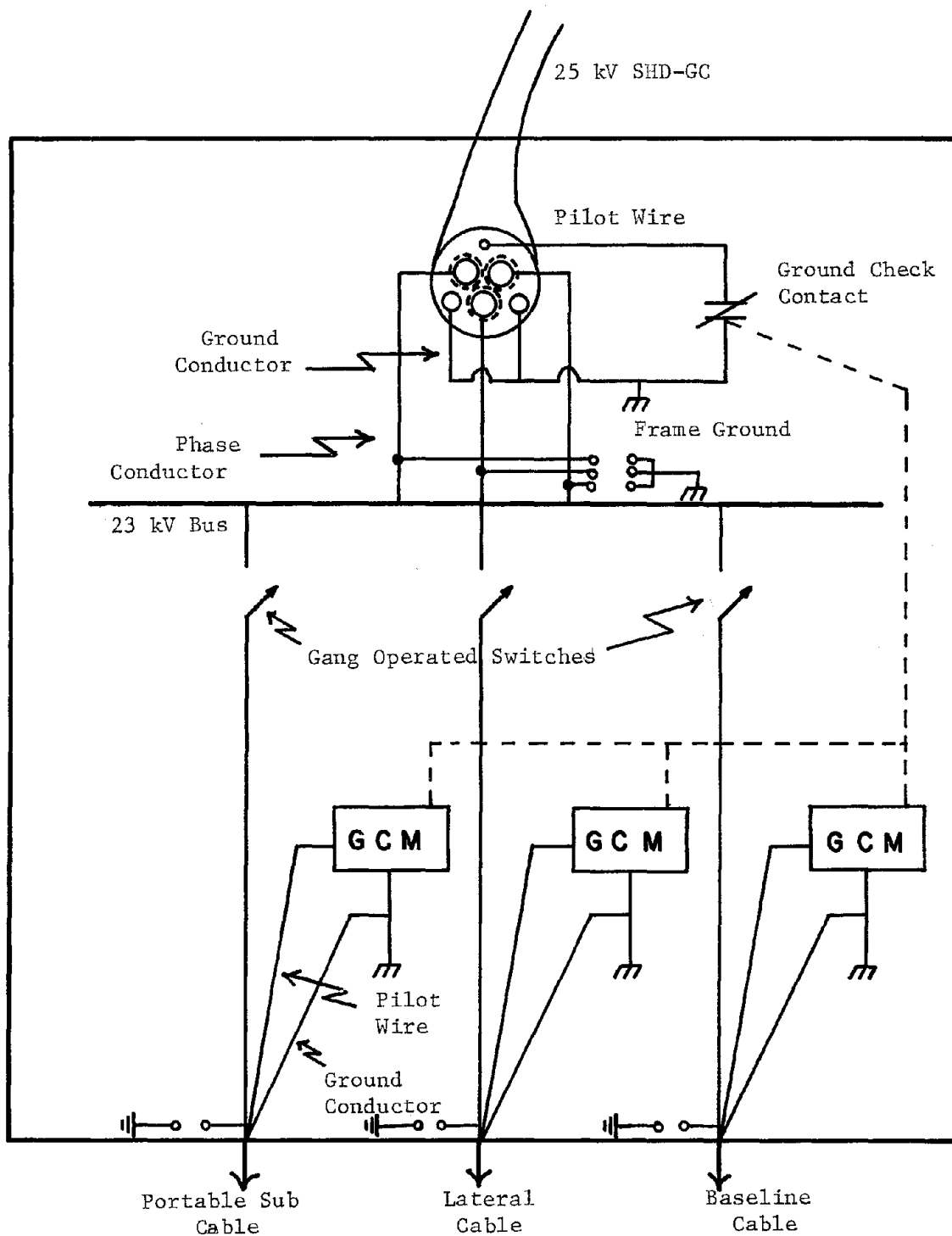


FIGURE 6.18. 3-way switchhouse.

will trip the GCM of its supplying cable and so on until the pit breaker is reached, which then removes power from the entire system. The initially tripped monitor is easily found by retracing the tripped monitors. Many operations place a circuit breaker just before the baseline at the end of the pit feeder cable so that it is not necessary to travel back to the pit sub in order to restore power. Oftentimes that is an appreciable distance, and the travel time translates to costly downtime.

Each section of baseline cable is monitored by a monitor in the 3-way switchhouse. One output from the switchhouse is always employed in continuing the baseline, except for those at the ends of the baseline. Another output is reserved for a cable which runs perpendicular to the baseline towards the pit. The last output usually feeds the portable substations supplying the drills and pit tower.

A one-line diagram of these subs is given in Figure 6.19. Again, these units are skid-mounted, housed in a metal case, and provide visible disconnection via sight-windows. The transformer is a 2 MVA, 23/7.2 kV, delta-wye, with a resistance grounded secondary. Two separate protected outputs are created with time- and instantaneous-overcurrent and ground-fault protection. A blast hole drill, pump, sub, or pit tower may be supplied from either output through an 8 kV, AWG #2 SHD-GC cable.

Figure 6.20 shows the configuration of the breaker skids which protect the dragline (see Figure 6.14) and in some applications protect the baseline. These units have the usual protection on the output circuit. A 23 kV feed-through is incorporated in the unit which may sometimes be used to power a portable sub. The breaker, relaying, and switches are all housed in a metal case and mounted on a skid. Two of these units are used at the end of adjacent lateral feeds to facilitate the movement of the dragline. When the dragline has reached its maximum available distance from one breaker, the trailing cable (4/0, 25 kV SHD-GC) is disconnected from it and moved to the next breaker. This method of operation shortens the downtime associated with this necessary movement.

Figure 6.21 gives a one-line diagram of the pit tower. This device is a portable unit located on the pit floor and supplied from one of the portable subs, on the bench, through a cable run over the pit wall (see Figure 6.14). Depending upon location of the portable sub, a junction box or load break switch is installed in the feeder cable at the edge of the bench to shorten the length of cable hung over the wall. This is done for handling purposes. The tower is structurally equipped to lift the cables running to and from it off the ground to provide a place for haulage trucks and other equipment to cross the cables without damaging them.

A single 7.2 kV protected output similar to those of the previously-described breaker skid is contained in this unit to supply the production shovel. Three 480 V outputs are available to supply the pit pumps. Each output is protected by a molded-case circuit breaker and includes ground-check monitoring. If pumping is needed along the bench area, a separate pump sub is used. It will contain the same features shown in the pumping section of Figure 6.21 and be powered by one of the portable subs.

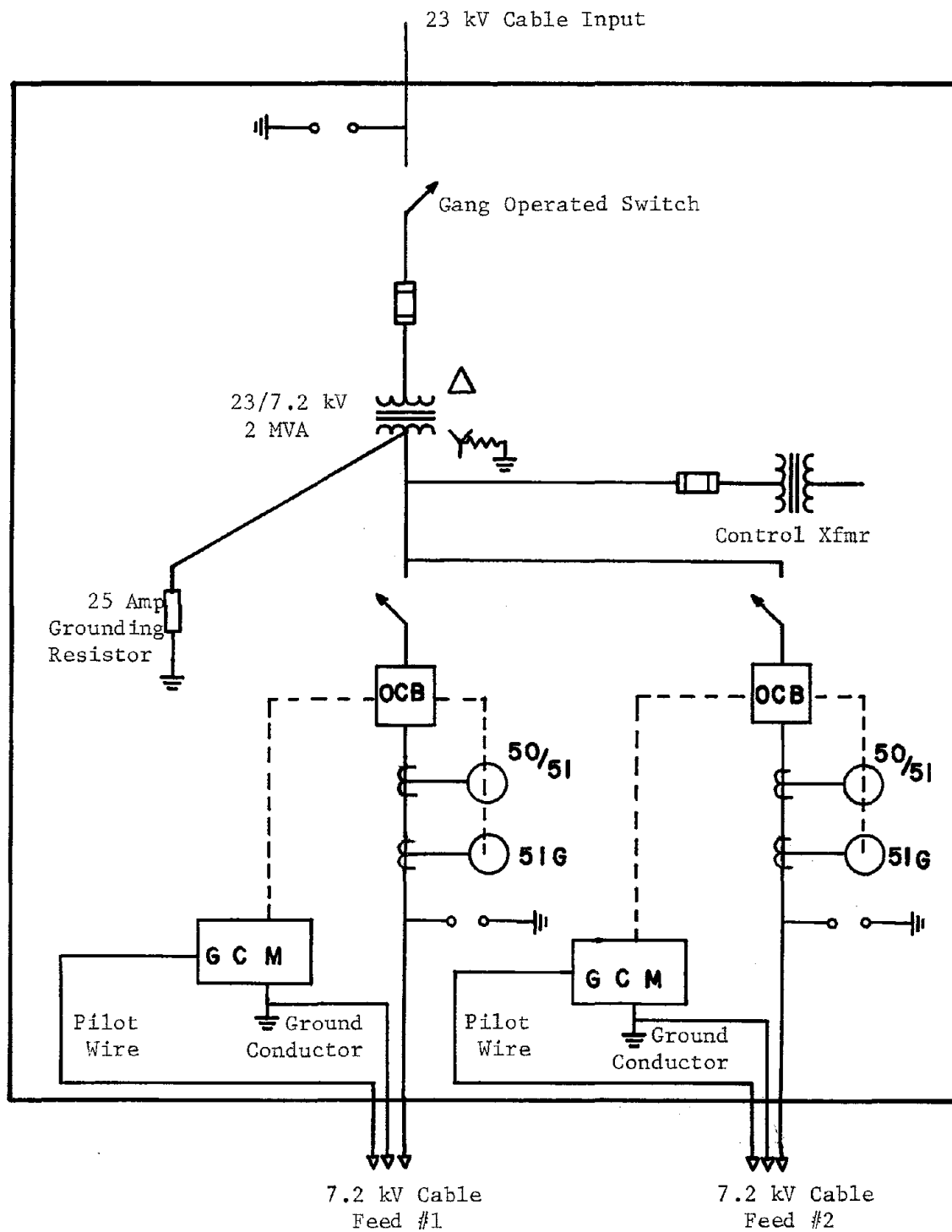


FIGURE 6.19. Portable substation.

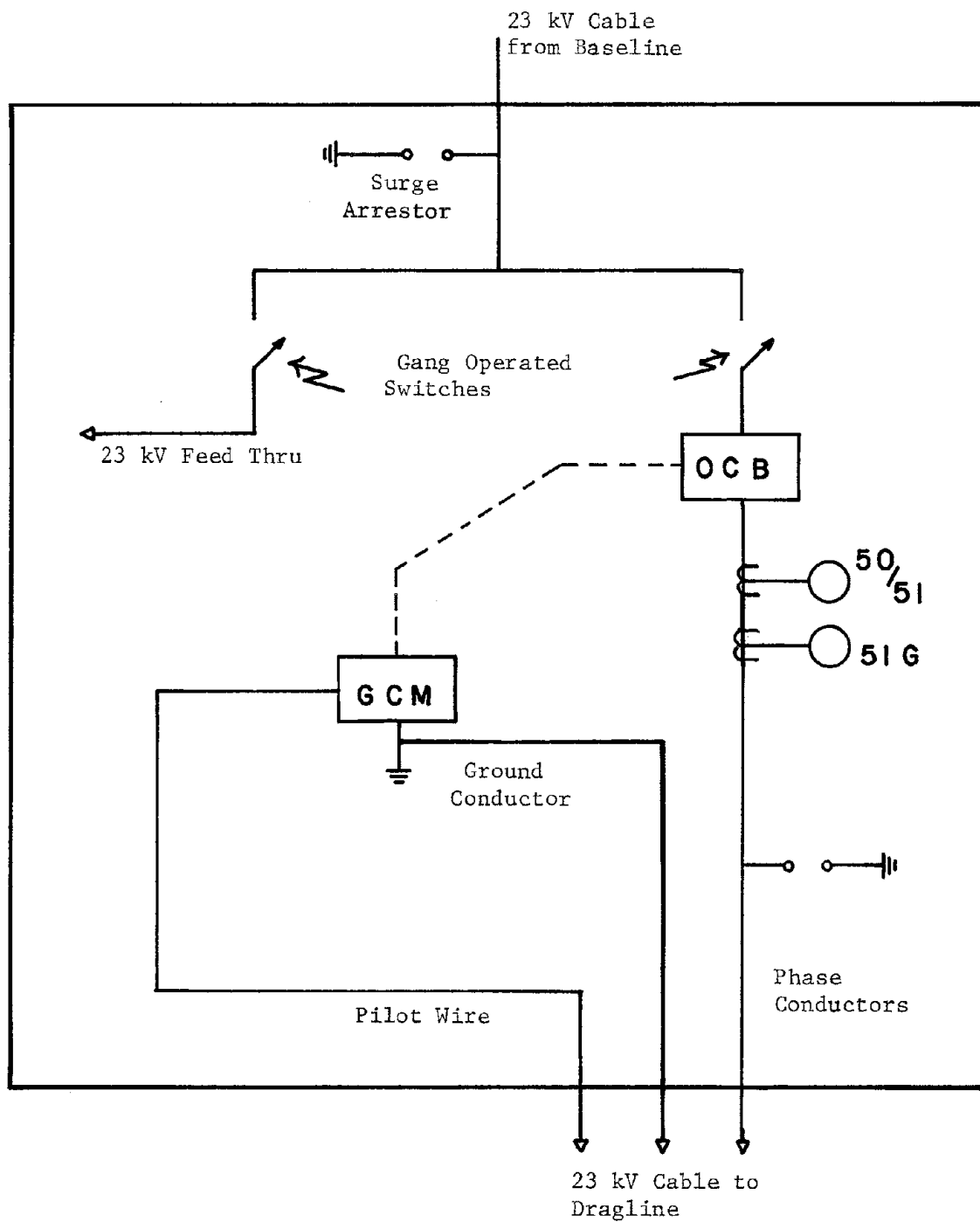


FIGURE 6.20. Breaker skid.

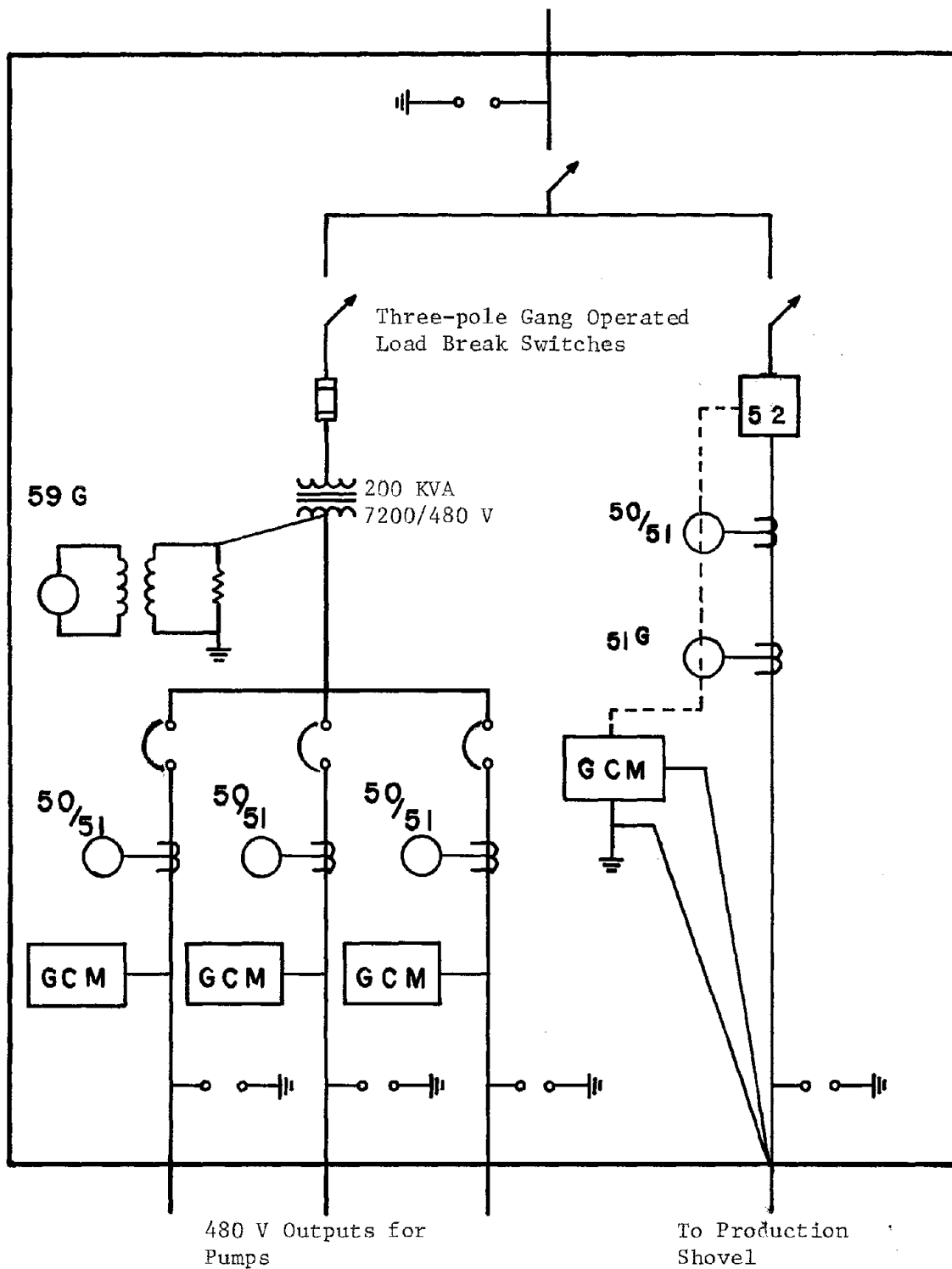


FIGURE 6.21. Pit tower.

CHAPTER VII

APPLICATION OF RESEARCH RESULTS TO MINE MODELS

7.1 INTRODUCTION

The objective of this chapter is to evaluate what type of power system and/or procedural changes would occur upon implementation of the research results and to assess the relative industry costs of such changes based upon the models' parameters.

This objective is accomplished by using the research summaries and assumptions developed in Chapters IV and V to determine what changes each category would impose on the models developed in Chapter VI. An associated cost to the mine operator is estimated based upon the magnitudes and types of changes occurring. This cost estimation is not a rigorous cost analysis. Such an analysis is beyond the scope of this research and besides, any costs developed would only pertain to the models and would not be any more meaningful in terms of actual cost to any particular mine. A rigorous "replacement cost model" (RCM) is presented in section 7.2 to show the impracticality of application of such an analysis to the models. The industry cost assigned to each category is given only to show the relative cost of one category versus another in the benefit/cost comparison. Due to the imprecise nature of estimating costs, scales were developed to allow for inaccuracies in the estimation. These divisions were defined to reflect the impact the changes would have on the company's profits.

7.2 RIGOROUS COST ANALYSIS MODEL

The following model shows the intricate detail which goes into an actual replacement cost analysis. The basic structure and definitions were presented in an Engineering Economy Text but rephrasing and additional explanatory information is included to facilitate understanding by the nonengineering economist [1]. This model can be used for new installations as well as replacements by simply ignoring the information required about the old equipment and substituting zero into the equations where the resale value of the old equipment has an effect upon the cost of the new equipment.

7.2.1 Replacement Cost Model

Procedure:

Obtain Information: Old Equipment = OE Safety Enhancement Equipment = SE

V_{OE} Before-tax net realizable value of old equipment (net realizable value is the present salvage value less the cost of removal and any subsequent loss due to production interruption)

Note: (Production loss may be eliminated by scheduling replacement during non-production periods)

- B_{OE} Current book value of old equipment (Book value is the value of an asset which has not yet been fully depreciated)
- N_{OE} Remaining service life of old equipment (The amount of time left before natural replacement would be required) Note: Many of the safety changes are only expected to be made at the time of natural replacement of the old equipment
- Z_{OE} Salvage value relizable after the remaining life (N_{OE}) of the old equipment (The value of the old equipment at the time of natural replacement)
- A_{OE} Annual operating cost of old equipment (Includes scheduled and unscheduled maintenance, replacement devices, production losses, etc.)
- V_{SE} Investment cost of safety enhancement equipment (The principal investment cost of the new equipment)
- N_{SE} Service life of the safety enhancement equipment
- Z_{SE} Salvage value realizable after the service life (N_{SE}) of the safety enhancement equipment
- A_{SE} Annual operating cost of the safety enhancement equipment
- t Company's marginal income tax rate
- i Company's cost of money (i.e., interest rate or minimum acceptable rate or return (MARR))

Also, the method of depreciation for both the old equipment and the new safety equipment must be known.

Calculate Gain or Loss on Disposal

Disposal cost is the difference between the current book value, (B_{OE}), and the before-tax net realizable value, (V_{OE}), of the old equipment being replaced. A gain or loss on disposal depends on whether V_{OE} or B_{OE} is larger, respectively. Thus if V_{OE} is larger than B_{OE}

$$G = V_{OE} - B_{OE} \text{ and } L = 0$$

and if B_{OE} is larger than V_{OE}

$$L = B_{OE} - V_{OE} \text{ and } G = 0$$

Calculate the net receivable after-tax (NRAT)

A gain on disposal is considered a capital gain which is taxable and a loss on disposal is a capital loss and is deductible from taxable income. These gains and losses may be either short-term or long-term and are dealt with differently. There are options available for treating capital gains and losses, but to simplify the model it is assumed that a loss is deductible and that only 50% of a gain is taxable. Thus, the net receivable after-tax for disposing of the old equipment is

$$NRAT_{OE} = V_{OE} + t(L) - t(0.5 G)$$

where t is the marginal tax rate.

Compute a uniform annual depreciation for both the old equipment and the
new equipment

Depreciation is an allowed tax deduction and is the amount of the initial investment minus the estimated salvage value which is written off each year. There are several methods of depreciation, but regardless of the method used, an equivalent uniform annual depreciation can be calculated using the company's MARR. This uniform depreciation should be computed for both the old and new equipment. (More information concerning this computation can be found in the reference).

Calculate the annual write-off

The allowed annual tax write-off for a piece of equipment is the annual operating cost (A) and the uniform depreciation (D) just computed. Thus, for the old equipment the annual write-off is

$$WO_{OE} = D_{OE} + A_{OE}$$

and for the new safety equipment the write-off is

$$WO_{SE} = D_{SE} + A_{SE}$$

Compute the equivalent annual cost of the old equipment

The equivalent annual cost of the old equipment is the annual operating cost minus the expected salvage value spread uniformly over the remaining service years minus the amount realized as a tax break. Thus the equivalent annual cost which is the actual amount of money it takes to operate the equipment each year after taxes is

$$EAC_{OE} = A_{OE} - Z_{OE} (A/F, i, N_{OE}) - t(WO_{OE}).$$

The term $t(WO_{OE})$ is the realized tax savings and the term $Z_{OE} (A/F, i, N_{OE})$ is the annual equivalence of the salvage value at the end of the equipment's

usable life. (The term $(A/F, i, N_{OE})$ is the distributing factor and is explained fully in the reference).

Compute the equivalent annual cost of the new safety equipment

The equivalent annual cost of the new equipment is the actual after-tax cost of operating the new equipment each year. The formula for computing this value is

$$EAC_{SE} = (V_{SE} - NRAT_{OE})(A/P, i, N_{SE}) - Z_{SE} (A/F, i, N_{SE}) + A_{SE} - t(WO_{SE}).$$

The term $(V_{SE} - NRAT_{OE})$ is the investment cost of the new equipment minus the net value received upon disposal of the old equipment. This represents the actual principal investment and is spread over the expected service life of the equipment by the factor $(A/P, i, N_{SE})$. A_{SE} is the operating cost of the new equipment, the term $t(WO_{SE})$ is the yearly realized tax savings and the term $Z_{SE} (A/F, i, N_{SE})$ is the annual equivalence of the salvage value. The sum of all these terms represents the actual after-tax cost of operating the equipment.

Compare the annual cost

If EAC_{SE} is larger than EAC_{OE} , then the difference reflects the amount of money it actually costs to implement the new safety equipment. This additional cost will necessarily be reflected in the profits. If, on the other hand, EAC_{OE} is larger than EAC_{SE} the difference is the savings realized by implementation of the new equipment.

7.3 COST MODEL RESTRICTIONS AND COST SCALE DEVELOPMENT

Obviously, application of the previous cost model to the research categories and the model mines is not practical. There are no means of obtaining specific numbers which would be meaningful, and application of such numbers would provide no insight to the actual cost to any particular mine. Thus, the purpose of the cost assessment is only to provide relative figures for the comparison of different safety changes. Any mine desiring to know their actual cost for implementing the safety changes can go through the analysis presented in section 7.2 and substitute in their own appropriate values.

The cost assigned any specific change was based upon limited cost experience developed mainly through association with the industry and from manufacturers' literature. This limited experience dictated that cost ranges or bands be established to absorb estimation errors. The expected implementation could certainly be placed more comfortably into a region than identified as a specific value, and since the cost assessment is only intended to be used for comparison and not as a representative figure for actual implementation, this method seemed appropriate.

The cost ranges were developed to reflect the expected impact on the mine's profits. Using the model mines' annual coal production and a selling price of \$30 per ton, a gross profit value was established. Then, using a five and six percent profit for the underground and surface mines, respectively, a net profit of approximately \$300,000 was realized in each model.

After reviewing the categories and the intended changes, it was decided that three separate bands representing a minimal, moderate, and high cost to the company would be sufficient to represent the costs. A minimal cost was considered a cost incurred for safety improvement which would not significantly affect the profit margin. This band was chosen to be from \$0 to \$10,000, or in terms of percentage of the net profit, 0% to 3%. A moderate cost was considered to be a cost incurred for safety improvement which would produce a noticeable effect on net profit, but is not overly burdensome. This band was chosen to be from \$5000 to \$50,000, or in terms of percentage of the net profit, 2% to 17%. The overlapping of the bands represents the transformation area where the costs are becoming less minimal and more moderate. Also, considering the accuracy of the estimation process, it allows a degree of leeway when the estimated cost approaches the defining line. A high cost was considered to be a cost which represented a major portion of the net profits. This band was chosen to be from \$30,000 and up or from 10% of the profits up. Again, these scales are based upon the models which have a \$300,000 net profit each year.

7.4 APPLICATION OF RESEARCH TO THE MODELS

This section applies the results of the research to the models and projects what changes would occur and the expected cost of such changes. The impact on the system by the research is evaluated and recorded under the heading "Assumed Impact on Power System". Also, the expected impact on system components and procedures is noted under the same heading along with the replacement and purchasing decisions affecting each cost estimate. Each of these is separated from the others by three *'s and comes in the same order as just presented. Whether to phase in the system and component changes or to replace immediately upon decision to implement the change is the purchasing decision just mentioned. "Natural replacement" is used to describe the first decision and "installation or purchase upon decision to use" is the phrase used to describe the second decision.

The changes were analyzed to determine what costs are associated with them. Any savings are considered along with the costs and a resultant or net cost is estimated using the levels already determined. Savings is defined as the direct monetary benefit associated with implementation of the research results, such as lower maintenance costs. Although it certainly exists, no attempt was made to assign any monetary benefit to a reduced accident rate. Each cost is identified individually and the definite and possible costs and savings in each category are separated by three asterisks.

7.4.1 Application of Category #1 - Cable Fault Locators

Surface and Underground Model

Assumed Impact on Power System

No expected system alterations *** Impact fault-locating procedure and time
*** Purchased upon decision to use

Implementation Costs

Costs - Initial cost of device, additional training for personnel ***

Savings - Nondestructive fault testing on cable *** Possible savings - speed up fault locating process

Resultant

Minimal

7.4.2 Application of Category #2 - Cable Splice Material Improvement

Surface and Underground Model

Assumed Impact on Power System

No expected system alterations *** Possible impact on - cable design, splice kit composition and design *** Natural replacement of kits and/or cables

Implementation Costs

Costs - *** Possible costs - increased cost of splice kit, additional training of electrical personnel, longer splice time

Savings - *** Possible savings - longer splice lifetime, more durable and reliable splices (ie less unscheduled downtime)

Resultant

Minimal

7.4.3 Application of Category #3 - Protective Device Reliability and Coordination

Surface and Underground Model

Assumed Impact on Power System

No expected system alterations *** Possible impact on replacement components and maintenance scheduling for protective devices *** Purchase of more reliable and fail-safe components upon natural replacement

Implementation Costs

Costs - Incremental costs of better components *** Possible costs - more maintenance time due to scheduling

Savings - Less downtime due to unscheduled maintenance *** Possible savings - minimization of parts stocking

Resultant

Minimal

7.4.4 Application of Category #4 - DC Circuit Breaker Performance - Withstand Capability

Underground Model

Assumed Impact on Power System

Replace present dc breakers with new more-improved ones *** Impact on reliability and durability of dc breakers *** Natural replacement

Implementation Costs

Costs - Incremental cost of new breakers *** Possible costs - maintenance adaptation due to frame size differences

Savings - Less maintenance on breakers, less downtime due to dc breaker failure

Resultant

Minimal

Surface Model - No Application

7.4.5 Application of Category #5 - DC Discriminating Circuit Breaker

Underground Model

Assumed Impact on Power System

Additional on-board equipment on track vehicles and additional control circuitry in the rectifier *** Possible impact on breaker calibration ***
Installation upon decision to use

Implementation Costs

Costs - Additional maintenance on new devices and control circuitry, additional training of electrical personnel, initial cost of equipment and circuitry, installation cost

Savings - *** Possible savings - reduction of damage due to mine fire

Resultant

High

Surface Model - No Application

7.4.6 Application of Category #6 - Proximity Warning Devices

Underground Model

Assumed Impact on Power System

Devices installed on all surface equipment likely to contact overhead power lines *** Possible impact upon operational procedure around overhead power lines *** Installed upon decision to use

Implementation Costs

Costs - Initial cost of devices, installation cost, additional maintenance and calibration of devices

Savings - None

Resultant

Minimal

Surface Model

Assumed Impact on Power System

Devices installed on all equipment likely to contact overhead power lines *** Possible impact upon operational procedure around overhead lines *** Installed upon decision to use

Implementation Costs

Costs - Initial costs of devices, installation cost, additional maintenance and calibration of devices

Savings - None

Resultant

Moderate

7.4.7 Application of Category #7 - Inter-Machine Arcing - Ignition Hazard

Underground Model

Assumed Impact on Power System

Possible replacement of cables with symmetrical cables or installation of arc suppressors on ground wires *** Possible impact on the ground fault system *** Possible natural replacement of cables and installation of suppressors upon decision to use

Implementation Costs

Costs - *** Possible costs - incremental cost of symmetrical cable, additional cost of purchase and installation of suppressors, possible replacement of pilot ground monitors with pilotless monitors if use symmetrical cable

Savings - *** Possible savings - more reliability due to less false tripping, reduced damage due to mine explosion

Resultant

Minimal

Surface Model - No Application

7.4.8 Application of Category #8 - Predicting Incipient Failure

Surface and Underground Model

Assumed Impact on Power System

No expected system alterations *** Impact on procedure for periodic testing of components *** Purchase of test equipment upon decision to use

Implementation Costs

Costs - Purchase and maintenance cost of test equipment, training of personnel and labor time allocated to perform test

Savings - Decreased downtime due to unexpected equipment failure

Resultant

Minimal

7.4.9 Application of Category #9 - Ground Wire Monitoring

Surface and Underground Model

Assumed Impact on Power Systems

No expected system alterations *** Possible impact on components and method used in ground wire monitoring *** Possible purchase of improved components upon natural replacement or in new installations

Implementation Costs

Costs - Maintenance and calibration cost

Savings - *** Possible savings - improved reliability

Resultant *Minimal*

7.4.10 Application of Category #10 - Stray Currents - Generation and Effects

Underground Model

Assumed Impact on Power System

Possible implementation of a two-wire trolley system, otherwise no expected system alterations *** Possible impact on materials used in ground beds, procedure for detecting defective trolley line insulators and defective rail bonds *** Possible purchase of device used to detect defective insulators and bonds and/or possible purchase of a two-wire system upon decision to use.

Implementation Costs

Costs - *** Possible costs - purchase, installation, and adaptation to a two-wire trolley, purchase of device to detect leakage, training required to use device, labor time allocated for device usage.

Savings - Less power loss, less false tripping (ie more reliability), less deterioration due to stray currents.

Resultant *Moderate*

Surface Model - No Application

7.4.11 Application of Category #11 - Improved Trolley Pole Operation

Underground Model

Assumed Impact on Power System

Track motors, jeeps and mantrips would be equipped with the new mechanism
*** Impact trolley and pole life *** Replaced upon scheduled rebuild and
purchased in new track equipment

Implementation Costs

Costs - Additional cost of mechanisms in new equipment and rebuilt
equipment, additional training of maintenance people

Savings - *** Possible savings - reduced wear and tear on the trolley, pole,
and harp (ie longer lifetime)

Resultant

Moderate

Surface Model - No Application

7.4.12 Application of Category #12 - Low-Voltage Shielding for Shock
Elimination

Underground Model

Assumed Impact on Power System

Replace all low-voltage unshielded trailing cables with shielded cables
*** Impact low-voltage splicing *** Natural replacement

Implementation Costs

Costs - Higher initial cost of cable; longer splice time; less lifetime
on reeled situations *** Possible cost - more expensive splice kits;
additional training of electrical personnel

Savings - None

Resultant

Moderate

Surface Model - No Application

7.4.13 Application of Category #13 - Cable Mechanical Stress Elimination

Underground Model

Assumed Impact on Power Systems

Replacement of current cable reel systems with new improved systems
*** Impact reeled cable failure *** New shuttlecar purchases would insure inclusion of new reel and the old reels replaced with new ones at the time of scheduled rebuild.

Implementation Costs

Costs - Additional cost of more sophisticated reel in shuttlecar, additional training of maintenance personnel *** Possible costs - higher level of maintenance on the reel.

Savings - Increase reeled cable life, reduce reeled cable failure (ie less downtime)

Resultant

Minimal

Surface Model - No Application

7.4.14 Application of Category #14 - Sensitive Ground Fault Detection

Underground Model

Assumed Impact on Power Systems

No expected system alterations *** Impact on ground fault scheme
*** Purchase of new and more sensitive ground fault detection components upon decision to use.

Implementation Costs

Costs - Purchase and installation of new components *** Possible costs - nuisance tripping (ie less reliability), additional difficulty to maintain

Savings - None

Resultant

Moderate

Surface Model - No Application

7.4.15 Application of Category #15 - Remote Control Trolley Energizing/
Deenergizing

Underground Model

Assumed Impact on Power System

Additional equipment on-board track vehicles, additional control circuitry in the rectifier, possible additional switching devices in the trolley line
*** Possible impact on breaker life and maintenance *** Installation upon decision to use

Implementation Costs

Costs - Initial cost of equipment and circuitry, installation cost, additional training of electrical personnel, additional maintenance on the new devices and circuitry

Savings - Less stray current generation (ie deterioration and false tripping due to)

Resultant

High

Surface Model - No Application

7.4.16 Application of Category #16 - Cable Handling Devices (Underground)

Underground Model

Assumed Impact on Power System

Continuous miner cable would be handled by a separate device while energized
*** Impacts the method of handling energized miner cable. Possible impact on the reliability of the system by adding another machine which might fail
*** Purchased upon decision to implement

Implementation Costs

Costs - Initial cost of the device, additional training of personnel operating tender, additional maintenance on device *** Possible costs - more downtime

Savings - *** Possible savings - increased cable life

Resultant

Moderate

Surface Model - No Application

7.4.17 Application of Category #17 - Elimination of Shuttle Car Trailing Cable

Underground Model

Assumed Impact on Power System

All shuttle car trailing cables would be eliminated *** Impact shuttle car design, power center composition, maintenance methods *** Replacement upon purchase of new shuttle cars

Implementation Costs

Costs - Operating cost of nonuseable equipment, incremental cost of new shuttle car, cost of alternative power source *** Possible costs - ventilation improvement if fossil fuel is new power source, training for maintenance personnel

Savings - No cable costs, unrestricted movement, *** Possible savings - less maintenance and downtime due to faulty protective gear

Resultant

Moderate

Surface Model - No Application

7.4.18 Application of Category #18 - DC Ground Fault Interruption

Underground Model

Assumed Impact on Power System

Installation of dc ground fault detection and interruption system
*** Impact on dc circuit breaker control circuit *** Purchase upon decision to use

Implementation Costs

Costs - Purchase, installation, and maintenance of dc ground fault system
*** Possible costs - replacement of current dc cable with a three-wire cable, reduced reliability

Savings - *** Possible savings - reduction in dc cable fires

Resultant

Moderate

Surface Model - No Applications

7.4.19 Application of Category #19 - Cable Shield Integrity

Surface and Underground Model

Assumed Impact on Power System

No expected system alterations *** Possible impact on splicing and replacement of shielded cables *** Purchased upon decision to use

Implementation Costs

Costs - Initial cost of device, additional training of personnel to use it, labor time given to use of device, labor time required to repair or replace discovered defects

Savings - None

Resultant

Minimal

7.4.20 Application of Category #20 - Cable Handling Methods and Devices -
Surface

Surface Model

Assumed Impact on Power System

No expected system alterations *** Possible impact on the devices and procedures used in handling cable *** Possible purchase of personal protective devices or cable handling equipment upon adaptation of new methods

Implementation Costs

Costs - Additional training of personnel *** Possible costs - purchase of personal protective gear, purchase of cable handling equipment

Savings - Extended cable life *** Possible savings - less downtime due to cable damage resulting from faulty handling methods

Resultant

Minimal

7.4.21 Application of Category #21 - Battery and Battery-Charger Safety

Surface and Underground Model

Assumed Impact on Power System

No expected system alterations *** Possible impact on training programs and procedures dealing with battery charging *** Possible purchase of new devices to implement charging guidelines.

Implementation Costs

Costs - Procedural training for personnel *** Possible costs - cost of safety equipment used during charging procedure

Savings - Increased battery life

Resultant

Minimal

7.4.22 Application of Category #22 - Reduction of Accidental Contact with the Trolley

Underground Model

Assumed Impact on Power System

Rebuild or replace the current trolley wire with one employing continuous insulation along its length *** Possible impact on the trolley pole harp design *** Install upon decision to use

Implementation Costs

Costs - Trolley wire replacement cost (initial and installation), trolley pole adaptation cost

Savings - *** Possible savings - new system would provide self-guarding

Resultant

Minimal

Surface Model - No Application

7.4.23 Application of Category #23 - Ungrounded Power System Analysis

Underground Model

Assumed Impact on Power System

The grounding resistor would be replaced by a large value of resistance or an open-circuit and the ground fault detection scheme must be changed *** Impact on ground fault scheme, protective device coordination *** Replace the grounding resistor and ground fault protection upon decision to use

Implementation Costs

Costs - Purchase and installation of resistor, purchase and installation of ground fault protection scheme, higher insulation stress due to increased transients and neutral shift

Savings - *** Possible savings - increased service continuity

Resultant

High

Surface Model

Assumed Impact on Power Systems

The grounding resistor would be replaced by a large value of resistance or an open-circuit and the ground fault detection scheme must be changed *** Impact on ground fault scheme, protective device coordination *** Replace the grounding resistor and ground fault protection upon decision to use

Implementation Costs

Costs - Purchase and installation of resistor, purchase and installation of ground fault protection scheme, higher insulation stress due to increased transients and neutral shift

Savings - *** Possible savings - increased service continuity

Resultant

Moderate

7.4.24 Application of Category #24 - Cable Handling Methods (Underground)

Underground Model

Assumed Impact on Power System

No expected system alterations *** Procedural impact on present handling methods, possible impact on personal protective equipment *** Possible purchase of personal protective equipment upon adaptation of new methods

Implementation Costs

Costs - Additional training of personnel *** Possible costs - purchase of miner protective equipment

Savings - *** Possible savings - increased cable life

Resultant

Minimal

Surface Model - No Application

7.5 REFERENCE

Mallik, Arup K. Engineering Economy with Computer Applications. Engineering Technology, Inc., Mahomet, Illinois, 1979, pp. 147-156.

CHAPTER VIII

PROPOSED SAFETY PRACTICES

8.1 INTRODUCTION

This section presents a subjective ranking of the proposed safety changes in terms of safety benefits vs industry costs. The benefits were presented in Chapter V and are the same ones used in the cost/benefit comparison to the Bureau. The costs developed in Chapter VII are combined with these benefits in Table 8.1. The costs shown are followed by the letters U, S, or B which represent the cost to an underground or surface mine or (if the cost is about the same) for both models. If the cost is applicable to both but different for each model, both costs are shown with the appropriate identifier following.

8.2 RANKING OF PROPOSED SAFETY PRACTICES

Table 8.1 together with any expected implementation difficulties was evaluated to determine the relative cost-effectiveness of the different categories. Four stages of recommendation were chosen to represent the various levels of expected safety benefit per dollar expended. These stages are:

Highly Recommended

Recommended

Marginal

Not Recommended

The recommendation level was based primarily upon the safety benefits, but taking into consideration the expected cost, the difficulty of implementation and useage, and the anticipated effectiveness of the change to actually reduce the number of accidents. "Highly Recommended" represents a category with extremely high safety benefits which can be implemented with reasonable effort and is not prohibitively expensive. "Recommended" represents a category with substantial safety benefits, but may be difficult to implement or is extremely expensive. It also includes those categories with moderate benefits which can be implemented easily for a reasonable cost. "Marginal" is where the category has moderate or less safety benefits and is either difficult to implement or is relatively expensive in relation to the expected benefits. "Not Recommended" represents those categories which are extremely expensive relative to their expected benefits. Table 8.2 presents the ranking of the categories in the same order as they have been presented previously. All comments pertinent to the decision are included for completeness.

TABLE 8.1. Possible safety benefits and cost to the industry of proposed electrical safety measures

Research Category	Electrical Accidents Definitely Impacted			Electrical Accidents Possibly Impacted			Cost to Industry to Implement
	No.	Lost Days	Fatals	No.	Lost Days	Fatals	
Cable Fault Locators (#1)	15	152	0	15	465	0	Minimal - B
Cable Splice Material Improvement (#2)	16	131	0	71	673	0	Minimal - B
Protective Device Reliability and Coordination (#3)	51	562	0	10	107	0	Minimal - B
DC Circuit Breaker Performance-Withstand Capability (#4)	2	6	0	28	529	0	Minimal - U
DC Discriminating Circuit Breaker (#5)	11	153	0	20	134	0	High - U
Proximity Warning Devices (#6)	10	3915	6	1	999	0	Minimal - U Moderate - S
Intermachine Arcing - Ignition Hazard (#7)	3	18	0	4	24	0	Minimal - U
Predicting Incipient Failure (#8)	6	44	0	57	653	0	Minimal - B

TABLE 8.1. Possible safety benefits and cost to the industry of proposed electrical safety measures (continued)

Research Category	Electrical Accidents Definitely Impacted		Electrical Accidents Possibly Impacted		Cost to Industry to Implement	
	No.	Lost Days	Fatals	No.	Days Lost	Fatals
Ground Wire Monitoring (#9)	4	16	0	16	139	1
						Minimal - B
Stray Currents - Generation and Effects (#10)	0	0	0	8	47	0
						Moderate - U
Improved Trolley Pole Operation (#11)	24	256	1	16	64	0
						Moderate - U
Low-Voltage Shielding for Shock Elimination (#12)	45	646	0	6	81	0
						Moderate - U
Cable Mechanical Stress Elimination (#13)	0	0	0	73	1117	0
						Minimal - U
Sensitive Ground Fault Detection (#14)	147	2653	2	114	2071	5
						Moderate - U
Remote Control Trolley Energizing/Deenergizing (#15)	85	825	0	15	172	1
						High - U
Cable Handling Devices (Underground) (#16)	7	26	0	28	378	0
						Moderate - U

TABLE 8.1. Possible safety benefits and cost to the industry of proposed electrical safety measures (continued)

Research Category	Electrical Accidents		Electrical Accidents		Cost to	
	No. Days Lost	Fatals	Definitely Impacted	Possibly Impacted	Industry to	Implement
Elimination of Shuttle Car Trailing Cables (#17)	37	565	1	111	1806	1 Moderate - U
DC Ground Fault Interruption (#18)	0	0	0	7	24	0 Moderate - U
Cable Shield Integrity (#19)	2	37	0	12	98	0 Minimal - B
Cable Handling Methods and Devices - Surface (#20)	2	37	0	0	0	0 Minimal - S
Battery and Battery-Charger Safety (#21)	42	150	1	0	0	0 Minimal - B
Reduction of Accidental Contact with the Trolley (#22)	82	701	2	7	29	0 Minimal - U
Ungrounded Power System Analysis (#23)	9	112	0	30	493	0 High - U Moderate - S
Cable Handling Methods (Underground) (#24)	52	677	0	38	864	0 Minimal - U

TABLE 8.2. Recommendation for implementation of proposed safety measures

Cable Fault Locators ****Recommended**** Moderate safety benefit, but system should pay for itself, and may reduce direct operating costs.

Cable Splice Material Improvement ****Recommended**** Moderate safety benefit, but very little cost. New splice materials may reduce direct operating costs.

Protective Device Reliability and Coordination ****Marginal**** Safety benefit may not be fully realized because many failures are due to poor maintenance.

DC Circuit Breaker Performance-Withstand Capability ****Recommended**** Moderate safety impact. Improved performance should significantly reduce equipment damage and maintenance costs, and may reduce direct operating costs.

DC Discriminating Circuit Breaker ****Not recommended**** Moderate safety impact. High cost. Unproved technology. Possible resistance and sabotage. Will require MSHA enforcement.

Proximity Warning Device **** Highly Recommended **** Extremely high benefit to cost ratio - with good equipment design should be nearly 100% effective. Will require MSHA enforcement. May not be as beneficial for underground mines.

Intermachine Arcing - Ignition Hazard ****Recommended**** Primary safety impact on accidents not classified as electrical, so benefits cannot be fully assessed. No direct monetary benefit. Requires MSHA enforcement.

Predicting Incipient Failure ****Marginal**** Safety impact likely to be slight. Significant cost of implementation expected to be offset by increased availability of production equipment, but this may not occur.

Ground Wire Monitoring ****Recommended**** Moderate safety benefit, but has already been required by MSHA for several years.

Stray Currents - Generation and Effects ****Marginal**** Little safety impact. Moderate cost of implementation may be offset by reduced maintenance costs and less downtime.

Improved Trolley Pole Operation ****Recommended**** Moderate safety benefit. No direct cost benefit.

Low-Voltage Shielding for Shock Elimination ****Highly Recommended**** High safety benefit, expected to be fully realized. Moderate cost.

Cable Mechanical Stress Elimination ****Marginal**** Possible safety benefit. Should pay for itself in reduced cable costs and reduced downtime.

Sensitive Ground Fault Detection ****Recommended**** Extremely large safety benefit, but may be difficult to implement with current technology. Should be researched more.

Note: (Better work procedures might reduce the number of accidents in this category).

Table 8.2. Recommendation for implementation of proposed safety measures
(continued)

Remote Control Trolley Energizing/Deenergizing ****Marginal**** Potentially large safety benefit, but not likely to be realized without use of very short blocks and numerous warning devices. Would require MSHA enforcement.

Cable Handling Devices (Underground) ****Not Recommended**** Some safety benefit. Similar benefits could be achieved through training and work procedure changes.

Elimination of Shuttle Car Trailing Cable ****Marginal**** Large benefit from moderate implementation cost. Other power sources would probably introduce new hazards which would reduce their benefit.

DC Ground Fault Interruption ****Not Recommended**** Little apparent need for electrical safety. May impact fire safety. Would require MSHA enforcement.

Cable Shield Integrity ****Marginal**** Some safety impact. May be some difficulty with implementation. Would require MSHA enforcement.

Cable Handling Methods and Devices - Surface ****Marginal**** Very little direct impact on electrical safety - May pay for itself in direct operating costs.

Battery and Battery-Charger Safety ****Recommended**** Some safety impact. Minimal cost. Mostly procedures, difficult to enforce. Requires MSHA enforcement.

Reduction of Accidental Contact with the Trolley ****Recommended**** Substantial safety impact. Likely to be effective. May require MSHA enforcement.

Ungrounded Power System Analysis ****Not Recommended**** Possible moderate safety impact. May cause difficulty in maintaining ground fault protection. High to moderate cost.

Cable Handling Methods (Underground) ****Highly Recommended**** Large impact on safety, minimal cost. Requires training and procedural changes. Difficult to enforce. Requires MSHA enforcement.

APPENDIX A
TRIP REPORTS

Mine visits were made to six underground coal mines and to four surface mines. Discussions were held with mine personnel and the power systems were investigated. In addition, discussions were held with MSHA personnel in District 7.

A.1 WEST VIRGINIA MINES

Visits were made in December 1980 to two coal mines in West Virginia. One is a small mine of a small, privately owned coal company while the other is a larger mine operated by a large corporation. The second is a mine which has been identified as "safe".

A.1.1 A Privately Owned Mine

A visit was made on December 30, 1980 to a West Virginia Coal Mine. The mine is privately owned and produces metallurgical coal from the Pocahontas 3 and 4 seams. They are a union operation with an employment level of approximately 400 workers, which is down considerably from 800 in 1978 with the lowest level reached being about 200. The company consists of nine different mines, most of which are one section operations. Most of their coal is contracted with the rest going to spot market. All of the mines truck their coal to the single preparation plant except for two which dump directly from their haulage belt. The plant is presently operating at near 50% reject because of the excessive amount of rock that must be taken at one of the mines.

The mine visited is a one section mine operating in the Pocahontas #3 seam. The seam height is approximately 36-38 inches and belt haulage is utilized. An approximate 300 ton-per-shift production level is claimed. The continuous mining method is employed with the section having its complement of miner, bolter, two shuttle cars, belt feeder, and battery powered scoop. Since the underground distance of this drift mine is only about 1200 feet, the battery charging units are located outside near the shop. Supplies are taken into the mine in the scoop since they have no trolley system. The men also ride in and out of the mine on a piece of belt dragged behind the scoop. They operate on a six heading system with approximately 20-foot entries and 75-foot blocks.

The company owns two substations where they buy power from the utility. They have one 6000 and one 15000 kVA unit, both of which are 46 kV - 4160 V (Δ -Y). All required monitoring for the underground circuits is placed at the point of entry and all required protection in the substation is present. One of the stations has an automatic recloser device and the comment about this device was, "It's saved me several trips out here to reset this breaker."

All surface poles lines are at least 20 feet off the ground with the static wire carried above the phase lines except for one small line which carries it below. Each pole is butt grounded and connected to the static wire. The safety ground is approximately 100 feet from the substation ground-bed. They claim to have very little high-voltage surface line problem. They have not had much problem with getting equipment into their overhead lines thus they have not considered using proximity warning devices.

They use 85 A Westinghouse fused cutouts as their visible disconnects at the bottom of the borehole. The 4160 V underground distribution line is shielded #2 cable. The total distribution length is approximately 1200 feet. The 36 inch belt is driven by a 480 volt, 75 Hp motor supplied from

a 300 kVA Pemco power center. The face power center is a 750 kVA unit from Sasser Electric. Both units contain the required monitoring and protection. Trailing cable lengths on the miner, bolter, and buggies are 700, 550, and 500 feet, respectively. The buggies are ac/dc units and they use a three conductor flat profile cable. Their major problem with trailing cables is breaking the pilot wire inside of the cable. They expressed interest in using pilotless monitors but as yet had not tried any. They own an Appalachian audio type fault locator but don't use it much because they claim it to be unreliable. They do all of their permanent splicing on section and they are presently using a CSI splice kit.

They operate on a two shift production-one shift maintenance schedule in their larger mines and a two-shift production - "fix-it when it breaks" philosophy in their smaller mines. They run weekly checks on their monitors and monthly inspection and maintenance on their breakers. All of their mechanics are certified electricians and they have at least one and probably two for each section. The company supplies all of their tools which are replaced on need. The company used to have its own training program but has terminated it.

Conversations with the maintenance superintendent and shop foreman resulted in some interesting comments about MSHA, the electrical regulations and safety in general. They felt that the MSHA electrical inspectors were knowledgeable and personally nice people. They also felt that MSHA did not treat everyone the same, meaning that violations might be overlooked in one mine and the same violations receive severe reprimands in another mine. The face equipment lighting regulation is the one they felt which is hardest to comply with. They said it is nearly impossible to keep the required lights from physical damage in low coal.

Their opinion on safety is that it must come from all ends - labor, management, and the Dept. of Mines. Every new work week for them begins with a safety meeting. Their "Key to Safety" is for one man not to take another man's word that the power is disconnected. This statement implies that they have seen many men hurt because they didn't remove the power to a circuit themselves before they worked on it.

A.1.2 A "Safe" Mine

A visit was made on December 2, 1980, to the main portal of an underground coal mine owned by a large corporation. This mine is reputed to be one of the safest coal mines in the United States as witnessed by the bestowal of the "Sentinels of Safety Award" upon them for the past two consecutive years. It is also the largest producing coal mine per man-hour in the corporation. The mine operates in the Redstone seam and sells most of its product as steam coal to a power company. It trucks its coal to a nearby preparation plant which has been renovated from 200 tons/hr up to 275 tons/hr raw material.

The mine has three operating sections and employs approximately 30 "machine repairmen", of which almost all are certified electricians. The continuous mining method is employed with belt haulage of coal and track

haulage of men and supplies. It utilizes a nine-heading method with the trolley, belt and distribution system in the #5 heading. The belt structure is hung from the roof with timbered supports alongside. Each section has a complement of one continuous miner, two shuttle cars, one roof bolter, one jeep or scoop, one battery charger, one welder, one belt feeder/crusher, and one portable 750 kVA combination power center.

The local power company owns and operates a central substation which supports four different company operations with 12 kV supply. The utility also owns the distribution lines from this substation to the particular mine substation where it is metered. The mine substation is a small unit containing power factor correcting capacitors, lightning arrestors, oil circuit breaker, 12 kV feed-through, and a three-phase transformer 12 kV/4160 V Δ -Y with a 25 amp grounding resistor. The phase conductors, pilot, and ground of the 4160 V outgoing lines are all strung horizontally on overhead poles. The substation and safety ground beds are driven-rod construction with at least 25 foot separation.

The 12 kV feed-through supplies the fan, two outside water pumps, and a shop by means of 3- ϕ connections of pole-mounted transformers, before continuing on to another portal. The 4160 V lines are pole-mounted for approximately 80 yards where they are terminated in a cable which runs to the outside belt power center. This center is a 500 kVA unit which employs Ensign monitors and overcurrent and undervoltage protection. The belt starter powered by this unit is an older model resistance starter.

The dc trolley system is powered by only one 500 kW Ohio Brass rectifier unit. The total trolley length is approximately one mile. The track is blocked and stoned and utilizes 60# rail and, additionally a 1000 MCM copper return feeder is paralleled to the rail. The overall condition of the track, trolley and rail equipment seemed good. In fact, the general appearance of the mine and equipment was neat and orderly.

A.2 KENTUCKY COAL MINES

Visits were made to two underground coal mines in southeastern Kentucky during the week of June 22, 1981. Both mines contained conventional mining sections and a trip was made inside the second mine to view the power system components and equipment in operation. Unfortunately, the bolter was inoperative and had the rest of the equipment shut down. Despite this, the power system layout and component application was observed and several pictures were taken.

A.2.1 A Family-Owned Mine

The first operation visited is a family-owned non-union mine superintended by one of the five controlling brothers. The mother company presently employs about 400 people in their five different mines. A tour of the surface facilities at three of these mines were made and although no actual trip underground occurred, the section electrical components were observed in operation at an infant drift mine which had not progressed underground far enough to necessitate movement of the components from the surface. Also, equipment manuals were made available from which the

horsepower load of each piece of mining equipment was determined. These values are shown in Table A.1. These values are important in determining total section load and when comparing power systems for conventional and continuous mining.

The infant mine had a new portable Pemco substation on the surface. The company-owned pole line ran right up to the sub where it was terminated in a cable which fed the 1250 kVA unit. The delta-wye transformer was grounded through a neutral grounding resistor to the safety ground bed. The safety ground was approximately 150 yards away across the mountain top. The ground lead, a bare aluminum conductor, was carried on the incoming 13.8 kV overhead line below the phase conductors and static wire. This conductor became a #2 15 kV insulated cable approximately 50 feet from the substation. The substation was a completely enclosed structure containing two load-break switches, the 500 kW trolley rectifier, the outside belt starter box, and circuits supplying the underground workings, fan, outside belthead, and air compressor. It was indicated that no safety interlocks were incorporated in the substation. Oil circuit breakers were used because of past experience and familiarity.

The underground power center (face) was a 750 kVA unit incorporating Westinghouse breakers on all of the following outputs:

- 6-225 Amp - 480 V - Shuttlecars & Twin-Boom Bolter
- 2-600 Amp - 480 V - Miner & Spare
- 4-225 Amp - 480 V - Water Box - Scoop Charger - Bolter - Feeder

The 4160 V distribution cable supplying this power center consisted of sections of 2/0, 5 kV SHD-GC cable. However, the last section in this line, immediately outby the power center, was a #2 cable. This cable was always kept as the last section in the distribution line. Any extension or shortening of the line was made immediately outby the #2 cable section. The reason given for carrying the #2 cable was that it is much easier to handle.

A "water box" was built using a submersible pump in a contained enclosure which supplied all of the section's water needs. The pump ran constantly, circulating the water in the tank when not supplying the miner. This type of arrangement was claimed to be a more efficient and reliable mode of operation than running a high pressure line all the way from the outside. A smaller, more economical water line running under less pressure could supply the water box.

Only four different trailing cable sizes were used in the entire mine. The superintendent felt this to be beneficial in terms of stocking and purchasing. The following is a sample of the types and possible uses:

#6	Flat G-GC	Shuttlecars
4/0	Round G-GC	Miner
#6	Round G-GC	Single-Head Bolter
#4	Round G-GC	Twin-Head Bolter
		Belt Feeder

Table A.1. Mining equipment motor sizes

18 SC JOY Shuttlecar - (AC/DC)	(All DC Motors)
2 - 15 Hp	Traction Motors
2 - 10 Hp	Conveyor Motors (2 Speed) [Fast - 10 Hp]
1 - 10 Hp	Pump (Hydraulics) Motor [Slow - 5 Hp]
14 BU10-11 SH Loader - (AC)	(All AC Motors)
2 - 24 Hp	Traction Motors (2 Speed) [Fast - 25 Hp]
2 - 35 Hp	Gathering Head [Slow - 12.5 Hp]
1 - 10 Hp	Pump
16 RB-2BH Cutter - (AC)	
1 - 135 Hp	Cutting Motor
	Hydraulic Tram
1 - 65 Hp	Pump Motor
Galis 300 Roof Drill - (AC)	
	Hydraulic Tram
1 - 30 Hp	Pump Motor
Galis Coal Drill - Face Drill	
1 - 30 Hp	Pump Motor
Stamler Feeder/Crusher - (AC)	
1 - 50 Hp	Conveyor Motor
1 - 50 Hp	Pick Breaker Motor (Crusher)
14 CML Continuous Miner - (AC)	
2 - 90 Hp	Cutter Motors (125 Hp now)
1 - 50 Hp	Gathering Motor
2 - 35 Hp	Traction Motors
1 - 50 Hp	Pump Motor
14 CMS-10 Continuous Miner - (AC)	
2 - 135 Hp	Cutter Motors
1 - 70 Hp	Gathering Head
2 - 35 Hp	Traction Motors
1 - 50 Hp	Pump Motor

Table A.1. Mining equipment motor sizes (continued)

Scoop - Battery Powered - (DC) (All DC Motors)

1 - 20 Hp (60 V) Tram Motor
1 - 7.5 Hp (60 V) Pump Motor

Scoop Battery Charger - (AC)

AC Input: 440 Volt - 30 Amp - 3 ϕ
DC Output: 65 Volt - 88 Amp

A Raychem splice kit was used to make all permanent splices.

The trolley system was powered by 300 kW rectifiers spaced every 3000 feet for supply haulage (1500 feet for coal haulage). It was a 300 volt dc system using 40# rail and #4 trolley wire. No parallel feeders or returns were used and the trolley was only used to power rail equipment.

The coal was transported outside by belt where a stacker belt piled it up. A 36-inch belt was used which was powered by 125 Hp beltheads spaced every 3000 feet. Once outside the coal was loaded into trucks where it was transported to a central cleaning plant. This plant had over 1000 tons per hour raw capacity and was presently running at 25-30 percent reject.

The superintendent said that when he was designing for a power center, he summed up the total horsepower load using 1 kVA per Hp and added 20 percent. He felt he had more power than he needed but he said the system could only grow, it would never decline. He also indicated that as a whole the MSHA electrical rules were good but some inspectors' interpretations were sometimes inconsistent and that they did not always agree with the interpretation. His philosophy concerning government regulation followed this quotation which another and older gentlemen had told him. "Rules and regulations were made to protect lives and property and when those politicians in Washington failed in that respect, then we should have sense enough to ignore them."

The company provided complete medical and mental insurance for the employees and their families. In addition to paying union scale or above wages the company developed a fund into which they placed all of the money they would normally have to pay into a union. This fund was divided amongst the men every few months. As an incentive to work safely and within the law, the company took money from the fund to pay any and all citations they received from MSHA.

A.2.2 The Second Kentucky Operation

The second operation visited consisted of three mines. The first mine is an eight-section mine having two continuous sections and six conventional sections. The second mine is about the only shaft mine in the area and the third is the mine in which the underground visit occurred. All of the miners belong to a union but not the UMW.

The utility supplies the mine with power at 7200 volts from an on-site utility substation. This power is distributed over three different surface lines which originate from a switching station located near the utility sub. Each circuit is protected by an oil circuit breaker (OCB) and has short circuit, overload, and ground protection (where applicable). The shop supervisor indicated that they didn't normally carry a static wire but MSHA forced them to on their newer installations. Thus, one circuit carried a static wire and it used the guy wires as the grounding leads. They run approximately 17 miles total of overhead line with the longest line being approximately 10 miles. The total connected transformer load on the three lines is nearly 25 MVA. This is the summation of all the surface transformer capacities.

A mine substation supplying power underground contains the usual components: resistance-grounded transformer; ground fault, time and instantaneous overcurrent, and undervoltage release relays; ground monitor; etc. One of the subs also contained a PR 460 Westinghouse recloser. MSHA had forced them to block it to a single trip operation mode.

An equipment list for the eight-section mine is shown in Table A.2. The supervisor indicated that a conventional section represents less power load even though the total connected horsepower may be nearly equal. This is due to the load factor. He said that a conventional section would run about 50 percent load factor compared to about 80 percent for a continuous section.

Tables A.3 and A.4 give a summation of the electrical equipment and trailing cable sizes witnessed during the underground visit. The coal seam was about 40 inches and conventional mining was the only method used. The trolley rectifiers were spaced at 2500 foot intervals and they used 40# rail. The only time they used the trolley wire for anything except powering rail equipment was for moving equipment. During such a move they were supposed to use clamp-on nips but the supervisor said he had seen them use the hook-over type. The trolley was used only for haulage of men and supplies, while the coal was transported by belt. The general appearance around the power center and rectifier was cluttered. The distribution box terminals and outgoing cables were muddy and tangled and the shuttlecar trailing cable was anchored directly around a roof jack.

A.3 A LARGE EASTERN COAL COMPANY

A visit was made on December 18, 1980 to the central headquarters of a large eastern coal company. An engineer, who is singularly responsible for all design specifications, layout, and purchasing of power system materials and equipment for the regional operation, spent the afternoon discussing the company's operations, procedures, and practices. The conversation also included general power system considerations, regulation and inspection problems, and safety philosophies. Additionally, arrangements were completed for the following morning's visitation to a nearby company mine to observe its power system from substation to face utilization.

The regional operation consists of 34 working sections in twelve mines and three preparation plants. These mines produce metallurgical coal, 25 percent of which is exported, with an all-UMWA labor force. All mines operate on a two-shift production - one-shift maintenance schedule. All electrical planning is done through the engineer's office and because of this he has the ability to standardize all equipment layouts and specifications. This he does by specifying not only the electrical components but also their structural layout within the mechanical enclosure before an equipment order is sent out for bid. By doing this, he may reduce the number of pieces needed because of interapplications between mines and make personnel training and placement simpler by means of uniformity. This is very advantageous both in terms of economy and safety.

The company has a research and development center supplied with shop equipment, drafting facilities, and is constructing an electronics shop..

Table A.2. Mine production equipment list

Section #	Loader	Shuttle Car	Cutting Machine Miner
1	A-77, 14 BU 10-AC A-78, 14 BU 10-DC	B-03, B-34, B-49 6 SC (Wide)	C-55 11 RU (Long)
2		B-26, 6 SC (Wide) B-36, 6 SC (Wide) B-41, 6 SC (Wide)	C-86, 14 CM Joy
3	A-71, 14 BU 10-DC A-84, 14 BU 10-AC	B-21, 6 SC (Wide) B-207, 21 SC B-208, 21 SC	C-50, 11 RU (Long)
4	A-79, 14 BU 10-AC A-96, 14 BU 10-11DE-DC	B-67, Torkar B-211, 21 SC B-214, 21 SC	C-22, 10 RU (Long)
5		B-08, 6 SC (STD) B-23, 6 SC (Wide) B-38, 6 SC (STD)	C-84, 14 CM Joy
6	A-74, 14 BU 10-AC A-82, 14 BU 10-DC	B-30, 6 SC (Wide) B-43, 6 SC (Wide) B-82, 6 SC (Wide)	C-03, 10 RU (Long)
7	A-83, 14 BU 10-AC	B-06, 6 SC (STD) B-48, 6 SC (Wide)	C-68, 16 RB
8			

Section #	Coal Drill	Roof Drill	Scoop Tractor	Feeder Breaker
1	E-82, 300 Galis	E-82, 300 Galis E-89, 300 Galis		R-42, Stamler
2		E-80, 300 Galis E-83, 300 Galis	H-24, Elkhorn	R-40, Stamler
3	D-33, Joy	E-72, 300 Galis E-73, 300 Galis		R-12, Long Airdox
4	D-56, Schroeder	E-42, 320 Galis E-47, 320 Galis	F-26, S&S	R-45, Stamler
5	D-36, Joy	E-71, 300 Galis E-90, 300 Galis	H-13, Elkhorn F-36, S&S	R-36, Stamler
6	D-50, Schroeder	E-40, 320 Galis E-49, 320 Galis		R-41, Stamler (1) Car Spotter
7	D-37, Joy	E-85, 300 Galis E-88, 300 Galis	H-14 Elkhorn	R-24, Stamler
			F-27, S&S	R-09, Long Airdox (1) Car Spotter

Table A.3. Underground electrical equipment

Ensign 300 kW rectifier - Face Rectifier

Xfmr - 315 kVA, 3 ϕ , 60 H, Class H, 150°C Rise Core & Coils
 480 V primary with 2½% taps. Secondary 205 Y/118 Volts
 Circuit Breaker - MA Frame, 600 Amp Thermal Trip & 1000 Amp Magnetic Trip
 120 Vac Undervoltage resistor in series with UVR
 Miscellaneous - 25 VA Control Xfmr 240/480 - 120/240
 DC - Voltmeter & Ammeter
 36 Diode Rectifier Rack

Ensign 8 - Circuit DC Distribution Box

9 - Contactors, 500 Amp. Single
 8 - Bulletin 7328 Overload Relays
 Labeled Outputs - Loader; Shuttlecar #1 - #2 - #3; Coal Drill, Roof Drill
 #1 - #3

Ensign Double Sectionalizing Switch

2 - LBS, 7.5 kV, 630 Amp. 3 Pole
 Manually operated w/120 V undervoltage release
 6 - Fuses, 7.5 kV, 200 Amp
 2 - Ground Check System
 Strip Heater - 300 watt, 240 volt
 Electrical Interlocks

Ensign 750 kVA Power Center

1 - 750 kVA, 3 ϕ , Class H, 150°C Rise, 4160/7200 Y/4160 Δ - 480
 1 - LBS, 10 kV, 400 A, 3 Pole
 3 - 125 Amp, 7.5 kV Fuses
 3 - Lightning Arrestor 7.5 kV
 Emergency Stop Pushbutton
 1 - 15 Amp; 18.5 Ω Neutral Grounding Resistor
 2 - Breakers, NB Frame, 3 Pole, 100 A, W/ADT Magnetic Trip
 Range 2500-5000 Amp W/120 V ST & Co. Switch
 1 - Breaker, FB Frame, 2 Pole, 20 Amp
 Zig-Zag Xfmr Secondary 480 V Delta
 GCS-GCR - Interlocks

Table A.4. Trailing cable sizes

#2	3	Conductor SHD-GC 8 kV 7200 V Distribution
4/0	3	Conductor G-GC 480 V Continuous Miner
#6	3	Conductor G-GC 480 V AC/DC Shuttlecar [Flat or Round] AC Roofbolter AC Face Drill
#4	2	Conductor Type W 300 V DC Shuttlecar DC Roofbolter DC Face Drill
#1	3	Conductor G-GC 480 V AC Feeder/Crusher AC Cutter AC Loader
1/0	2	Conductor Type W 300 V DC Loader
2/0	2	Conductor Type W 300 V DC Cutter

They experiment with structural and operational improvements on different pieces of machinery. The engineer feels that most of the electrical regulations are just good common sense practice and, as a group, are good regulations. However, the belt fire monitor requirement is an exception because the extreme environment and resulting failures make it inoperative more than operative making continual compliance an impossibility. He has a man working full time on just these monitors and claims he still cannot maintain them. He would like to see this regulation changed or struck and the remaining ones left alone. He said the electrical inspectors are the "best of the bunch". He has recently been given four electrical inspectors of his own to ensure that all of the mines are operating within the guidelines of his design. The company also has their own health and safety inspectors which investigate all accidents occurring on their property. They have reported a large number of accidents to HSAC but they claim this is because they report everything as opposed to some operations reporting almost nothing. They do economic analysis of accident data as well as safety analysis and estimate an underground death to cost them approximately one-half million dollars.

The engineer had some suggestions for needed research associated with mine power systems. A Coal Mining Electrical Handbook written with emphasis toward electrical maintenance is the most pressing need he feels. He says there simply is no good reference written specifically for coal mining power systems. Also he would like to see a fast way to check multi-case circuit breakers developed.

The mine visited is a three-section operation with plans to extend to a five section mine. They operate on a five-heading development scheme with the belt and track in the same heading. The chief electrician has been with the company for about 13 years. The company owns their own substation at the mine site. The portion supplying the underground system is a 2500 kVA transformer bank, 34.5 kV/7.2 kV (Δ -Y_g), with a Westinghouse Type ESM outdoor oil circuit breaker. The transformers supplying the fans and outside loads are also a 2500 kVA unit, 34.5 kV/4.16 kV (Δ - Δ). A one-line diagram of this substation is shown in Figure A.1. 7200 volt distribution was stated as being more preferable than 4160 V because of extended range and better voltage regulation. They claimed they could run approximately five miles with a five-section load and experience only about ten percent voltage drop with 7200 V. This ability eliminates the need for boreholes at this particular mine since it is only under about three miles.

The underground distribution flows through 4/0 SHD-GC 8 kV cable and is hung on insulators in the same heading containing the beltline and trolley. This cable runs in 1000-foot sections connected together mostly through PLM cable couplers. Each section has a 7.5 kV load-break switch containing a feed-through and two branch circuits. The fused load break is a three-pole, gang-operated, 10 kV, 620 amp switch with safety interlock on doors and covers. Each unit contains a ground fault and ground monitor system.

The trolley is fed from the 7200 V cable through a 150 kW rectifier. The trolley wire is 350,000 MCM grooved round (6/0) conductor with a 4000 foot spacing between rectifiers. All rectifiers are 4160 or 7200 volt ac input, 300 volt dc output equipped with a 10 kV, 400 amp, three-pole, gang-operated,

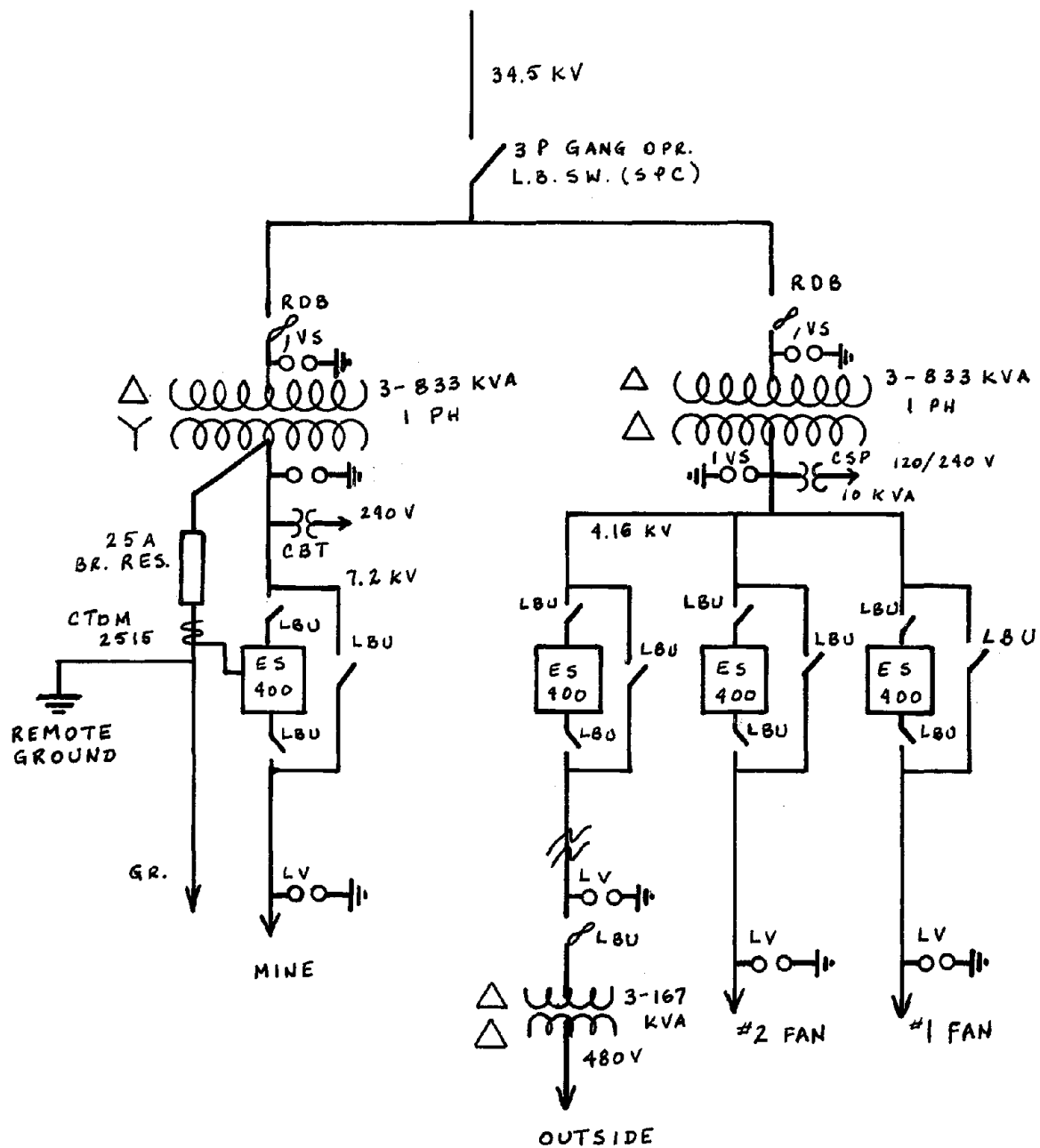


FIGURE A.1. Surface substation.

fused load-break switch with safety electrical interlocks. Each unit is supplied with a feed-through and a breaker-protected auxiliary circuit. The units are employed in the grounded negative configuration and have transient voltage suppressors on both the ac and dc sides of the full wave rectifier bridge.

The belt conveyor is hung from the roof or supporting timbers and is powered by dual and single 150 Hp motors on the mainline and section belts, respectively. The belt heads are Continental units, with Westinghouse motors, and they are welded to I-beams which are set in a concrete form. A 400 kVA belt transformer supplies the power to the mainline beltheads and a smaller 225 kVA transformer is used for the section belt power center. Both units are of similar design and only the larger one will be described here. It is equipped with the same load break switch, safety interlocks, and feed-through as the trolley rectifier. The transformer is 4160 volts delta or 7200 volts wye on the primary and 480 volts delta on the secondary. A 15 amp, 480 volt, zig-zag neutral deriving transformer is employed with a 15 amp neutral grounding resistor. A 60 kVAR, three phase, capacitor bank and a 5 kVA, 480-120/240 volt, lighting transformer is also included in the package. There is a 100 ampere, "Auxiliary" output in addition to the 600 ampere "Belt Drive" output circuit. A 30 kVAR capacitor is used in the section belt power center.

All beltheads are accompanied with either a single-spaced or two-speed solid state starter. They are 460 volt, 3 phase, 60 hertz units with motor protection and a shut-down detection panel which indicates why the belt was stopped.

The section contains a Joy continuous miner, two Joy ac/dc shuttlecars, a Gould battery charger, a 5 Hp/275 volt trickle duster, a small low-resistance bonder, a scoop, a double boom Fletcher roof drill with temporary roof support, a belt crusher feeder, a 150 kW rectifier and a 500 kVA face power center. The power center is similar to the 400 kVA belt power center except that it has nine output circuits. There are two 800-amp outputs for "miner" and "miner spare", one 400 amp circuit for the "rectifier", one 225-amp circuit for the "100 Hp feeder breaker", three 225-amp outputs for "roof drill #1, #2, and spare" and two 30-amp circuits for the "trickle duster" and "pump". The 150 kW face rectifier is 480 volts ac input, 300 volts dc output. This unit is similar to the trolley rectifier and has five dc output circuits. There are three 225-amp outputs for "shuttlecar #1, #2, and spare", one 100-amp circuit for a "pump", and one 50-amp output for the "rock duster". A one-line diagram showing a typical underground layout for the power system is given in Figure A.2.

A.4 SOUTHEASTERN UNDERGROUND MINE

On January 6, 1981 a visit was made to an underground mine in the Southeast. Conversations were held with the manager of electrical engineering, and a mine electrical engineer and longwall coordinator. Topics included electrical inspectors, safety attitudes, training, and general power system layout. The visit was completed with a guided tour of the surface and underground power systems.

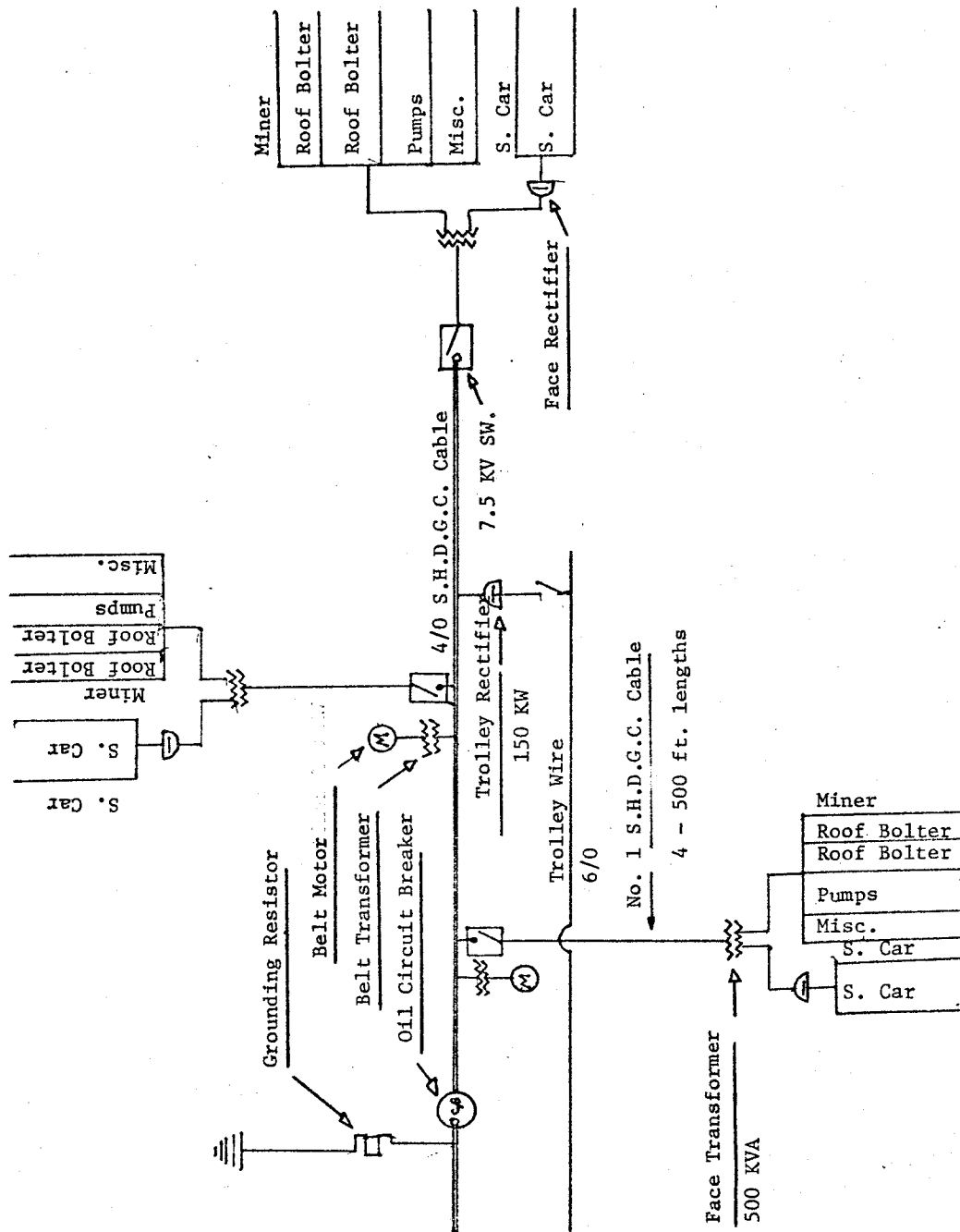


FIGURE A.2. Typical underground lay-out.

The company consists of six different underground mines, four of which are using or are in the process of establishing a longwall operation. The company feels it is in a learning process with these longwalls and they are having considerable maintenance problems mainly due to bad bottom and inexperience.

The company has long-term contracts with a utility and Japan with the rest of its coal going to spot market. Their coal runs about .5 percent sulfur and one of their larger mines will produce roughly two million tons annually of clean coal.

The company has an amazing number of new surface facilities. They have a new central office building, central supply warehouse, coal laboratory, shop, and training center. They have an excellent training program that alternates classroom and lab work with two weeks of related on-the-job training. The new training center has classroom facilities, closed-circuit TV, slide projectors, and a shop-type laboratory. The training supervisor along with the other instructors write their own text manuals and create video tape lessons on different aspects of machine maintenance. The course takes 23 weeks to complete and alternates three or four weeks of classroom training with two weeks of underground work in welding, hydraulics, mechanics, and electrical repair.

Both the engineers stated that they feel the major reason behind accidents is personal negligence. The manager added that it is probably because the company didn't enforce their attitude enough. Neither man wanted to comment on any of the electrical regulations. Both are under the similar impression that MSHA's electrical inspectors are less than adequately trained and that the position itself does not attract the most experienced people. This is a very interesting contrast to the view expressed from MSHA's people the preceding day. The company men also state that they felt the inspectors wanted to leave something (citation) so that their presence would be known. This comment, referring to a quota of citations issued, is very common among the industry people that have been contacted.

The mine visited is a shaft mine of approximate 2000 foot depth with a production capacity of about 800 tons per hour. The utility owns the substation that supplies power to this mine at 4160 volts from a 10 MVA unit. The 4160 volt line is fed into a building which contains all of the switchgear, breakers, and monitoring devices for the surface distribution. Here a 4160 volt bus is established which feeds all of the surface branch circuits and the two step-up transformers feeding the underground load. Figure A.3 is a one-line diagram of this distribution house. All of the circuit breakers are vacuum-type and all feeders leaving this switchhouse are run in conduit. In fact, at the newer mines, everything coming from the substations is run in underground conduit to help with lightning problems.

The production hoist is a 2200 feet-per-minute hoist with nominal 20 ton skips. It is driven by dual 1500 Hp G.E. motors. The motors are 0-700 Vdc 650 RPM, shunt wound, controlled by a G.E. solid state control panel. The service hoise runs at 900 feet per minute and is powered by a single 600 Hp motor. The step-up transformers for the underground circuit are equipped with fans which increase the nominal kVA rating when operating. One unit is 2500 kVA to 3500 kVA (with full fan operation) and the other is 3750 kVA to

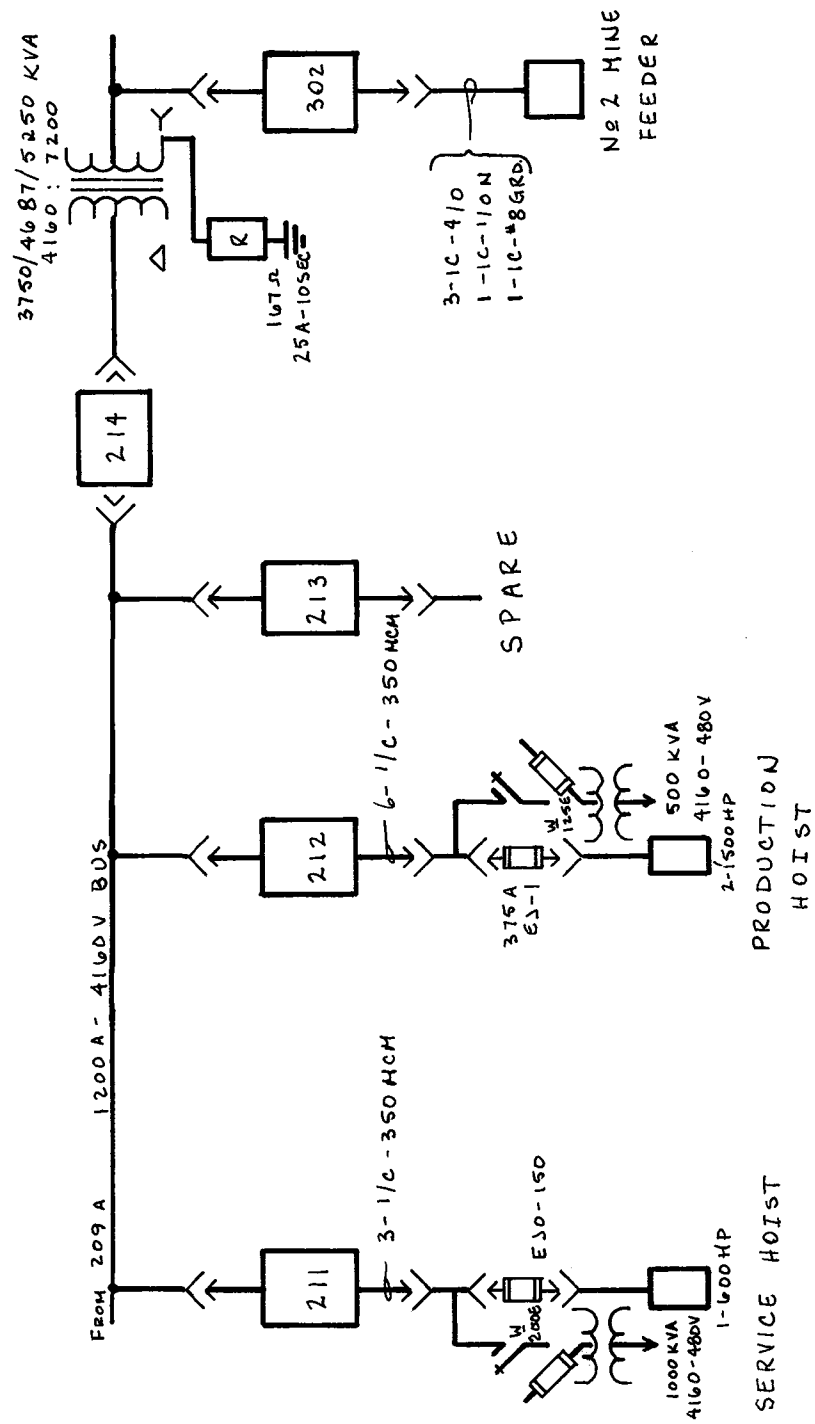


FIGURE A.3. Power distribution for underground shaft mine. (continued)

5250 kVA (with full fan operation). The step-up to 7200 volts allows them enough extended range to not need any boreholes.

The underground feeders are strung vertically in the production shaft. Hanging this 4/0 cable 2000 feet presents quite a problem in terms of physical stress and they are searching for new and better ways to do this. The double 4/0 feed runs down the shaft and into two circuit breakers at the bottom which have dual output circuits protected by two vacuum circuit breakers. Figure A.4 shows the daisy-chain connection of all the non-section power modules located in the vicinity of the service and production shafts. These modules supply the power needs associated with operation of the shafts, battery charging for jeeps and locomotives supplying the sections, and feed-through power going to the sections. The mine is very gassy and all of the locomotives and rail-mounted jeeps are battery powered because it is too dangerous to have a trolley system.

Figure A.5 shows a typical continuous miner section power layout. The skid-mounted circuit breaker feeds the complete section from a single vacuum breaker. The face power center is 750 kVA, 7200 volt primary with a dual-winding secondary. Secondary No. 1 is rated 500 kVA at 995/575 volts and secondary No. 2 is rated 500 kVA at 600/346 volts. Also, there is a 5 kVA lighting transformer, 600-120/240 volts, with a single-phase primary breaker and three 20 A secondary breakers. The outputs from this center are labeled in Figure A.5. The section also includes a belt power center and face equipment charging module.

The section equipment includes a 12CM Joy miner, two Joy 10SC shuttle-cars or two Ram cars, a twin boom Fletcher pinning machine, an S & S scoop, and a Stamler feeder. They try to maintain 500 foot trailing cable lengths. The miner cable is 1/0, 2 kV SHD-GGC. They use shielded cable on everything over 600 volts. Round TJB couplers are used for the 995 volt circuits and square Ensign couplers are used on the 575 volt circuits. TJB and Line Power couplers are used on high-voltage lines, no high-voltage splicing is done. Low-voltage splicing on trailing cables is usually done using CSI splice kits. They employ mostly Okonite, Anaconda, and Essex cable. Mechanical failure is the worst problem they have with trailing cables and they had some fault locators but the company men didn't know anything about them. They also complained about their Westinghouse breakers failing because rock dust could get in them. It was observed on one section that a foreman stayed beside the power center to reset a breaker which was operating two or three times a minute. Although both company officials present were in the electrical department, nothing was said about this procedure.

A.5 WESTERN UNDERGROUND MINE

On January 9, 1981 a visit was made to a western underground mine. The mine is a non-union operation which utilizes diesel equipment to transport men and supplies into the mine. The company has a long term contract with a company which distributes their coal throughout the southeast. They operate in the B seam which runs about 6.5 feet in that area and they sell their produce as steam coal. Annual production is approximately 900,000 tons of clean coal which is all shipped by rail. They have their own preparation plant at the mine site with a 300 tons per hour capacity which

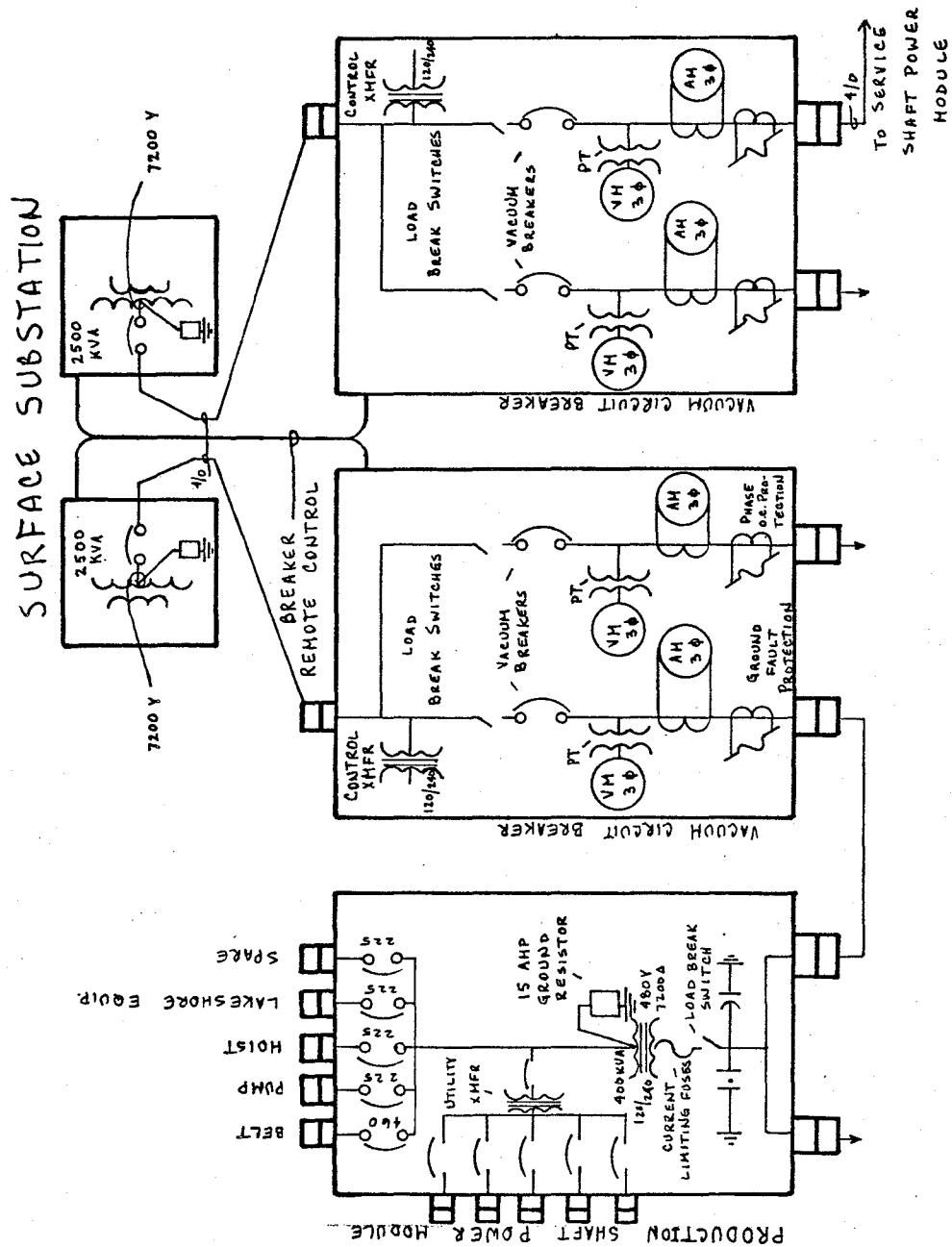


FIGURE A.4. Non-section power nodules in vicinity of service and production shafts in underground coal mine.

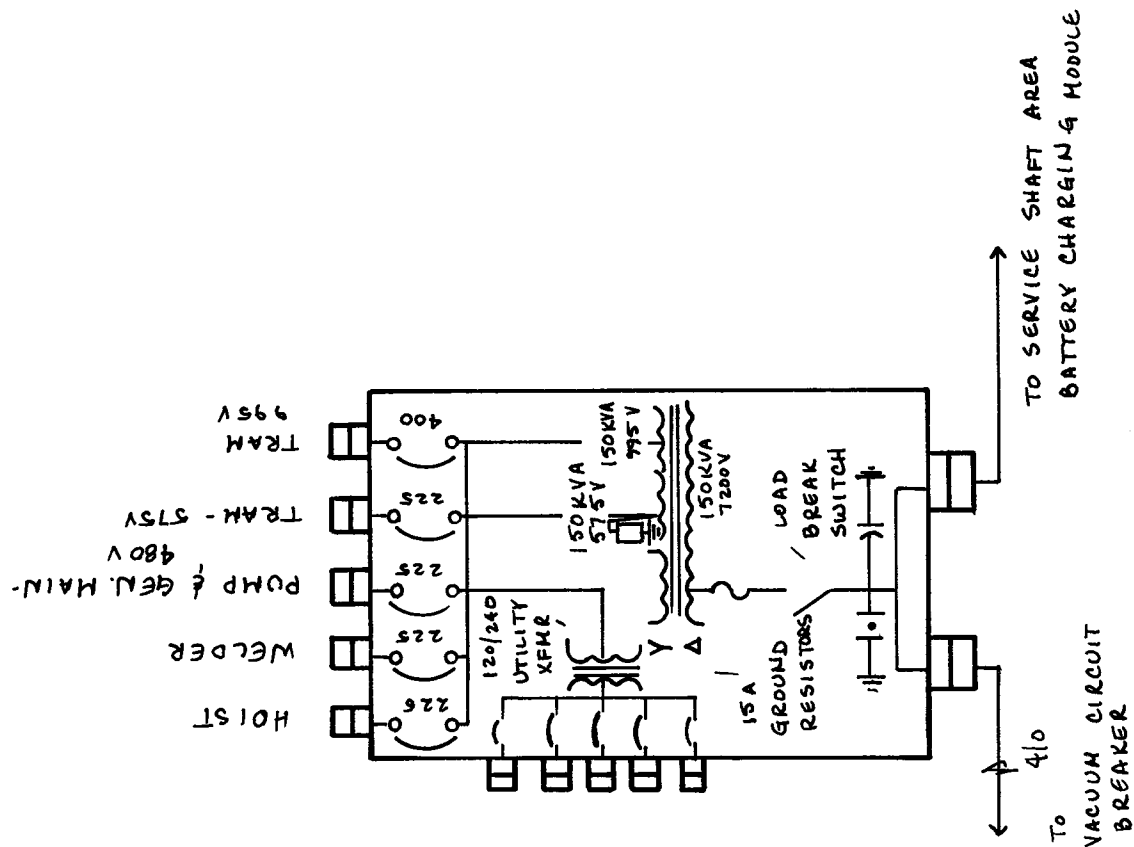


FIGURE A.4. (continued) Non-section power modules in vicinity of service and production in underground coal mine.

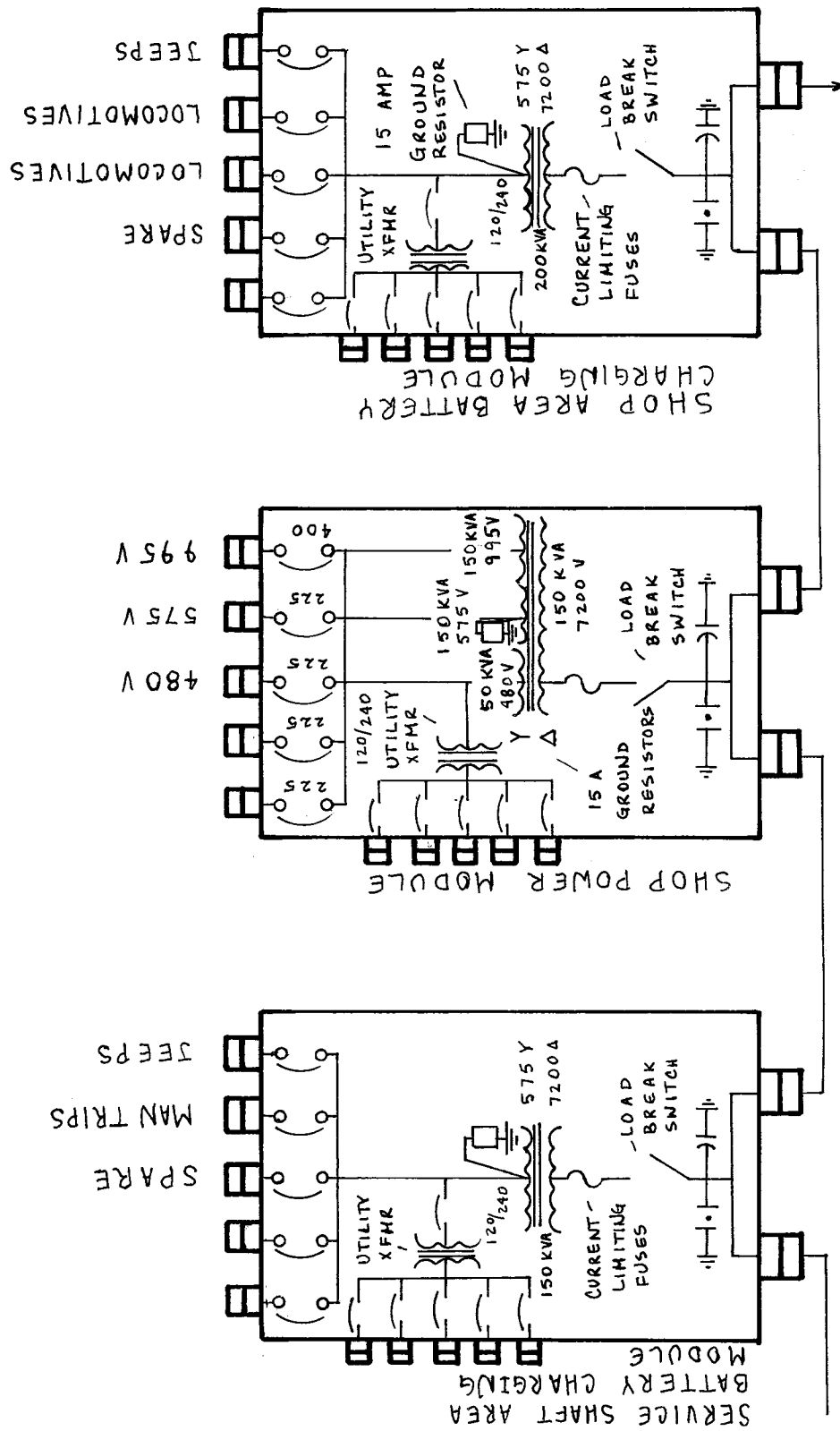


FIGURE A.4. (continued) Non-section power modules in vicinity of service and production in underground coal mine.

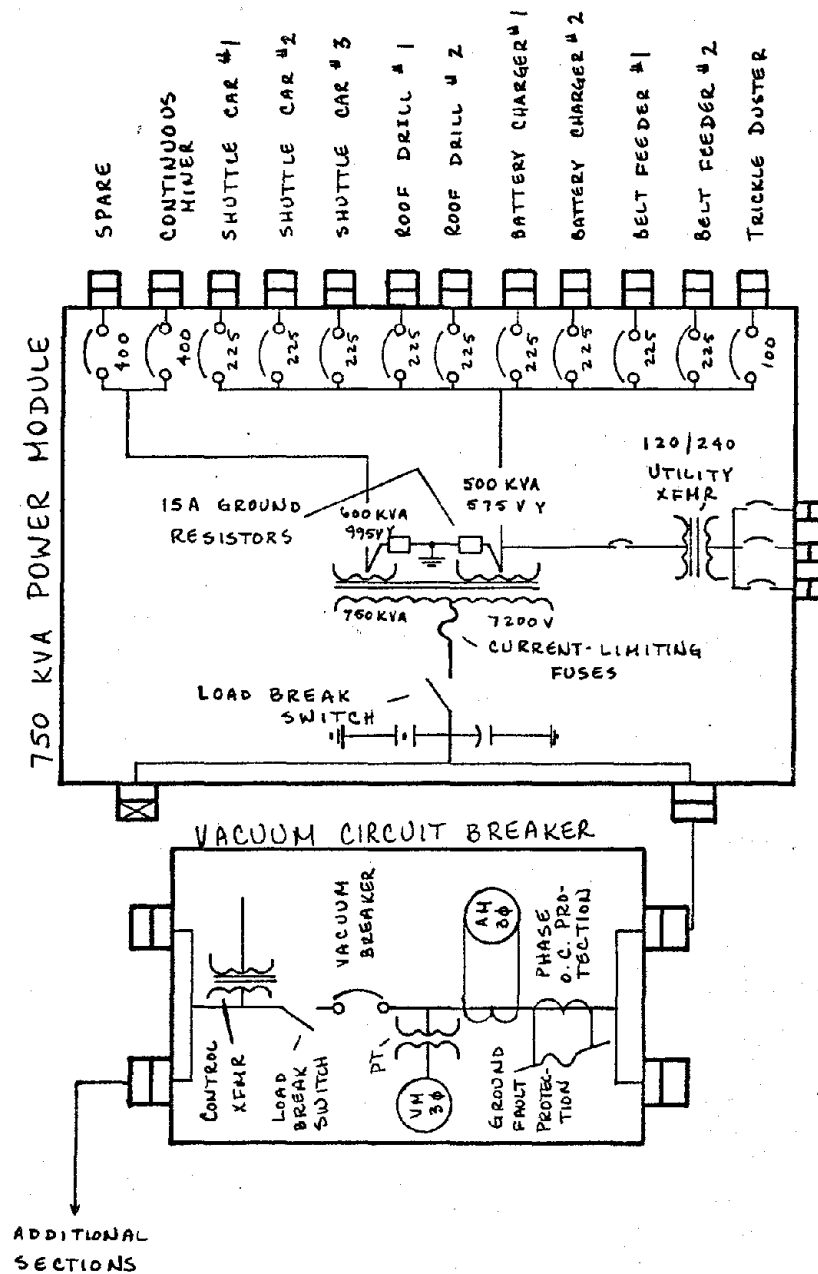


FIGURE A.5. Continuous miner section power layout.

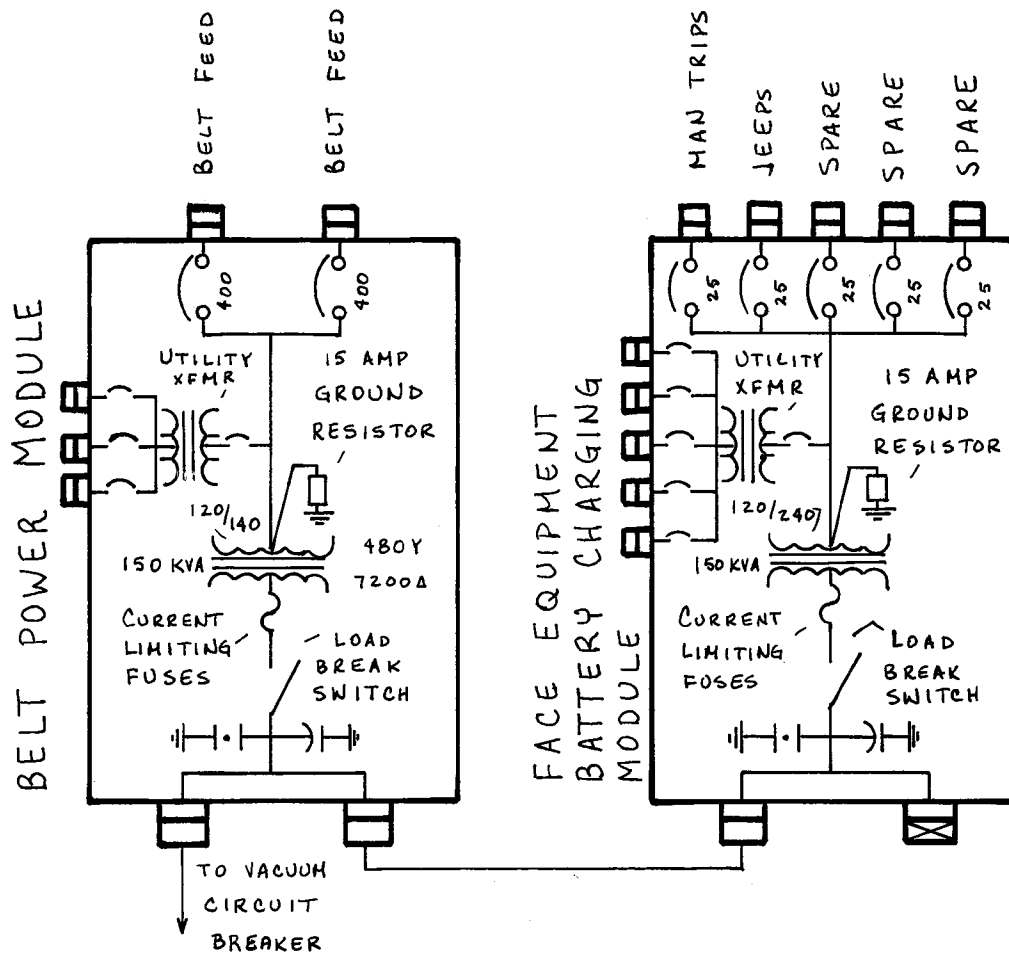


FIGURE A.5. (continued) Continuous miner section power layout.

is presently running at about 35 percent reject. They mine about 300 tons per miner shift and they give a bonus for each additional ton to every man working on the involved section. The company employs 320 people including the preparation plant, office, and a nearby mine.

They have a training program, mostly for the electrical people, and they utilize the facilities of a nearby college. They are trying to certify all of their mechanics and they presently have nine electricians which they distribute three to a shift. They operate two shifts of production and third shift maintenance with most of the electrical work done on Saturdays. The electrical supervisor commented that the requirements for certification certainly did not assure job competency. He said he knew several people who were certified electricians and "couldn't tie their shoe laces".

The mine has two substations by which it supplies power to the underground section through boreholes, and two more subs which support the prep plant, shop, and offices. The subs supporting the underground circuit are similar and a one-line is given in Figure A.6. Both are 25 kV-4160 V (delta-wye), 2500 kVA stations. The boreholes are tied to the substation ground which is a grid configuration. Monitoring is of the impedance type. Substation "A" feeds one section through a 2/0 SHD cable and substation "B" supports three sections. There is a 4500 foot surface separation between the two subs. The supervisor said he much preferred 13.8 kV to 4160 V underground distribution. The new mine they are opening is going to have 13.8 kV distribution.

The mine consists of four continuous miner sections. Each section contains its necessary complement of mining equipment. They have three scoops which are the only battery powered equipment they have. The pinner is a twin-boom Fletcher without the temporary roof support feature. The buggies are 10SC Joy shuttlecars, ac/dc, 480 V with a 500 foot length of #4 Flat G-GC trailing cable. They want to go to wireless monitors on these cables because they claim it will increase cable life by ten percent. The miners are 12CM Joys with an 800 foot length of 2/0 shielded, 8 kV trailing cable. They claim a 12-14 month life on this cable. They use Ensign-Hubbell couplers for low voltage and PLM couplers for high voltage. The face power center is a 1000 kVA, Ensign-Hubbell unit. It has two 995 V outputs for the miner and spare and five 480 V outputs for two shuttlecars, roofbolter, pump, and spare. It also contains four 120 V outlets and two 240 V outlets.

The borehole switchhouses are Ohio Brass modules with two output feeds. There is a mechanical switch on the circuit breaker with an outside handle labeled "Interrupter" and a handle labeled "Disconnect" which goes to the visible disconnect switch. They have an Elmac 500 kVA Belt Drive/Pump power center which contains both a feed-through and a switched feed-through. It uses Ensign-Hubbell monitors and Westinghouse breakers. The supervisor felt Ensign-Hubbell makes good low-voltage monitors but Compton Electric makes the best high-voltage monitors.

Our conversations with the supervisor brought out some of his views towards MSHA and its inspectors. He said that MSHA makes the industry do things its way and that its electrical inspectors are not trained well. He felt inspectors have a quota and a theme in mind before they ever enter a mine. He said that you have to patronize them and all of the inspectors

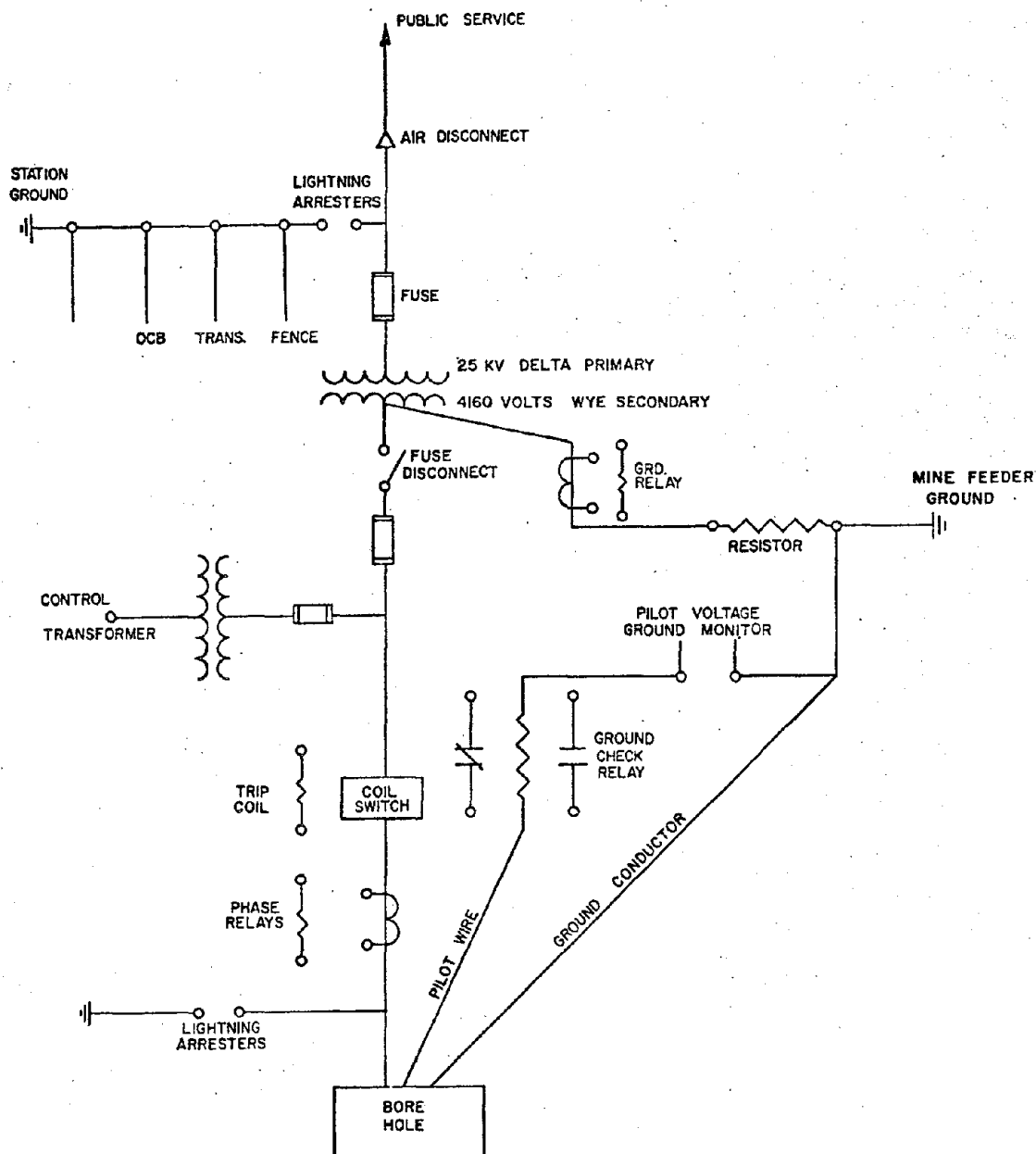


FIGURE A.6. Surface substation.

interpret the rules differently. He said that they study the regulations and try to abide as best they can but that their interpretation is often different from MSHA's. He also said that the average miner relies on MSHA to protect him and that he is neglecting responsibility that should be his. The major reason for most all accidents is personal negligence. A miner must be responsible for his own actions and MSHA should shift some of their safety emphasis towards making the individual miner aware of this. The supervisor also felt that accidents reflected the face boss's attitude. He said that a crew learns from what he does instead of what he says.

The circuit breaker settings requirement is the hardest for this mine to comply with. The inspectors don't have any test equipment (just a chart) and he said he had to go to oversize cables just to maintain compliance. He complains that the industry doesn't supply breakers to fulfill MSHA's regulations. His Westinghouse breakers are 25% on the high side and 10% on the low side and they simply aren't accurate or reliable enough. He would like to see some clarification on the breaker schedule and to find out just what the inspectors want. He said they try to set their breakers on no information and the inspectors tell them it's wrong based on no information. The lighting regulation is another problem area for them. He said that if they were strict about enforcing this regulation, they simply couldn't operate. The Belt Fire Monitor law is difficult to comply with also. The presently available monitors are unreliable and are inoperative more often than operative.

In terms of needed research, physical construction of cables is high on the list. He would like to see shielding on 480 V cable developed fully. Cables are their number one problem in the electrical system. Without cable failure, their electrical downtime is very small. He would also like to see some multi-test equipment for circuit breakers and lighting design developed to a competent level. He said to give them something that worked before requiring it by law.

A.6 SURFACE COAL MINES

Visits were made to four surface operations; one operation each in Alabama, Arizona, Utah, and New Mexico. All these operations sell steam coal to local utilities.

A.6.1 Alabama Surface Mine

A visit to a coal company in Alabama was the first surface operation to be visited. The visit included conversation with the Manager of Electrical Engineering and trips to two mines.

All of the power system planning and design specifications originate from the central office. The manager has three electrical engineers and a total of 35 electricians which try to maintain a two and one-half percent or less electrical downtime. The manager claims he has a hard time finding good qualified electricians and that he searches statewide to find them. The company itself does not have a training program for electricians. The bulk of the electrician's work, as much as 60 percent, deals with cable handling. Cable failure is the largest source of electrical downtime they

have. They claim that if they could reduce cable downtime by one-half they could increase profits by one million dollars per year. Their major cable problem is handling and transportation damage. They presently drag their cable by dozer but are investigating application of cable reels. To alleviate some of the physical stress on the cable, the manager specifies the jacket thickness to be 295 mils with a minimum of 280 mils. He also increases the phase conductors by 5-10 mils and increases the ground check to be the same size as the ground conductors.

Spikes on phase conductors which cause failures in the ground monitors is another major problem they have. The manager claims to have seen 90 mA of current on the ground check circuit due to shunting. He wanted to have more data available to him to make a personal judgement on the best type of monitoring method. He is looking for something to stand up to a 25 kV system. Additionally, he would like to have a reasonable cable testing procedure which is nondestructive. He presently uses a thumper but expressed concern that, by its nature of operation, they may be creating or speeding the deterioration of the cable. He would also like to have an industry-wide opinion of vacuum breaker technology as a replacement for oil breakers.

The first mine visited employs 100 people and operates three shifts a day. They have four electricians at this mine who work strictly on electrical repair and cable handling. The draglines are serviced one day a week with the remaining equipment being scheduled every 200 hours. They are erecting a new dragline which they anticipate to take 160,000 man-hours to set up.

A typical distribution circuit from the company's mines is given in Figure A.7. The diagram shows the overhead distribution to the pit subs and the preparation plants. The static line is carried above the phase conductors in the distribution circuit and underneath them on utilization circuits. All surface poles have a butt ground and possibly some driven rod grounds in an attempt to maintain a 15 ohm or less pole ground. No proximity warning devices are used on any equipment. The company owns all of the substations in by the metering point. The pit subs are 15 MVA, 161/22.9 kV. They make their neutral resistor ground by drilling a hole through the water table and coal seam, lowering in a bare ground conductor, and refilling with coal slurry, salt, or some other material. RJL impedance monitors are used in these subs.

Figure A.7 shows the trailing cable from the pit sub to the dragline and also the onboard transformers and representative load. This cable may extend as far as 10,000 feet from the pit sub and services rock drills and pumps as well as the dragline. The cable runs in 1,000 foot sections which are joined together by junction boxes. There are also switchhouses in the cable which have two output feeders, two separate monitors, and three knife switches. These units are not load-breaks. Cables supplying rock drills and pumps are taken off at these switchhouses. The drill subs convert from 22.9 kV to 7200 volts. The drill cables are #4 SHD-GC 8 kV while the "trunk line" is a 25 kV 2/0 SHD-GC cable. Each dragline will have a separate pit sub and "trunk line" cable. One dragline is a 115 yard machine with a 335 foot boom length. It weighs 13 million tons and has 12,000 Hp ac in its motor/generators sets.

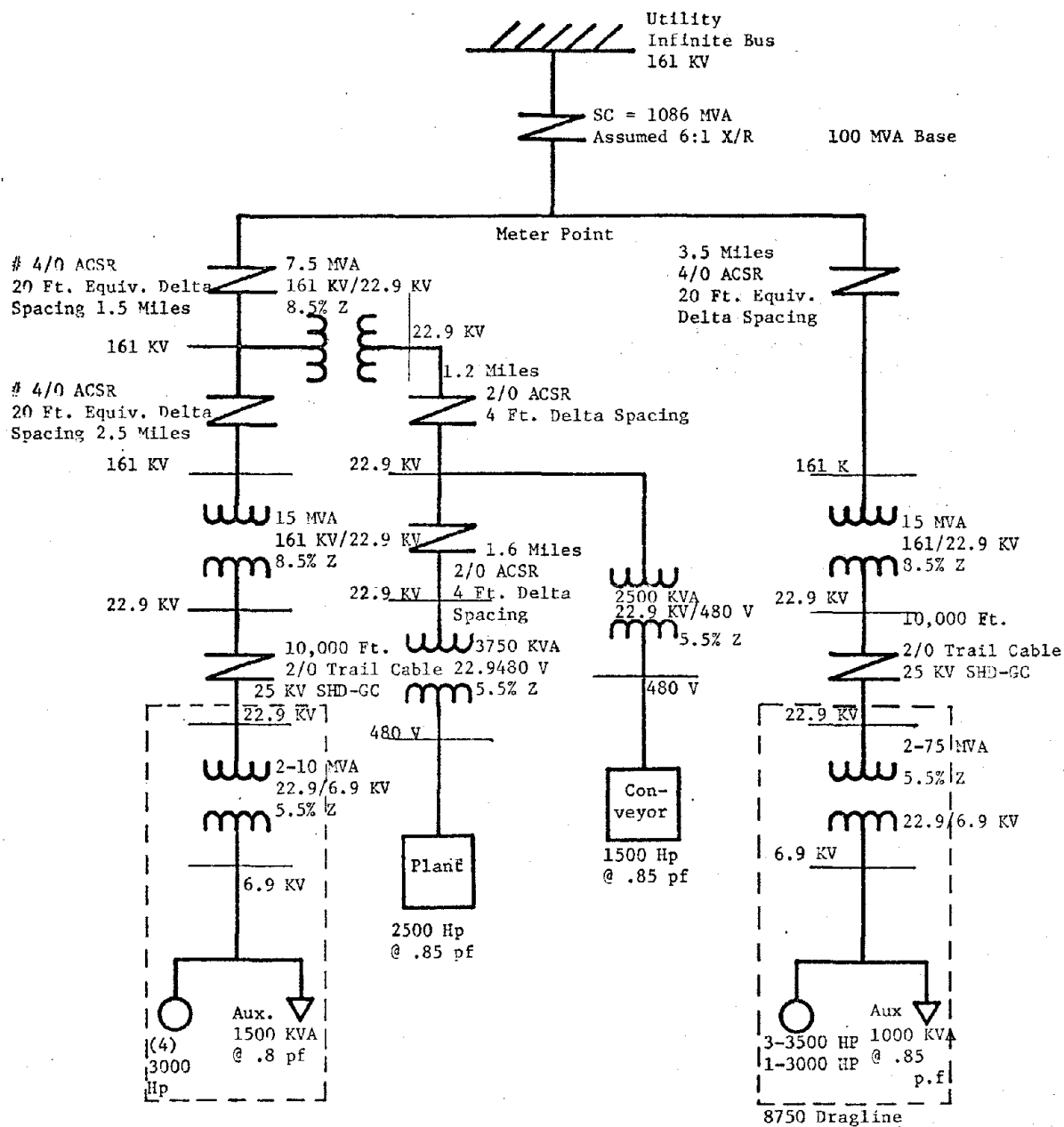


FIGURE A.7. Distribution circuit of surface coal mine.

The second mine is very similar and Table 5 gives a listing of its electric powered equipment.

Table A.5. Mine power equipment

- 1 - B.E. 1570W Dragline 75 yd. - 305 ft. boom
- 1 - 5323 Marion Power Shovel, Electric
- 1 - 60R Diesel Electric Drill
- 1 - B.E. 50R Electric Drill
- 1 - 1500 kVA Substation, 13 kV/4.16 kV
- 1 - 10 MVA Substation, 44 kV/7.2 kV
- 1 - 10 MVA Substation 115 kV/44 kV

A.6.2 Arizona Surface Mine

A major company's Arizona Division was the second surface operation visited. The Arizona Division operates two mines. Together they produce 12 million tons of coal annually which they market by means of a 35-year contract with two local generating plants. During this 35-year period, the division expects to mine 500 acres per year from the 15,000 acres of lease area. The mines lie entirely on leased lands. One mine employs 359 people with the other mine employing 516 people. The labor force belongs to the UMWA.

The coal from the first mine is transported 274 miles by a coal slurry pipeline to the generating plant. Coal from the second mine is shipped by overland conveyor for six miles and then by unit train for 90 miles to the generating plant. The coal is low-sulfur bituminous, rated at approximately 11,000 BTU per pound. The seam runs between three and twenty feet in thickness with the overburden going to a maximum of 180 feet.

The company obtains power at 69 kV from the utility. They own all power system apparatus from the utility metering point. They run this voltage level directly into their pit subs which are 10 MVA, 69/23 kV. From the pit subs, a 25 kV 2/0 SHD-GC cable takes power to the draglines, drills, and shovels. They have run up to 12,000 feet of cable on this "trunk line". Tables A.6 and A.7 give an equipment listing for the two mines.

They employ Atkinson impedance monitors and maintain time-and instantaneous-overcurrent protection in their substations. They run a 13.2 kV overhead line to their water pumps where they transform to 2300 volts. Also the 69 kV line is run to the preparation plant where power is transformed to 4160 volts.

The division employs a total of 32 electricians and 10 chief electricians at both mines. These people maintain a less than 15 percent downtime due to electrical causes with an eight percent average. The company has its own training program for electricians which includes some equipment training as well as classroom training. No cable splicing is done at the mine site. All cable is sent off to be repaired, but they are experimenting with a 3M kit.

Table A.6. Equipment list for the first Arizona Mine

<u>Draglines</u>	<u>Bucket Size</u>	<u>Boom Size</u>
Marion 8750	80 cu. yd	300 ft.
Marion 7800	30 cu. yd	180 ft.
Marion 7400	14 cu. yd	160 ft.
<u>Drills</u>	<u>Dozers</u>	
1 - Gardner Denver 120	1 Caterpillar D-10	
1 - Robbins D-9	10 Kamatsu (5 on reclamation)	
1 - Robbins D-10	1 Michigan 380	
1 - Bucyrus Erie 40-R	7 Caterpillar D-9 (2 on reclamation)	
1 - Ingersoll Rand 5100	1 Caterpillar D-8	
<u>Haulage Trucks</u>		
12 - Dart bottom dump trucks - 120 ton rating		
2 - Rimpull end dump trucks - 100 ton rating		
<u>Loading Shovels</u>		
1 - H 241 Demag hydraulic shovel 19 cu. yd.		
2 - 191 Marion 12 cu. yd.		
<u>Scrapers</u>		
3 - Caterpillar 631 scrapers for reclamation.		

Table A.7. Equipment list for the second Arizona Mine

<u>Draglines</u>	<u>Bucket Size</u>	<u>Boom Size</u>
Bucyrus Erie 2570	90 cu. yd	360 ft.
Marion 8750	79 cu. yd	300 ft.
Bucyrus Erie 1260	31 cu. yd	225 ft.
<u>Drills</u>	<u>Dozers</u>	
1 - Gardner Denver 120	12 - Kamatsu (5 on reclamation)	
1 - Ingersoll Rand T-4	6 - Kamatsu (5 on reclamation)	
1 - Ingersoll Rand T-4	6 Caterpillar D-9	
1 - Bucyrus Erie 50-R	2 Michigan 380	
1 - Bucyrus Erie 61 R		
1 - Bucyrus Erie 60 R		
4 - Ingersoll Rand DMS-35		
1 - Robbins D-9		
<u>Haulage Trucks</u>		
12 - Rimpull bottom dump trucks, 150 ton rating		
3 - Rimpull end dump trucks, 100 ton rating		
3 - Dart bottom dump trucks, 150 ton rating		
<u>Loading Shovels</u>		
2 - 191 Marion 12 cu. yd		
2 - 295 Bucyrus Erie 18 cu. yd		
<u>Scrapers</u>		
3 - Caterpillar 631 scrapers for reclamation.		

Part of our visit included some interesting conversations with the regional electrical supervisor. He felt that most accidents are a direct result of personal negligence. In his opinion, safety comes from the individual worker himself. This attitude certainly reflects the company's approach to safety awareness. They have what they call a "total-concept" safety program which uses safety awards, preventive safety measures, frequent foreman safety meetings, and an effective accident awareness campaign. In 1979, over 1,000,000 man-hours were worked without a lost-time accident at the two surface mines.

The supervisor commented that the regulations allow the companies to spend more money for safety and general upkeep than could be economically justified otherwise. However, he feels that the non-uniformity of interpretation creates problems and animosity. He said that the inspectors spend more time protecting machines than they do people. He was also certain that they had a quota of citations to write and if they couldn't find anything valid they would resort to nit-picking. He continued to say that if they (inspectors) were of the quality they should be, to be inspectors, they would be wasting their time to work for the government. He contended that they went blindly by the book and had lost their sense of reason.

The electrical certification test was the only other major complaint the company representative had. He said that it tests mostly engineering instead of practical aspects and that it should be the other way around.

A.6.3 Utah Surface Mine

The third visit on our surface mine tour was in Utah. The mine has an employment level of over 550 and produces eight million tons of coal annually. The coal runs between two and twenty feet, multi-seam, with 20 to 100 foot of overburden. The mine is a captive operation with all of its coal going to supply a utility generating plant which is located beside the mine. The company has a long term contract with the utility to supply 10,000 BTU coal to this plant. The coal from the pit stockpiles is loaded onto a company train which transports it to the prep plant where it is crushed and belted directly into the generating plant. There is little transportation cost associated with this coal.

The company distributes power at 69 kV over nearly 12 miles of overhead line. The static line is carried above the phase conductors and grounded to each pole through a butt wrap. They were very interested in proximity warning devices for two reasons. First, they have had trouble with getting equipment into their overhead lines and recently had a man killed that way. Secondly, they think the devices will soon be required by law and they want something that functions properly before that happens. One company official had reservations that the proximity devices would make the worker less cautious and more likely to contact the lines in case of device failure. They mark all of their lines over crossings with "Danger; Overhead Power Line; Clearance __ feet".

All of the overhead line construction is contracted out to a one-man outfit. Their climate is very dry, averaging only nine inches of annual precipitation. The Electrical Supervisor said that occasionally they

have trouble with the 69 kV line arcing to ground through a dust cloud. This is not a frequent problem but it may be an unsolvable one.

The mine employs four draglines, four blast hole drills and an electric load-out shovel. Table A.8 lists this equipment along with some pertinent information. A maximum of 5000 feet of cable extends from the pit subs to the draglines. The drill cables may extend to 7000 feet but they try not to go over 5000 feet. The lower voltage level used on these machines allows cable couplers to be used instead of junction boxes. The couplers are color-coded for ease of identification.

Table A.8. Electrical equipment for Utah Mine

Draglines

8050 Marion	6500 Hp	7200 V	500 MCM cable	55 yd ³
7920 Marion	5800 Hp	7200 V	300 MCM cable	55 yd ³
1350 Bycyrus Erie	5800 Hp	7200 V	300 MCM cable	55 yd ³
7900 Marion	3300 Hp	7200 V	2/0 cable	45 yd ³

Blast Hole Drills

M4 Marion	4160 V	#2 cable
100 Gardner Denver	4160 V	#2 cable
45 R Bucyrus Erie	4160 V	#2 cable
60 R Bucyrus Erie	4160 V	#2 cable

Loading Shovel

1900 P & H	650 Hp	4160 V	1/0 cable
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Cable handling damage is a major problem for all surface mines. The most frequent problem is the breaking of the ground monitor wire or jacket destruction by dozers and other equipment running over the cables. This company uses cable reels mounted on 988's which load, transport, and unload de-energized cable during moves. They also use cable boats which they lay the cable in off of the reels and then uncurl it as the dragline moves forward. They pull these trays with a dozer and when they come to a coupler they simply lay it off the tray. They claim good cable life using this method and they are very strict about their cable rules. Deliberate running over of a cable is a firing offense.

Each piece of equipment has its own separate substation. All of these portable subs are of similar physical construction. Table A.9 gives the switchhouse components and substation ratings for various pieces of equipment. Atkinson monitoring is employed for most of the ground check circuits.

The company operates three shifts of production and schedules each machine to be down one shift a week for maintenance. They employ 12 certified electricians and complain vehemently about the certification

Table A.9. Substation ratings

7920 Dragline

Switchhouse - G.E. Oil Blast Circuit Breaker (13.8 kV; 1200 Amps rated)
G.E. Type IAC Ground Relay
G.E. Type IAC Phase Overcurrent Relays
Substation - G.E. 5000 kVA 69/6.9Y kV 6.92% Impedance
G.E. Magne-blast Circuit Breaker (7200 V; 1200 Amps rated)
G.E. Ground Neutral Resistor 25 A Continuous Rating

1350 Dragline

Switchhouse - G.E. Oil Blast Circuit Breaker (13.8 kV; 1200 Amps rated)
G.E. Type IAC Ground Relay
G. E. Type IAC Phase Overcurrent Relays
Substation - G.E. 5000 kVA 69/6.9Y kV 6.92% Impedance
G.E. Magna-blast Circuit Breaker (7200 V, 1200 Amps rated)
G.E. Ground Neutral Resistor 25 A Continuous Rating

7900 Dragline

Switchhouse - Westinghouse Oil Circuit Breaker (13.8 kV, 1200 Amps rated)
Westinghouse CO-11 Ground Relay
Westinghouse CO-11 Phase Overcurrent Relays
Substation - Allis-Chalmers 3750 kVA 69/7.2Y kV
Allis-Chalmers Ruptair power Circuit Breaker 13.8 kV;
1200 Amps rated)
Ground Neutral Resistor 27 A Continuous Rating

1900 Shovel

Substation - G.E. 2000 kVA 69/4.16 kV 6.58% Impedance
G.E. Magna Blast Circuit Breaker (4160 V; 1200 Amps rated)
G.E. Neutral Ground Resistor 25 A Continuous Rating

45R Drill

Substation - Allis-Chalmers 2000 kVA 69/4.16Y kV 6.9% Impedance
Allis-Chalmers Ruptair Power Circuit Breaker (4160 V; 1200
Amps rated)
G.E. Neutral Ground Resistor 27 A Continuous Rating

60R Drill

Switchhouse - Allis-Chalmers Oil Circuit Breaker (4160 V; 600 Amps rating)
Westinghouse Type SC Ground Relays
Westinghouse Type CO-5 Phase Overcurrent Relays

test. They say it is too theoretical and expects the electricians to have a strong background in engineering. They also complain about the ambiguity of the regulations. Each inspector interprets them differently and they had one inspector who wanted them to put rubber mats under their light switches inside the shop and offices. They feel that they should separate the underground from the surface inspectors and not let them interchange.

Once again, personal negligence is the number one cause of accidents in the opinion of the company officials present.

A.6.4 New Mexico Surface Mine

A surface coal mine in New Mexico was the last surface operation visited in January of 1981. The company is operating two areas at the same mine. The North Area was started in 1975 when the South Area was closed. The South Area was later restarted in 1979 and they presently have a long term contract with a utility to supply 10,000-11,000 BTU coal. The coal runs in an eight foot seam, plus partings, and has about 60 feet of overburden. The mine produces about five million tons of coal annually. It operates six days a week and three shifts a day. Third shift is maintenance on all the equipment except the draglines. They employ 16 certified electricians and they too complain about the certification exam. They claim it to be too theoretical and say that it doesn't deal with reality or safety and that most problems encountered in normal mining work are not covered on the test.

The company purchases power at 115 kV at their main substation in the South Area. They transform from 115 kV to 13.2 kV through a 5 MVA sub which supplies the South Area shop, offices, and preparation plant. Power is supplied to a single 1370 Bucyrus Erie dragline through a 115/22.9 kV 10 MVA pit substation. The trunk and dragline cable is a 4/0 SHD-GC 25 kV conductor which may extend up to 10,000 feet in length from the pit sub to the dragline. Figure A.7 shows a typical cable layout for one of their pits.

A trunk line is established which runs parallel to the open pit. The dragline has 3000 feet of cable with which to operate from this line. As it moves from right to left in Figure A.7, it travels as far as that 3000 feet of cable will allow and then the cable is moved to the next portable switchhouse in the trunk line. The trunk line consists of 1500-foot cable lengths, junction boxes, and three-way switchhouses. The switchhouses have no protection and consist of non-load breaking knife switches.

The breaker house has one 22.9 kV breaker which protects two output circuits. The dragline is connected to one of these protected feeds. The drill sub is run off of the feed-through circuit in the breaker house. It is a 22.9/7.2 kV 1500 kVA sub and supports a Robins R15 blast hole drill. All the subs have time-and instantaneous-overcurrent protection and ground check and ground fault monitoring. Atkinson Armature Works supplies all of the electrical apparatus at this mine including the subs, air switches, breaker skids, junction boxes, and switch skids. They also manufacture the cable transporter used during cable moves.

The North Area is supplied by a 115 kV feed from the main substation in the South Area. The company owns and maintains all of the overhead lines on their lease area and they don't have any problem with machines getting into their distribution lines. The North Area operates in the same manner as the South except that they have three different pits. The draglines are all 1370 BE units with 320 foot booms, 55 yard buckets, and 6000 Hp of ac synchronous motors in their motor/generator sets. There are two Robins R15 drills and one 60R BE drill. The power layout is exactly the same as the one previously described and Table A.10 gives an electrical equipment list for the entire mine. Table A.11 gives a coal haulage and handling equipment list for the North Area.

Table A.10. Electrical equipment list

5	10 MVA Pit Subs 115/22.9 kV (1 spare) G.E. Relays, Ohmser Monitors
5	115 kV Air Switches
10	23 kV Breaker Skids
18	23 kV Switch Skids (3SW)
7	1500 kVA Drill Subs 22.9/7.2 kV
36	23 kV Junction Boxes
18	8 kV Junction Boxes

Table A.11. Coal haulage and handling equipment list

10	120 ton Wabco diesel-electric dump trucks
5	100 ton Unit Rig (Lectra Haul) diesel-electric dump trucks
2	L-700 LeTourneau diesel-electric loaders
1	L-800 LeTourneau diesel-electric loader
2	M151 Marion electric shovels
2	O & K (Orenstein & Koppel) hydraulic shovels

The only electrical problem they claim to have is the effect of temperature variation on their monitors. Sometimes they experience a variation of 40-50° and it apparently affects the resistance enough so that the monitors fail to function properly.

A.7 MSHA OFFICE (DISTRICT #7)

On January 5, 1981, a trip was made to the office of the subdistrict manager of MSHA district #7. Conversation topics included inspection methods and philosophies, safety, federal regulations, and needed research. The subdistrict manager, John E. Weekly, has a total of 51 inspectors under him including 4 supervisors. Two of his electrical inspectors were present during our discussions and they seemed very sincere and dedicated toward their job. In fact, they seemed to feel they were rendering a great service to the industry by being a readily-available consultant. They emphasized that many of the industry's electrical people called on them frequently for advice on a variety of problems. Mr. Weekly claimed that his inspectors are some of the most knowledgeable electrical people in the area and any specialized or highly technical information they aren't familiar with is available to them through either the Denver or Pittsburgh technical support group.

Mr. Weekly's philosophy on accident investigation is "to find the root of the problem". He feels that MSHA's work is not finished until the reason behind the accident occurrence is discovered and everyone is made aware of the contributing circumstances. He claims that MSHA has a good working relationship with both labor and management in district #7 and attributes this partially to the attitude under which his office operates. He tries to train his people to reason out situations and not to just blindly follow the book. He also feels that MSHA has played a significant role in increasing worker safety over the past years by "making an unsafe mine a high cost mine." So even though they endeavor to aid the industry, they are first and foremost a regulating body.

Concerning inspections, both inspectors denied having a quota of citations to meet and stated that they hoped they didn't leave that impression on anyone. However, they did say that sometimes they developed a theme around which to center their inspections. Also they admitted that, being human, they possibly didn't always treat everyone the same, however, they emphasized that there is only one set of regulations and they try to apply them with equal fairness to every individual mine.

Both Mr. Weekly and his inspectors agree that a safe attitude is instituted through management and the union. They feel it is important for management to believe in safety and to transmit that attitude down through the ranks, however, the ultimate responsibility for safety lies with the worker. Their key to safety is to make peers aware of unsafe men. One of the inspectors said that the "younger man is safer than the older miner" because he has gone through all the safety training before entering a mine and is much more sensitive to possible unsafe conditions than the older man.

Before any new mine is energized, the electrical inspectors team inspect every inch of the electrical system. They have the proper equipment to test circuit breakers, relays, and the entire tripping circuit. Once they have checked the system and given it a clean slate they then feel that they can be more understanding towards an unforeseen violation when the system is energized. Their most frequent compliance problem is with mechanical failure of ground checks. They also complained about circuit breaker problems involving undervoltage relays and ground fault and ground trip circuits. They feel the most pressing research needed is improvement in trailing cable splices and in automatic fire detectors for beltlines. The complaint about the fire detectors is that they simply are not adequately constructed and designed to withstand the abusive conditions in which they must operate.

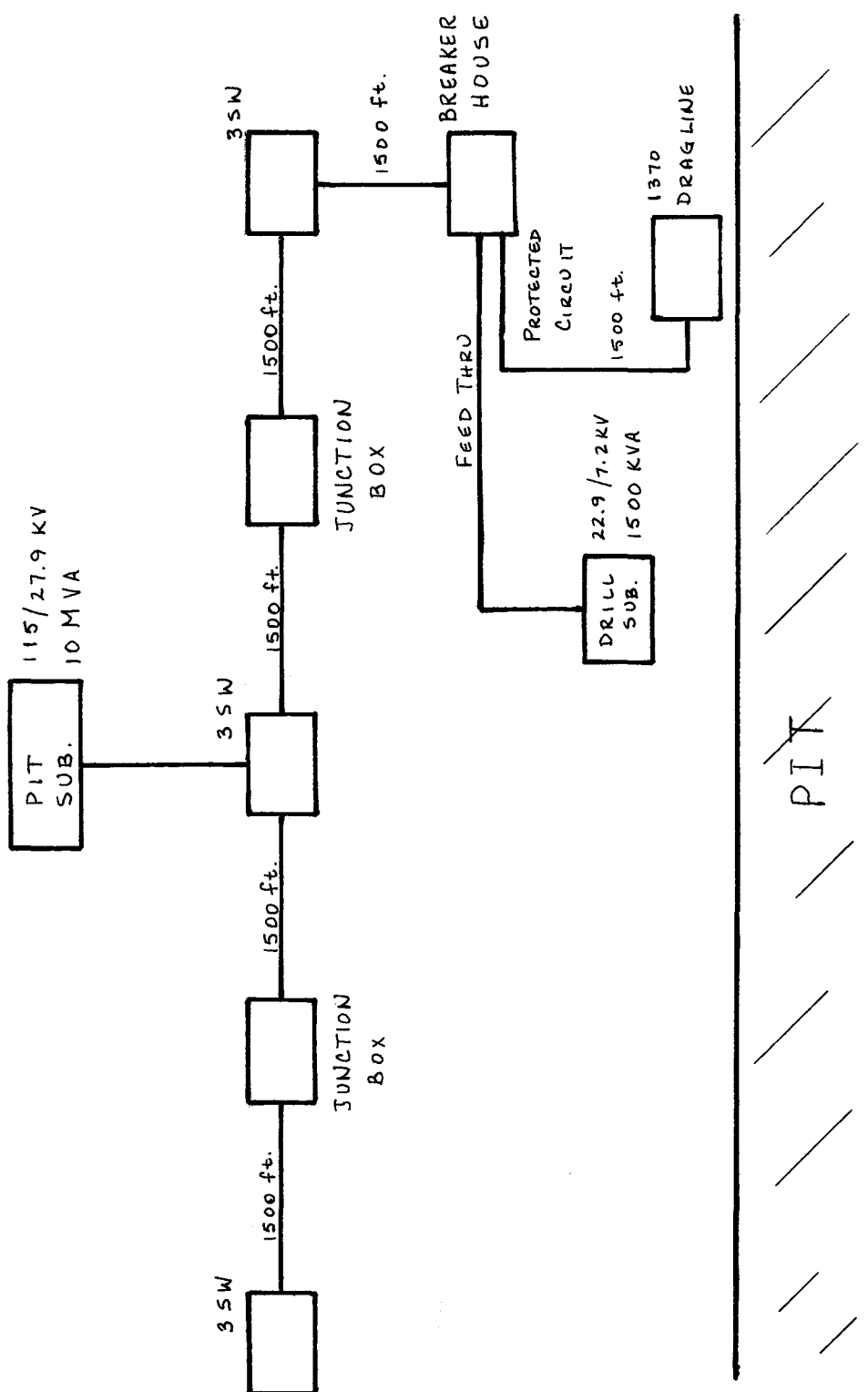


FIGURE A.3. Power cable layout for surface mine.

