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VOLUME IV – OVERHEAD-LINE CONTACT FATALITIES

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16. Abstract (Limit: 200 words)

Volume IV of this report examines the problem of indirect contact of overhead high-voltage powerlines by mining personnel. This refers to the contact of energized lines by workers through an intermediate conductor such as a metallic tool or a piece of high-reaching mobile equipment. The shock hazard by such contact has been a major cause of electrical fatalities associated with mining operations. The report is divided into three areas. The first gives a general background of overhead lines, basic characteristics, and associated hazards and describes presently used techniques and devices that attempt to alleviate the contact problem. The second area presents a detailed analysis of 39 overhead-line contact accidents in mining since 1970. The third section used the information in the first two areas to formulate recommendations to prevent these accidents and subsequent electrocutions as mining operations.

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FOREWORD

This report was prepared by The Pennsylvania State University, Departments of Mineral Engineering and Electrical Engineering, University Park, Pennsylvania, under Bureau of Mines Contract Number J0113009 administered under the technical direction of the Pittsburgh Research Center with Mr. D. Ambrose and Mr. M. Yenchek acting as technical project officers. Mr. Frank Naughton was the contracting officer for the Bureau of Mines. This report is a summary of the work recently completed as part of this contract during the period April 1, 1981 through December 8, 1982. This report was submitted by the authors in December 1982. This technical report has been reviewed and approved.

No inventions have been developed from Contract J0113009 and no patents are pending.

Project personnel are grateful to outside individuals and companies who provided valuable inputs through discussion.

This report contains information that might help improve mine-power-system performance. No product endorsements or disapprovals are intended.

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Chapter I

INTRODUCTION

General

The most common method used for electric-power transmission and distribution is overhead conductors. Although size and detail of construction vary widely, overhead power lines normally consist of bare metallic conductors, supported by insulators from some elevated structure. The conductors use air space for insulation over most of their lengths, while their elevation protects them from contact with grounded objects.

The most obvious example of overhead lines is the vast network owned and operated by electric utilities. Overhead lines, however, also find extensive use in the mining industry. Surface facilities associated with mineral production and many types of surface-mining operations can use large amounts of electric power. Although the use of multi-conductor cables is typical for many surface mines, such as coal, overhead lines are still a common means of power distribution for many surface operations of any mine, as well as associated processing and transportation facilities.

The height of overhead-line installations is an attempt to isolate them from external contact. They are though, by their nature, a hazard to anyone contacting them directly or indirectly.

Statement of Problem

Overhead lines, whether utility transmission and distribution lines or part of the mine-site electrical system, present a serious electrical shock hazard to mining personnel. Overhead lines in and near mining operations are exposed to contact by many types of mobile equipment and even hand-held tools. Metallic frames of such equipment, upon contact of energized overhead lines, can become elevated above earth potential, and simultaneous contact of the "hot" frame and ground by a workman can create a path through the body for lethal levels of phase-to-ground fault current. Personnel are therefore exposed to a shock hazard through the "indirect contact of overhead power lines." This category of mining electrocutions includes any situation wherein workers contact overhead power lines through intermediate objects such as high-reaching mobile equipment or hand-held tools. Cases where personnel directly touch an overhead conductor are not included.

Although this mode of electrocution seems (at least outwardly) straightforward, it has to date eluded an effective means of prevention. Examination of mining-industry statistics since 1970 reveals that one-third of surface coal-mine electrical fatalities and approximately one-third of all electrical fatalities in metal/nonmetal operations are directly attributable to the indirect contact of overhead lines [1]. The majority of these accidents involved mobile equipment. These figures strongly indicate the need for a thorough examination of this problem.

Scope of Research

An investigation into indirect worker contact of overhead lines is the basis of this report. The goal of the research is to set forth recommendations for surface-mine and mine-plant operators, which will minimize the overhead-line hazards in their operations. This requires an analysis of the problem as it exists in the mining industry based on a general overview of line-contact accident characteristics in mining and non-mining fields. Recommendations will be formulated using the information complied from general overhead-line hazards, mining-industry accidents, and presently used line-contact accident prevention techniques.

Report Format

The examination begins with a review of relevant background information which is contained in the next chapter. This is followed by a detailed analysis of previous fatal accidents in mining due to indirect contact of overhead lines. Recommendations for the reduction of overhead-line hazards are then established and verified in Chapter IV. The report ends with conclusions and recommendations for future work in this area.

Chapter II

BACKGROUND

General

This chapter examines the basic characteristics of overhead-line indirect-contact hazards in the mining industry. It describes common aspects of and discusses areas related to the problem. Information on overhead-line hazards, current means of prevention, and their shortcomings will establish a basis for an accident analysis in Chapter III.

Mechanical and Electrical Aspects of Overhead-Line Contact

Indirect contact of overhead power lines is the number one cause of electrical fatalities in surface operations of mines, accounting for 48 deaths between 1970 and 1980 [1]. These coal and metal/nonmetal fatal accidents usually resulted from mobile mining equipment such as trucks, drills, cranes, and draglines contacting overhead lines, with grounded workers either simultaneously or shortly thereafter contacting the energized frame. Given the similarity of accident circumstances, the problem of overhead-line contact can be introduced by examining some of the situations surrounding actual mining-industry fatalities. Before describing overhead contacts in mining, however, some general information on overhead lines and power systems is appropriate.

Overhead-line installations use numerous types of conductor arrangements and support structures in various combinations. Systems range from single wooden poles carrying conductors at low voltages to self-supporting steel towers bearing major transmission lines. Wooden-pole lines with or without crossarms, for example, may be part of a single-phase or three-phase distribution system with voltages of 2.3 to 35 kV. By contrast, steel towers often carry lines transmitting large amounts of power at 115 kV and up, connecting major load centers of a utility company grid [2,3]. Utility-owned lines are commonly classified by function, which is related to voltage. There are no utility-wide standards for voltage classifications, but the system typically used differs from the classification used in the mining industry. Table 1 compares the two systems [3]. Overhead conductors are arranged in various configurations to reduce line-to-line contacts due to wind, ice loading, or sudden loss of ice load, and may include different combinations of phase, neutral, and static conductors. Aluminum conductors with steel reinforcement (ACSR) are commonly used due to their strength and relatively low price, but special applications may call for other materials such as copper [2,4].

The types of overhead-line installations used for mining applications are similar to those in utility distribution systems. Typical are pole lines to supply equipment in surface mining and lines feeding surface facilities related to mining [5]. These lines are normally installed on single wooden poles and may carry only two conductors, as in single-phase supplies, or have up to six conductors, including three phase, one neutral, one ground-check (pilot), and one static [2,6]. The pole lines may be relatively permanent installations such as those feeding plants, shops, and other surface facilities, and long-term pit baselines or ring mains. Figures 1 and 2 show the application of pole lines in strip and open-pit mining operations [5,7].

Table 1. Comparison of electric-utility and mining-industry voltage level classifications [3].

Classification	Voltage Level
Utility Systems	
Distribution	2.4 - 34.5 kV
Subtransmission	13.8 - 138 kV
Transmission	69 - 765 kV
High Voltage	115 - 230 kV
Extra High Voltage	345 - 765 kV
Ultra High Voltage	above 765 kV
Mining Systems	
Low Voltage	at or below 660 V
Medium Voltage	661 - 1000 V
High Voltage	above 1000 V

Temporary poles are mounted in portable bases (such as concrete-filled tires) for ease of relocation, and are commonly used in open-pit mining operations to carry power into the pit. Figure 3 shows a self-supporting portable pole. Conductors are again usually ACSR, but hard-drawn copper is used where blast damage is a problem [7].

Electric power conductors operate at some potential above a given reference such as another conductor, the neutral of a three-phase system, or the grounded conductor of a single-phase system. If a three-phase neutral for instance is connected to infinite earth (grounded), the phases are referenced to earth potential. Given a path, current will flow from these phases to the neutral.

Ungrounded utility systems (not referenced to earth) were at one time common, but today most transmission and distribution systems have the neutral points of their supplying transformers tied to earth directly or through some impedance. Transmission networks have their neutral points tied to earth and normally rely on the earth as a return path for any phase to neutral current [2]. Distribution-system lines often carry a conductor at neutral potential and connected to the same low-resistance ground bed that grounds the neutral point. In the case of utility distribution, this facilitates line-to-neutral loading on the system, while in mining the grounding conductor ties equipment frames to earth primarily for personnel protection [2,5].

When a line-to-ground fault occurs on a solidly or low-impedance grounded system, high currents can flow. Circuits with high impedance-grounded sources reduce fault current for equipment protection, but not below lethal levels for humans. The contact of an overhead line by mobile equipment can create a fault condition. If electrically powered equipment in a mining application contacts its own supply phase conductors, fault current may flow through the grounded frame and back to the source neutral through a

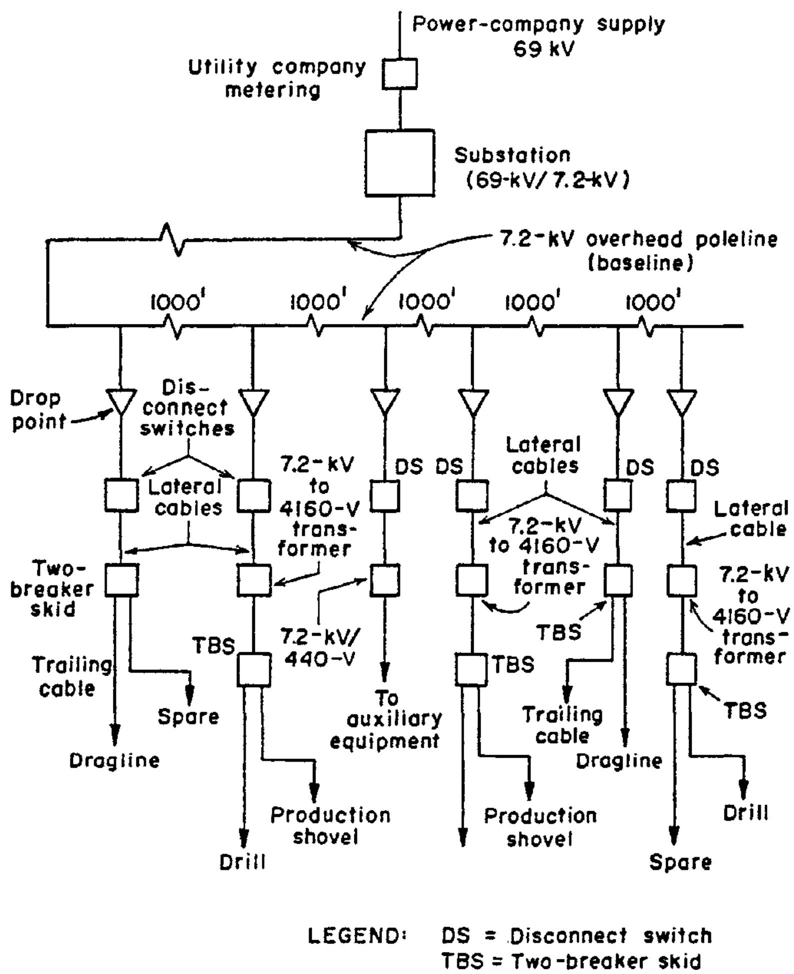

Figure 1. Radial distribution for a strip mine with overhead-poleline base line [5].

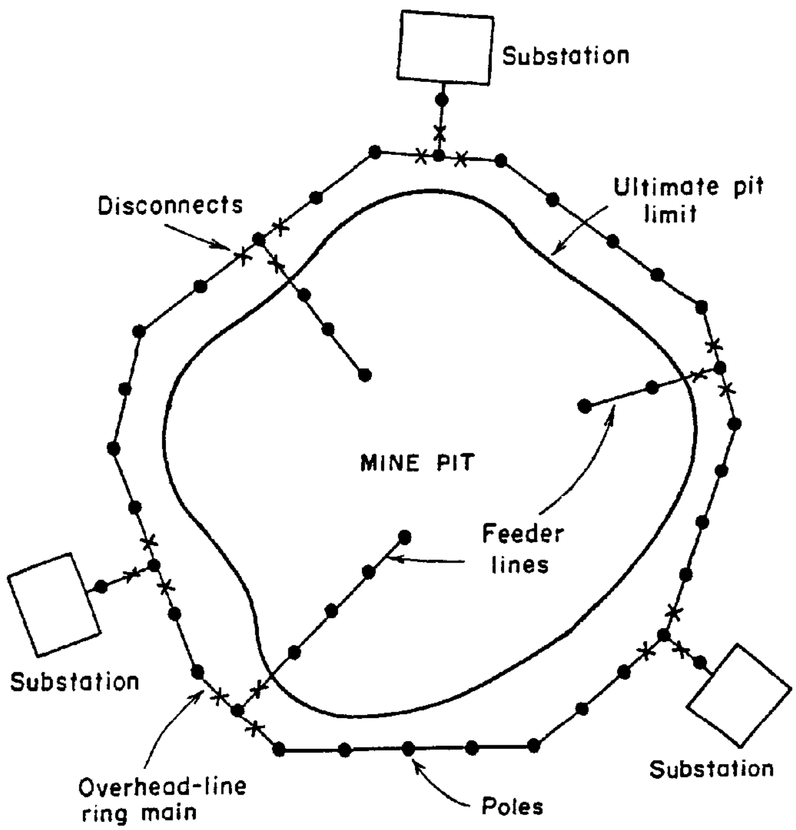

Figure 2. Open-pit power distribution system with an overhead-poleline ring main.

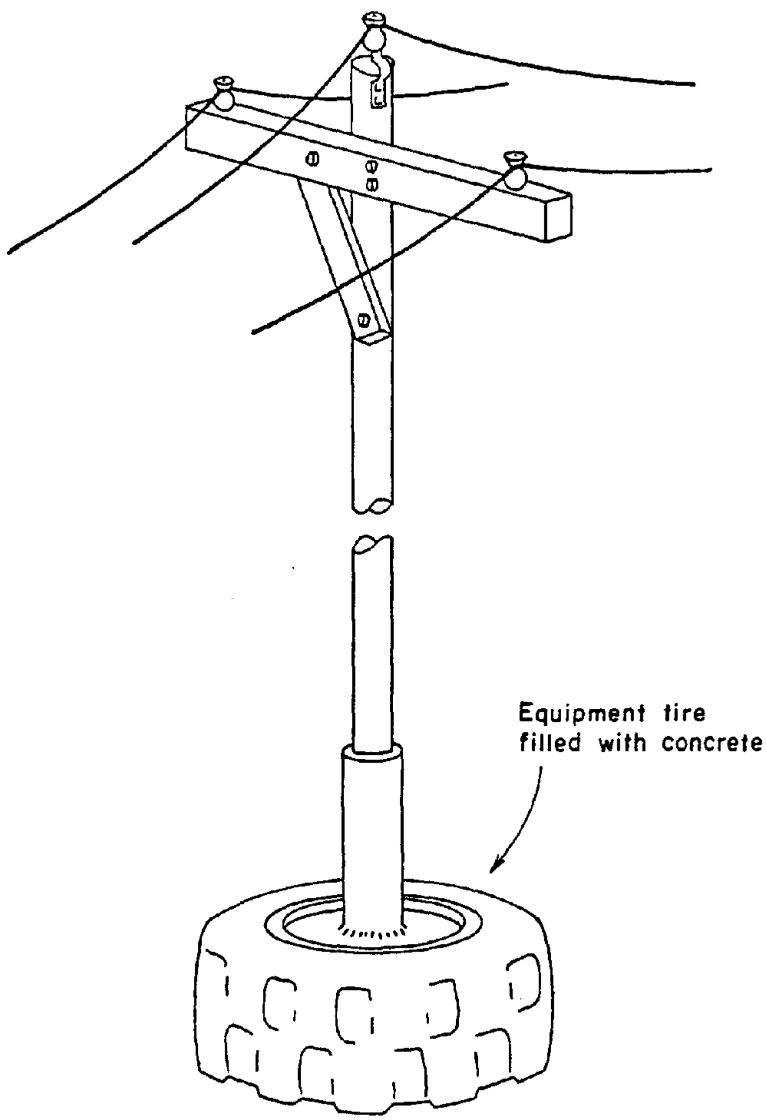

Figure 3. Portable pole for overhead lines in a surface mine.

grounding conductor [5]. Often, however, independently powered equipment have only their frames and ground contact as a path to earth for ground-fault current. Figure 4 shows a generalized overhead line-equipment contact situation. Ground-contact resistance can be quite high for rubber-tired machinery, and although metal-to-earth contact such as with crawlers usually reduces resistance, it may still be substantial [8]. Table 2 lists ground-contact resistances for various types and sizes of surface-mining equipment. When contact of an overhead line occurs with a high-resistance path to earth, equipment frames can be elevated above ground potential and dangerous gradients created between frame and ground (touch potential) and even along the surface of the ground (step potential) [5]. A worker bridging these gradients under the correct conditions can have lethal levels of current flow through his body.

Potential current levels depend on a number of factors, such as: phase-to-neutral voltage; impedances of the power system, including conductor, transformer, neutral connection, and ground bed; and resistances at the fault location. Conditions at the fault location are influenced by the resistance at the overhead-line and equipment-contact point, the resistance of the equipment ground contact, and the resistance of the human body. Ground-contact resistance and local earth resistance determine voltage gradients in the immediate vicinity of the equipment, although arcing to earth can occur with rubber-tired machinery. Dirt and moisture can also greatly affect contact resistances. Skin resistance has little effect on overhead-line accidents, in most cases, since potentials over 240 V puncture the skin [1,5].

If ground-fault current is high enough and ground-fault protective devices are sufficiently sensitive, the circuit may de-energize after the overhead-line contact. Fault current may be detected by phase overcurrent protective devices or by circuitry specifically for ground-fault protection. Protection ranges from fuses and circuit breakers on distribution systems to reclosers on lines at transmission levels. Ground-fault currents, however, can be at lethal levels and still below trip settings since this circuitry is designed primarily to protect equipment from sustained high fault currents [2,3].

The preceding paragraphs have briefly outlined the electrical situations involved in overhead-line contacts. The remainder of this chapter will examine the circumstances surrounding overhead-line contacts and methods employed to prevent the hazards associated with their occurrence.

Overhead-Line Contact in Industry

Contact of energized overhead power lines is by no means a problem unique to the mining industry. The hazard can exist anywhere high-reaching equipment operates near overhead lines. Construction activities using cranes are obvious examples of potentially dangerous situations, and much of the work to date on indirect overhead-line-contact fatality prevention has been directed toward mobile cranes [9]. Equipment using articulated booms such as elevated-bucket trucks for polework, as well as vehicles with vertical masts such as drill rigs also present a potential for overhead-line contact. Trucks can pose a hazard due to elevating dump beds or the transport of unusually high loads. Aerial fire-fighting apparatus is susceptable to overhead-line contact and can be particularly dangerous due to its operation

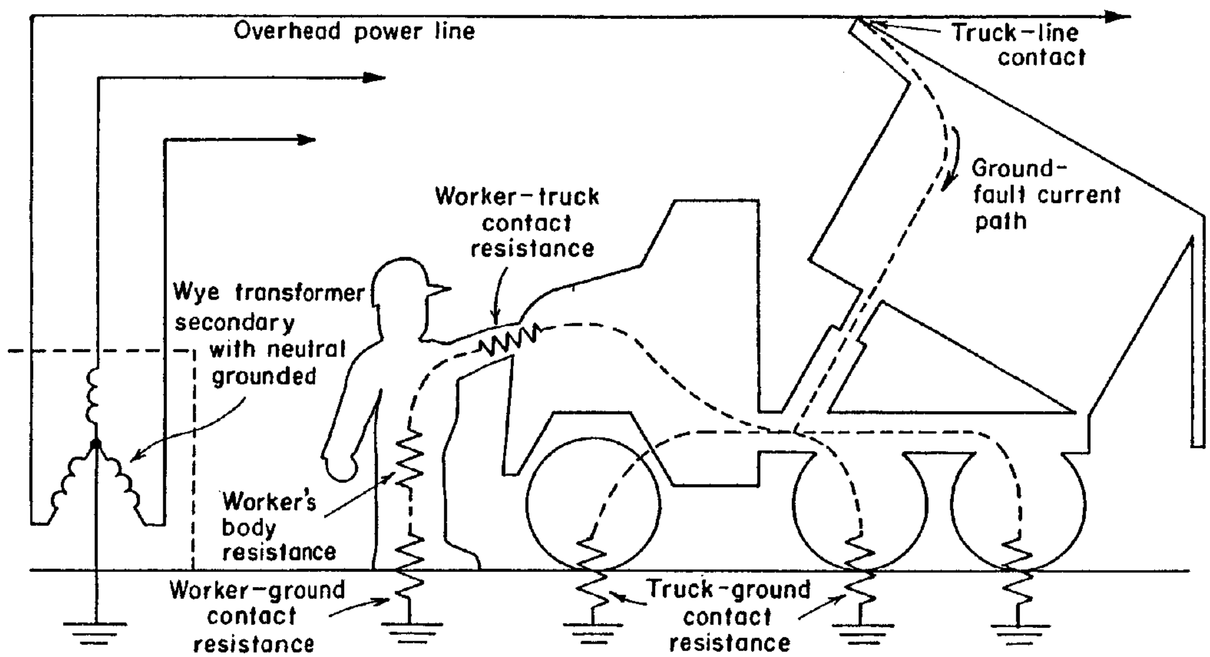

Figure 4. General diagram of an overhead-line contact accident, showing ground-fault current paths through the truck and victim.

Table 2. Ground-contact resistances for various surface-mining equipment.

Mine Type	Machine Type	Weight (lbs)	Contact Area (ft^2)	Resistance (Ω)
Open-Pit Metal	Drill	75,000	48	86
	Shovel	380,000	90	18.2
	Shovel	380,000	90	60.4
	Shovel	405,000	90	39
	Shovel	500,000	107	4.25
	Shovel	950,000	140	21
	Shovel	379,000	147	4.5
	Shovel	379,000	147	10.2
	Shovel	379,000	147	8.1
	Shovel	379,000	147	5.3
	Shovel	580,000	155	13.5
	Shovel	580,000	155	7.5
	Shovel	975,000	158	8
	Shovel	972,000	163	29
	Shovel	915,000	166	5
	Shovel	915,000	166	34.8
	Dragline	1,600,000	1018	0.9
Surface Coal	Drill	---	152	4.05
	Drill	---	152	4.8
	Drill	---	86	13.23
	Shovel	---	96	5.75
	Shovel	---	152	7.9
	Shovel	---	115	4.78
	Shovel	960,000	198	4.72
	Dragline	---	1520	1.4
	Dragline	1,271,000	804	1.05

under emergency conditions. Other less obvious overhead-contact situations can exist, such as contact by way of a fluid stream directed from a piece of equipment [10].

Overhead-contact circumstances in mining are somewhat representative of the problem in general. An introduction to overhead-line indirect-contact fatalities in mining can readily be organized according to the equipment involved. The following descriptions serve as an overview of the hazards presented.

Trucks commonly involved in overhead-line contacts are highway legal end-dump tandems, triaxles, and tractor trailers. Overhead-line contact and subsequent energizing of the frame often occur through beds being raised into lines or driven into them. Victims normally bridge lethal potentials by stepping from the cab onto the ground or by operating external controls.

Mobile cranes, which present a substantial line-contact hazard in other industries, find various uses around a mine site. They range from large, solid-boom, high construction cranes, to smaller hydraulically powered units with retractable booms. Lines can be contacted by the boom or hoisting cable, and in both cases workmen around the crane (laborers, hookmen) have the greatest shock-hazard exposure.

Mobile drilling rigs are susceptable to overhead-line contact due to their masts which can be raised or driven into lines. Operators are the most likely victims, bridging potential gradients while operating drill controls.

Prevention of Electrocutions

Because of the shock hazard to personnel, it is obviously desirable to prevent contact of overhead lines, or at least the subsequent energizing of equipment and loads. To reduce this hazard, various standards and devices have been developed, representing different approaches to the problem. Some solutions are based on the idea that the initial contact of an overhead line must be prevented. Other methods focus on holding equipment and loads at safe potentials even in the event of contact of overhead lines. The prevention techniques in the following discussions all fall into one of the above mentioned categories, but are not grouped as such.

Federal Regulations. The federal government has established regulations to safeguard individuals working on or about equipment in the vicinity of overhead lines. These regulations attempt to prevent overhead-line contacts by setting forth line-installation standards and equipment-operation guidelines including minimum equipment-to-line distances. Safety and health regulations for construction, Code of Federal Regulations (CFR), Title 29, address the hazard of construction-crane operation near overhead lines [11]. Similarly, CFR, Title 30 deals with the prevention of equipment contact of overhead lines in the mining industry [6].

Overhead-line safety guidelines for construction are in CFR, Title 29, Part 1926, Section 550, Paragraph (a), Subparagraph (15). These regulations require cranes to operate with a minimum clearance of 10 ft from lines rated at 50 kV or below. Minimum clearance from lines over 50 kV increases 0.4 in. for each 1 kV over 50 kV, or twice the length of the line insulator. Minimum clearances decrease for cranes in transit, with four ft for voltages below 50 kV, 10 ft for lines at 50 kV to 345 kV, and 16 ft for voltages up to and including 750 kV (extra high voltages). These requirements are summarized in Table 3. These distances apply except where lines in question have been de-energized and visibly grounded, or where insulating barriers (not part of the equipment) have been installed to prevent physical contact with the lines.

If it is difficult for an operator to maintain required clearances, regulations call for designation of a person to observe equipment clearances and give timely warning to prevent contact. Regulations also state that the use of safety devices such as boom guards, insulating links, and proximity-warning devices shall not diminish the requirements of other regulations, even if these devices are required by law. All lines are to be considered energized until the line owner or utility authority has indicated otherwise and they have been visibly grounded. These regulations for overhead-line safety in construction are under the enforcement jurisdiction of the Occupational Safety and Health Administration (OSHA) [11].

Table 3. Minimum overhead line clearances for construction cranes, CFR, Title 29.

Line Voltage (kV)	Working Clearance	Clearance In Transit
Up to 50	10 ft	4 ft
66	10 ft 6 in.	10 ft
115	12 ft 2 in.	10 ft
138	13 ft	10 ft
230	16 ft	10 ft
500	25 ft	16 ft
	(Calculated using 0.4 in/kV over 50 kV)	

Code of Federal Regulations, Title 30, Part 77, Sections 807-1 through 807-3, cover high-voltage overhead-power-line safety at surface coal mines and surface facilities of underground coal mines [6]. Section 807-1 requires high-voltage overhead lines to be installed with clearances above driveways, haulageways, and railroad tracks as set forth in the National Electrical Safety Code (NESC), but stipulates 15 ft as the minimum height of any high-voltage power line [12]. Table 4 lists applicable NESC standards. Section 807-2 states that booms and masts of equipment shall not be operated within 10 ft of energized overhead lines with voltages below 69 kV. Table 5 lists increased minimum distances for higher voltages. Section 807-3 requires high-voltage power lines to be de-energized or other precautions taken if equipment must operate closer to them than the distances specified in 807-2.

Safety precautions and installation requirements for overhead lines in surface metal/nonmetal mines, sand-and-gravel/crushed-stone operations, and surface facilities of underground metal/nonmetal mines are covered in CFR, Title 30, Section 12 of Parts 55, 56, and 57, respectively. These metal/nonmetal regulations require that overhead lines be installed according to NESC specifications. They also require equipment to maintain a 10-foot minimum clearance from energized high-voltage overhead power lines, but do not specify higher clearances with increasing line voltage [6].

Proposed revisions (published in 1977) to part 77 of Title 30, which have not yet been adopted, call for mandatory use of proximity-warning devices on equipment with booms and masts capable of extending greater than 15 ft above ground [13,14]. The table distances in Part 77, Section 807-2 would be the basis for initiation of an audible and visible alarm. This revision has been questioned by both the Institute of Electrical and Electronics Engineers (IEEE) and the Open Pit Mining Association (OPMA) due to the limited capabilities of present proximity-warning devices.

The IEEE in December 1981 submitted recommended changes and comments to the Department of Labor on electrical regulations in Parts 55, 56, and 57 of Title 30 [15]. In these recommendations, sections pertaining to overhead power-line safety were revised to more closely resemble and exceed similar requirements in Part 77. The present regulations for overhead lines in Parts

Table 4. Minimum vertical conductor clearances as specified by the NESC, applicable to mining and mining-related operations.

Nature of surface underneath wires, conductors, or cables	Open Supply Line Conductors: 750 V to 15 kV (ft)	Open Supply Line Conductors: 15 to 50 kV (ft)
Where wires, conductors, or cables cross over		
Track rails of railroads (except electrified railroads using over-head trolley conductors).	28	30
Roads, streets, alleys, parking lots subject to truck traffic.	20	22
Other land traversed by vehicles such as cultivated, grazing, forest, orchard, etc.	20	22
Where wires, conductors, or cables run along and within the limits of highways or other road right-of-way but do not overhang the roadway		
Roads in rural district	18	20

Table 5. Minimum distances from overhead lines for equipment booms and masts, CFR, Title 30.

Nominal Power Line Voltage (in kV)	Minimum Distance (in feet)
69 - 114	12
115 - 229	15
230 - 344	20
345 - 499	25
500 and up	35

55, 56, and 57 are somewhat incomplete and redundant, whereas IEEE recommendations clearly reference the NESC for overhead-line installation requirements and give a minimum-operating-distance table dependent on voltage. These minimum clearances are shown in Table 6 [15]. These revisions have not been adopted as of this writing.

It is evident that current federal regulations are aimed at the prevention of overhead-line contacts as a means of protecting personnel. There are several points, however, that should be noted. Adherence to NESC specifications for installation of overhead power lines does not elevate them above the reach of much equipment used in mining surface activities, and in many cases it is not feasible or practical to place the lines at these heights. More importantly, the effectiveness of rules and regulations depends on the intentions of all involved to follow the guidelines set forth. Also implicit in the law is the assumption that workers in question are aware of the presence of an overhead-line hazard. Finally, laws have the disadvantage of relying totally on the human element for their implementation, an uncertain factor at best.

Protective Devices. Devices exist which attempt to reduce overhead-line hazards either by insulation from line potentials, or warning of overhead-line proximity. Representative of the first method are insulated boom cages and insulating load hook links, while proximity-warning devices are intended to indicate the presence of energized conductors. Most devices are directed primarily toward protection of mobile cranes due to their common use and frequent exposure to overhead-line hazards but do have other applications. The following sections will discuss a few of these currently available methods for overhead-line hazard protection.

Table 6. IEEE recommendations for minimum equipment overhead-line clearances in metal/nonmetal operations.

Voltage (kV)	Distance (feet)
Less than 25	6
25 - 68	10
69 - 114	12
115 - 229	15
230 - 344	20
345 - 499	25
500 and up	35

A technique which limits elevation of frame potentials in the event of overhead-line contact is the effective grounding of equipment frames. A low-resistance ground-fault current path on a system referenced to earth will limit the potential rise of frames which are part of that path (such as in overhead-line contacts) [16]. Frame grounding though is not applicable in many cases involving mobile equipment not powered through trailing cables. Temporary "earthing" of mobile-equipment frames is not feasible due to the site specific and sometimes extensive requirements of low resistance ground beds.

An insulated boom cage is an enclosure or guard mounted on and electrically isolated from a boom or mast to be protected. In the event the boom is moved into an overhead power line, the insulated cage makes initial contact and prevents the boom from becoming energized. Such a device obviously protects only covered areas and cannot easily guard hoisting ropes. The effectiveness of boom guards also depends on the integrity and surface condition of the insulators used. Figure 5 shows an example of a boom cage [9].

During hoisting operations, workmen steadying or directing a load from the ground are in an extremely hazardous position should an overhead line be contacted. They are commonly in contact with both the ground and load and, therefore, immediately become paths for fault current should the load be energized through wire-rope rigging. In recognition of this situation, insulating links have been developed to isolate loads from the crane hoisting rope. The links are placed between the load hook and the hoist rope and are constructed of a dielectric such as resin-impregnated fiberglass. Some types load the link in tension while other designs place the dielectric in compression. Examples of both are shown in Figure 6 [9]. These links have a rated capacity but may deteriorate with field use and aging. If strength reduction occurs, a link in tension poses the danger of sudden failure, but a compression link can be designed so steel bearing surfaces continue to support the load should the dielectric material fail. Insulating links, even under optimal conditions, provide protection limited to workmen contacting the crane load. Should a line contact occur, the crane frame and hoisting rope are still elevated above ground potential.

Both boom cages and insulating links depend entirely on the performance of the insulators used. The most common mode of insulator failure is sparkover along the insulator surface; therefore, surface conditions are a critical factor in the protection provided. Tests have shown that insulating links subjected to contamination typical of construction usage and storage had reductions in insulating ability of 33 to 68% of rated values [9]. Stand-off insulators used in boom cages had similar serious reductions in insulation properties. Thorough and careful cleaning was necessary to restore rated insulation values. It is evident that normal handling and usage of insulators on construction equipment may degrade the performance of insulating links and boom cages to dangerous levels. Electrical sparkover is therefore the greatest hazard associated with their use.

A proximity-warning device indicates by a visual or audible alarm the proximity of equipment extensions to energized overhead-power lines [17]. Unlike the methods just discussed, these devices attempt to prevent

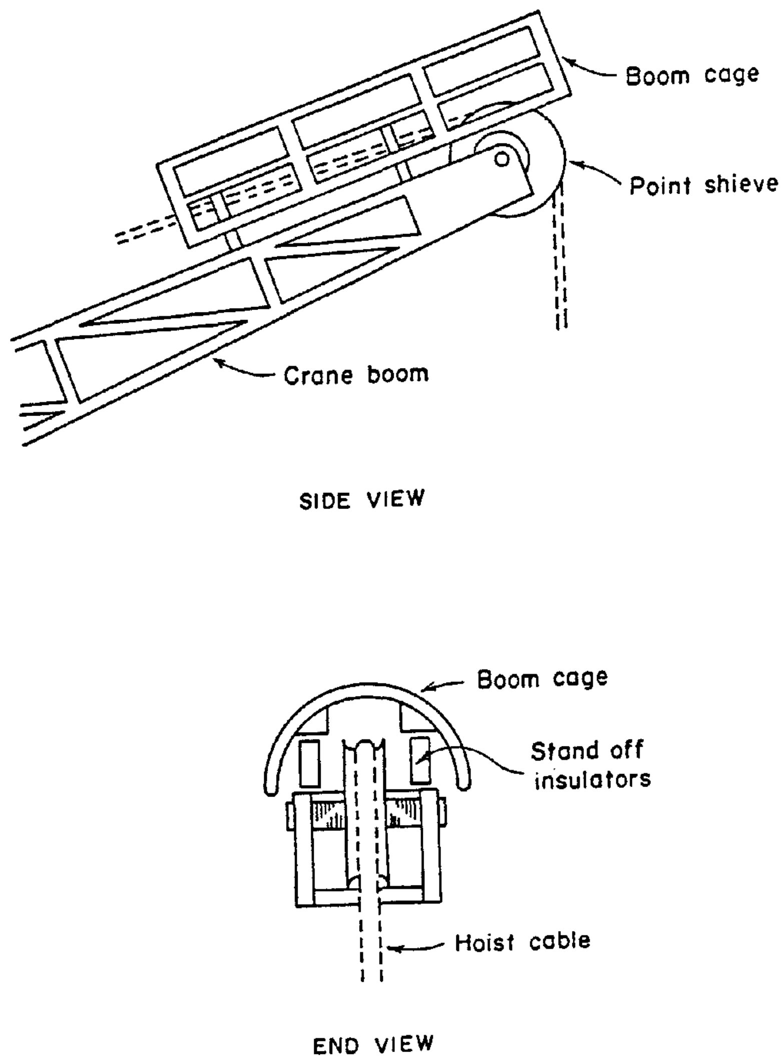

Figure 5. Boom cage protecting the point of a crane boom.

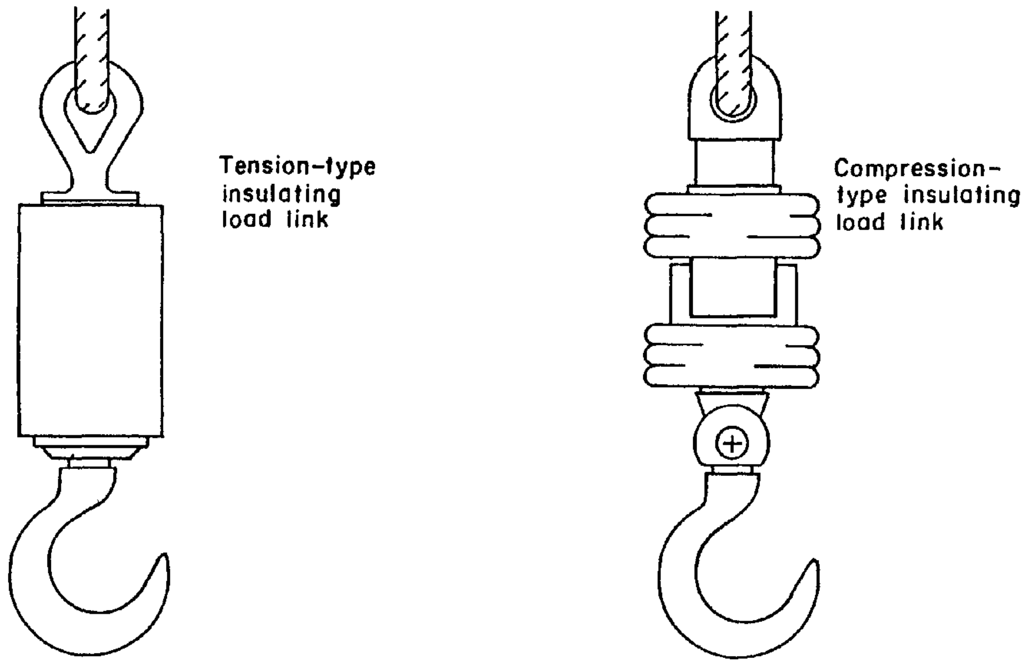

Figure 6. Two examples of insulating load links on crane hoist ropes.

equipment-line contact. Also, in contrast to applicable laws, the operation of a warning device is theoretically independent of human judgement, at least so far as indication of power-line presence is concerned. Their effective use assumes that they are in working order, have been correctly calibrated, are taken seriously by the work force, and that their limitations are understood by individuals involved.

Such a device would ideally alert an operator if the protected extension entered a predetermined zone about a power conductor. A zone meeting proposed MSHA Regulation 77.805-4 for CFR, Title 30, is shown in Figure 7 [13]. Here, the vertical section of the "alarm/no alarm" division line extends upward indefinitely. This will exclude from the danger zone any hoist rope extending downward from the point of a boom more than 10 ft above the conductor.

Several types of proximity warning devices are available in the United States, all operating on the principle of electrostatic-field detection [17]. The electrostatic field about a group of overhead conductors is primarily a function of their voltage and geometry. The units generally operate by monitoring 60-Hz electrostatic fields; amplifying, rectifying, and measuring the signal; and then activating an alarm at some preset signal level. The sensor used may be short and effectively a "point sensor" which will create a spherical detection area, or a "distributed sensor" spanning the length of a protected extension. The type, number, and location of these sensors greatly affect the operation of a proximity-warning device.

The use of proximity-warning devices has been largely directed toward mobile cranes in the construction and mining industries. They can, however, be applied to other mobile equipment such as articulating booms and extendable ladders.

Proximity-warning devices operate as intended under many circumstances, but their reliability can be severely reduced by a number of factors. These limitations are grouped into those arising from operational principles of electrostatic-field detection, and those which are due to the design of individual devices. The following list outlines inherent problems of electrostatic-field detection devices [17].

1. Multiple power-line circuits can distort electrostatic fields due to superposition of field vectors. A reduction of reliability occurs when the electric field of a distant power line has an order of magnitude greater than or equal to the field of a closer line. Multiple circuits on the same pole can have a pronounced effect on device operation, sometimes causing cancellation of field vectors (resulting in no alarm) inside danger zones.

2. Significant sensor-signal variations result from variations in electric-field polarization about power lines. Figure 8 shows an example of field-vector variation [17].

3. Performance of proximity-warning devices is influenced by boom and sensor interaction (boom of a crane for example). Because of the zero-voltage surface established by a grounded boom, the sensor actually provides a measure of the average voltage gradient between

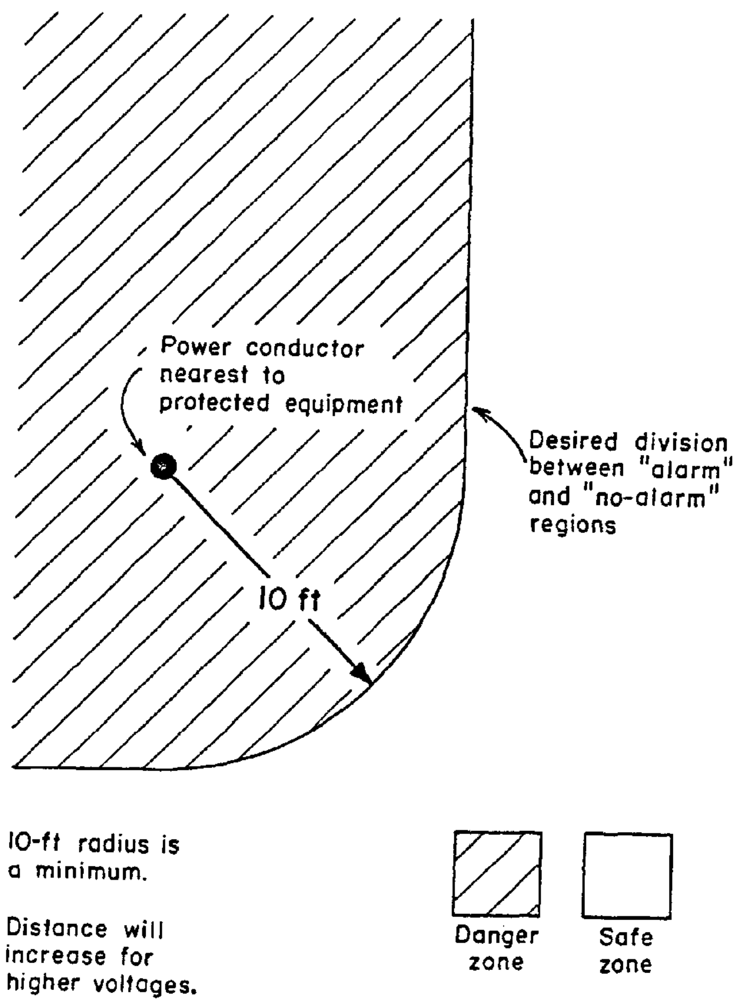

Figure 7. Theoretical zone of alarm activation for a proximity-warning device.

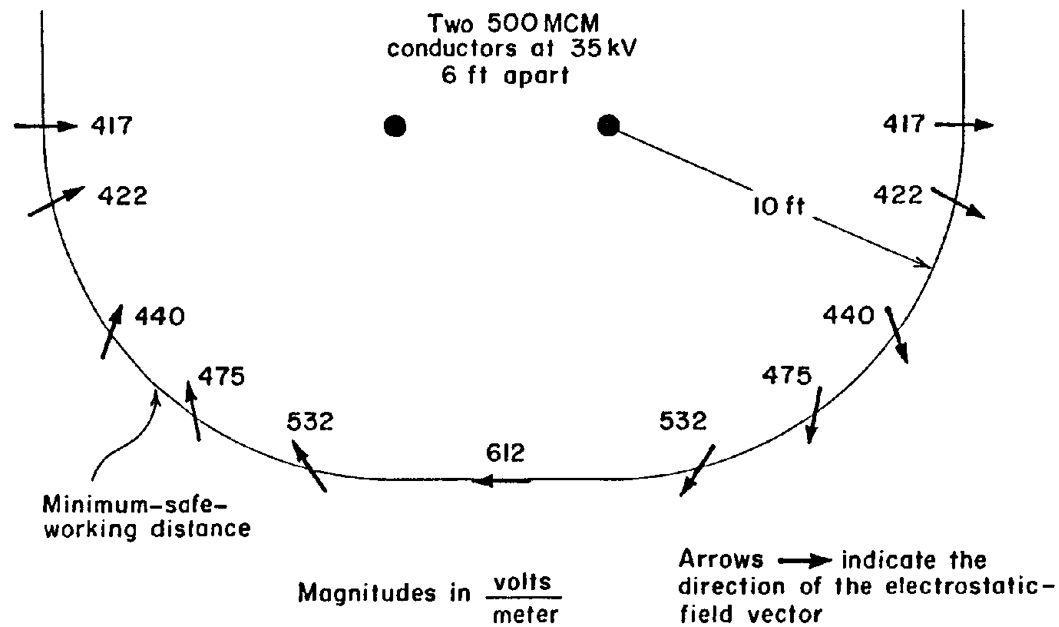

Figure 8. Theoretical variation of electrical-field vector around minimum-safe-working distance boundary.

the sensor and boom, and not the undisturbed field strength. Other factors are the location and attitude of the sensor on the boom, shielding of sensor by the boom or cable, and physical construction of boom.

4. The physical configuration of overhead lines has a major effect on the alarm-zone boundaries of warning devices. Figure 9 gives two examples of alarm-boundary distortion [17].

5. Large grounded metal objects in the vicinity of protected equipment alter device sensitivity.

6. Proximity-warning devices are often unable to protect crane hoisting ropes from overhead-line contact.

Other operational problems related to specific proximity-warning devices are: changes in sensitivity with extendable distributed sensors and variation in boom length, the need for multiple point sensors, a lack of provisions for signal conductor extension and retraction, fragile construction, poor temperature-change stability, and inaudible alarms.

It is obvious that warning-device reliability can be compromised by a complex array of factors. In the study responsible for the identification of these limitations (by the Southwest Research Institute, reference 17) over 150 alarm contours were developed under various conditions in scale-model experiments. In this testing 57 line contacts occurred with no alarm produced. The concept of a device to alert equipment operators to possible overhead-line contacts has great merit but, given the inconsistent operation of currently available devices, they should only be applied with full recognition of their limitations. Dangerous conditions can exist where workers place too much faith in a warning device, or ignore it due to previous unreliable operation. Such devices therefore seem best applied as a supplement to other overhead-line-contact safety measures.

<u>The Role of Electric Utilities</u>. Electric-power companies are by far the most common owner-operators of overhead-line installations, and so are justifiably concerned with accidental overhead-line contacts. Their efforts to maintain safety have a wide scope, but the prevention of electrocutions due to indirect contact of overhead lines aims primarily at the common problem of high-reaching equipment. The main thrust of power-company policy regarding overhead lines is the safety of individuals who inadvertantly work near these lines, or are required to do so. Line contacts can also affect electric utilities through line and equipment damage as well as unscheduled service interruptions, even when such a contact does not result in injury or electrocution.

The Pennsylvania Power and Light Company (PP&L) was contacted to discuss typical electric-utility procedures and policies regarding overhead-line accidents [18]. Line-contact prevention concern expressed by PP&L encompasses situations ranging from careless homeowners with ladders, antennas, and so forth to large industrial equipment. Efforts are primarily aimed at construction activities commonly including the use of cranes, which account for a large number of total overhead-line accidents. Utility overhead-line

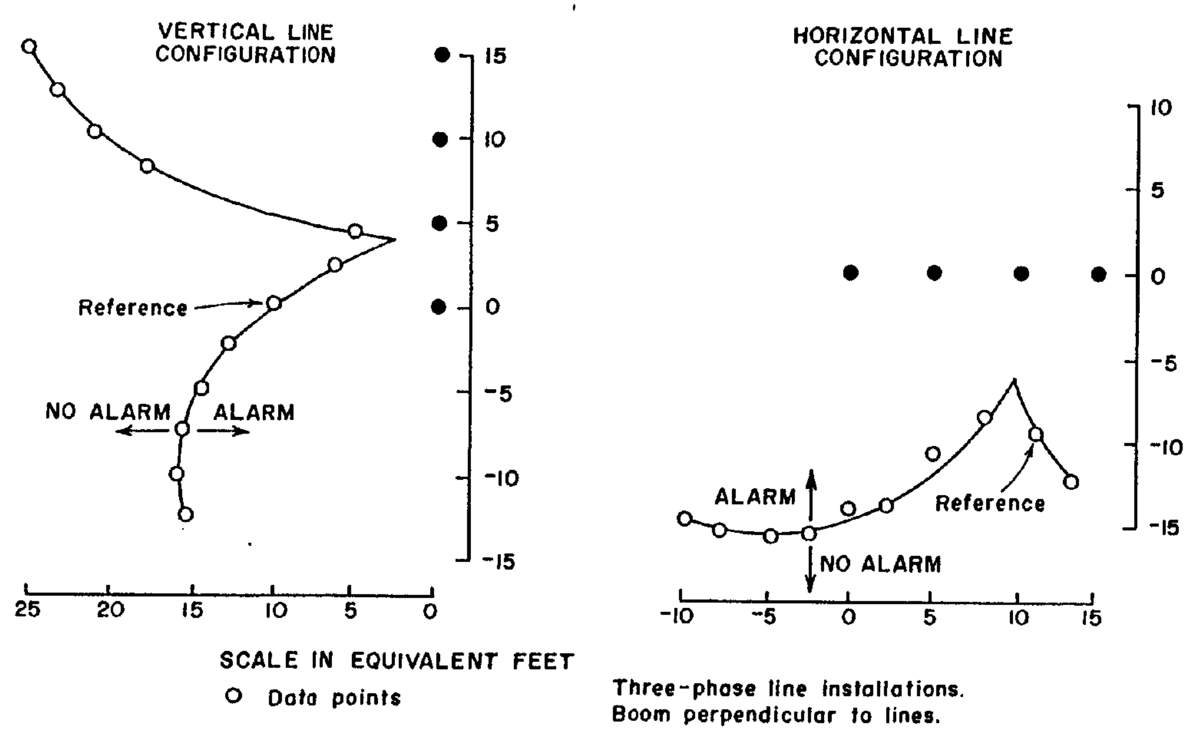

Figure 9. Alarm-zone boundaries around vertically and horizontally configured power lines.

safety philosophy centers on prevention of contacts through safe initial design of power-line installations and safe practices when working near overhead lines.

To promote safe operations near their overhead lines and facilities, PP&L sponsors a "Crane and Boom Safety Program." A kit called "Look Up to Live," containing overhead-line safety materials is forwarded to selected companies and individuals, and is available upon request [10]. This kit contains safety posters, a safety pamphlet outlining OSHA regulations, a sample warning sign to be placed on machinery, a mouth-to- mouth rescue breathing card, and a form to order additional materials. Also included with the packet is a transmittal letter, appropriate for its receiver, explaining the safety program. Different sample letters are available, aimed at municipalities, businesses, and organizations using high-reaching equipment, as well as union officials. This program also calls for the cooperation of utility employees in identifying and reporting potentially hazardous activities near overhead lines. It stresses adherence to OSHA regulations as well as work-force awareness and alertness for prevention of overhead-line accidents. With written permission of PP&L, Appendix A contains materials from the packet, as well as several sample transmittal letters. In addition to safety-program literature, provisions are made for direct interface between utility personnel and groups involved with work near overhead lines. An overhead-line crew is available to work directly with construction crews, contractors, etc., to ensure safe operation with respect to overhead lines [18].

An electric utility must also provide for safety of its own work force, obviously including prevention of overhead-line equipment contacts. The following are several examples of guidelines dealing with equipment-overhead-line safety taken from the Field Safety Rules of PP&L [19]. Wording is not exactly as found in rules.

1. 18.58. Vehicles with aerial baskets, ladders, or platforms shall not be moved when they are elevated.

2. 18.64. Metal lower booms of aerial baskets shall be kept at least six feet from energized equipment or lines. If not, the truck shall be grounded to the system neutral, the ground bus, a steel tower, or a driven rod, in that order of preference.

3. 18.65. Insulated telescopic booms must have a set minimum extension for safe operation, depending on line voltage.

4. 24.09. Vehicles, gin poles, cranes, etc., used in substation yards shall be operated by a qualified person under the direction of a qualified watchman.

5. 24.10. All mobile cranes and derricks shall be grounded when operated in close proximity to energized conductors and equipment.

6. 24.11. Vehicles will not enter energized areas where minimum safe distances cannot be maintained.

7. 32.01. Federal and state regulations for cranes and hoists shall be followed by all users of this type of equipment.

8. 32.02. Cranes and hoists shall be operated only by qualified persons.

9. 32.03. The controls of all cranes shall be distinctly marked as to their functions.

10. 32.04. Signals to crane operators shall be given by one person designated for the job.

It should be noted that the preceding safety rules are somewhat specific in nature, dealing with power-company operations. They are included, however, since they represent a utility-company's attempt to maintain safe operations near overhead lines and equipment. Also, several of the concepts can be applied to other areas.

Summary

The operation of high-reaching equipment near overhead power lines is a potentially dangerous situation frequently exposing individuals involved to shock hazards. Indirect worker contact of overhead lines as a specific accident category is a serious problem in the mining industry, resulting in over 48 fatalities over a 10-year period in the United States [1]. Methods to prevent these accidents have been developed and implemented to varying degrees, but have not adequately reduced their occurrence.

Federal legislation for the construction industry and mining industry contains guidelines for overhead-line safety with respect to equipment clearances and practices. Electric utilities, owners of many of the power lines in question, call for serious consideration of the line- contact problem by all involved parties, centering on compliance with regulations and increased work-force alertness. These two areas (federal legislation and power-company safety promotion) represent a substantial effort to reduce line-contact accidents. However, they both rely on the workers or supervisors involved to recognize potentially hazardous situations and take precautionary measures as required. Federal regulations would prevent all overhead-line indirect-contact fatalities if the guidelines therein were followed in all cases. Obviously though, the victims of such accidents either were not cognizant of the impending danger, or consciously exposed themselves to the shock hazard. In the first case, there exists a failure of the human element as a hazard indicator. The second situation may result from a misunderstanding of the hazard involved, ignorance of pertinent regulations, or a blatant disregard of safe work practices. Workmen can often lose sight of the connection between the law and safe practice, in the face of voluminous safety regulations.

Overall, regulations which center on work-force practices, including maintenance of minimum equipment-to-line distances, are relatively ineffective due to the activity-specific nature of many overhead-line hazard situations. In other words, the conditions which lead to overhead-line accidents often occur at random locations and are of short duration, and therefore can easily elude monitoring and regulation enforcement.

Efforts to increase worker and supervisory awareness of overhead-line hazards are an important aspect of any attempt to reduce related accidents. Programs which are effective in maintaining work- force alertness to overhead-line dangers may well increase the compliance with safety guidelines as found in federal laws. The use of other resources such as technical assistance and advice from power companies may also be productive. The mining industry, with a pre-existing safety-training structure, has substantial potential for worker education with respect to overhead-line shock hazards.

Various devices for use on construction cranes attempt to reduce the chance of electric shock after contact of an energized line. Boom cages and insulating links are such devices, the first shielding crane booms from direct line contact, and the second insulating hoisted loads from the crane frame and rope. Under proper conditions, both serve their purpose but, since they function after an overhead-line accident has occurred, they are best suited as a second line of defense against worker injury or electrocution. Such devices have the advantage of operating irrespective of worker hazard awareness, but in actual use they have major drawbacks relating to insulator performance. It is unlikely the insulators used in both cases will, under field conditions, remain clean enough to maintain safe insulation levels. In addition, insulating load links protect only individuals contacting the crane load.

The use of proximity-warning devices in theory overcomes the human element and after-the-fact drawbacks of safety regulations and insulation devices. These devices are designed to alert an equipment operator if some extension of the protected equipment moves into a dangerous area about energized overhead lines. Thus, an overhead-line contact can be avoided if the operator takes timely corrective action. The primary problem with the use of proximity-warning devices is the unreliable operation of currently available units. Although the devices in question can give accurate and reproducible results under controlled conditions, both inherent and device-related problems cause inconsistent operation in the field. The danger of this inconsistency goes beyond the failure of the device to give necessary warning, since operators may develop a false sense of security from its presence. Conversely, worker confidence in the unit will decrease with frequent unreliable operation, causing disregard for warnings or de-activation of the device. The foregoing look into currently available proximity-warning device characteristics and limitations shows that these units are applicable as one part of overhead-line-safety efforts. They are not, however, suitable for use as the sole protection against overhead-line contacts and, without the aforementioned recognition of their limitations, their presence may create an additional hazard.

When examining work-force safety, it is obvious that absolute safety cannot exist short of no activity whatsoever. It is evident though that methods employed to date have not reduced the hazard posed by overhead power-line contacts to an acceptable level. Operation guidelines, worker attitude, and protective equipment can be improved, but as long as bare overhead power conductors exist, they will be a hazard.

In addition to discussing hazards associated with overhead lines, this chapter has outlined the deficiencies of common techniques used for line-contact-accident prevention. The review of these deficiencies emphasizes the need for further examination of the problem, with subsequent identification or development of more effective accident-prevention methods. Chapter III will further delineate areas requiring attention for the reduction of line-contact hazards by examining in detail past overhead-line indirect-contact fatalities in the mining industry.

Chapter III

FATAL ACCIDENT ANALYSIS

General

Presented in this chapter is a detailed analysis of overhead-line indirect-contact fatalities in the mining industry. An examination of these accidents is essential to the development of procedures for prevention of such incidents. This analysis helps identify the conditions which create a hazardous situation, the circumstances surrounding the accident, and the factors which directly or indirectly led to the line contact and subsequent electrocution. This is done by describing individual circumstances, and more importantly, by noting trends and similarities among the accidents. Using this analysis as a base, the chapter concludes with general characteristics of overhead-line contact situations. The listing does not give solutions or recommendations but simply an outline of major factors leading to, or connected with, the accidents in question.

Accident Information

Reports of investigations of fatal electrical accidents supplied the information for this analysis [20]. These reports, covering both coal and metal/nonmetal mining, were obtained from the U.S. Department of Labor Mine Safety and Health Administration files. Investigations of fatalities, pursuant to federal regulations, fall under the authority of MSHA (or under MESA or the U.S. Bureau of Mines, depending on date of accident).

Reports of electrical fatalities resulting from indirect overhead-line contact were located using: an analysis of metal/nonmetal mining electrical fatalities [21]; a computer generated listing of coal fatalities of this type [22]; a listing of abstracts for metal/nonmetal electrical injuries for 1978-1980 [23]; and a number of personal interviews [24,25,26,27,28].

Accidents involving mobile equipment were the most prevalent type of indirect-line contacts, and were the primary target in the collection of accident-investigation reports. Information was also collected on similar incidents which did not include mobile equipment, using the criterion that the contact of high-voltage lines was by "indirect means." The accident reports obtained represent a nearly complete list of mobile-equipment indirect-contact fatalities in mining from 1970 to 1980. The equipment-related accidents covered in this analysis are listed in Table 7 according to type of mining, equipment involved, and date.

Accident Analysis

Each fatal-accident investigation report was examined and selected information extracted for comparison to other accidents. The information obtained from each report can be broken down into approximately 25 areas, a listing of which can be found in Table 8. As is apparent from Table 7, the accidents are readily grouped with respect to the equipment involved. This is due to the even distribution among equipment types, and also because of situation similarities within these groups. The fatalities are therefore

Table 7. Fatal accidents used in analysis.

Date	Equipment Involved
Coal Mining	
5-30-69	Truck
7-10-71	Truck
10-3-72	Truck
12-22-75	Truck
2-1-79	Truck
2-20-79	Truck
6-20-73	Mobile Drilling Rig
3-8-74	Mobile Drilling Rig
10-24-75	Mobile Drilling Rig
2-2-76	Mobile Drilling Rig
10-11-77	Mobile Drilling Rig
1-8-79	Mobile Drilling Rig
9-24-71	Mobile Crane
7-1-76	Mobile Crane
1-6-77	Mobile Crane (Double Fatal)
8-16-78	Mobile Crane
10-24-78	Mobile Crane
Metal/Nonmetal Mining	
1-26-73	Truck
1-9-75	Truck
5-14-75	Truck
4-25-78	Truck
6-29-78	Truck
2-21-79	Truck
5-21-70	Mobile Drilling Rig
8-26-70	Mobile Drilling Rig
10-3-70	Mobile Drilling Rig (Double Fatal)
12-17-70	Mobile Drilling Rig
6-7-78	Mobile Drilling Rig
4-24-70	Mobile Crane
7-23-70	Mobile Crane
1-4-73	Mobile Crane
7-9-77	Mobile Crane
12-15-78	Mobile Crane
11-20-79	Mobile Crane
7-12-80	Mobile Crane
6-10-74	Dragline (Crane?)

36 accidents - 38 fatalities

Table 8. Information areas for accident-report analysis.

(1) Equipment
- type
- height
- ground contact
- result of line contact (on equipment)

(2) Location/Activity
- specific accident location
- equipment activity or operation

(3) Overhead Line
- owner
- line purpose/use
- voltage
- height
- conductor arrangement
- overhead-line circuit protection
- result of contact (on line)

(4) Victim
- duty at accident scene
- age
- experience
- mining company or contractor employee
- safety training
- activity of victim (at time of accident)

(5) Accident Scene
- recognition of hazard by victim and/or others involved
- supervision
- hazard exposure of individuals other than victim(s)
- previous accidents of similar type or at same location

(6) Facility at which accident occurred
- type
- size

(7) Proximity-Warning Devices (primarily with respect to cranes)
- use in accident situations
- possibility of successful application

reviewed in four groups: trucks, mobile-drill rigs, mobile cranes, and non-equipment-related accidents. These groups are divided into sections dealing with the areas given in Table 8, and generally in the order as listed in that table. Additional points are included as necessary and several accident-scene sketches are included.

Fatal Accidents Involving Trucks

Equipment. Twelve indirect-line-contact fatalities examined involved trucks, all of which were highway-legal end-dump types. Half of the accidents occurred in coal operations, and five of these included tandem or triaxle end-dump trucks with the sixth being a tractor-pulled dump trailer. Conversely, five of the six in metal/nonmetal operations were tractor-trailer units. Tandems and triaxles had raised-bed heights of 19 ft 5 in. to 23 ft, but dump trailers were normally longer, giving them raised heights of 26 ft 6 in. to 29 ft 7 in.

In all truck-contact cases, tires were the primary means of equipment ground contact. The tires alone offered a high resistance, but current flowed by arcing in many cases, with reports of tracking along and through the carcass of the tire. This arcing along and through the tires created sufficient heat to start tire fires in most of the accidents. Fires due to the line contact caused the fatalities in at least two cases when personnel either exited the truck because of a fire or contacted the truck while checking for the source of the smoke. Although this factor was expressed only in two reports, it can be seen how a fire on a truck can divert attention from an overhead-line-contact situation, causing rushed and unsafe reactions.

Location/Activity. All but one truck accident occurred at the site of mining, processing, or loading operations. Eight took place in or about designated "dumping areas," which included actual dumping locations and roads in the immediate area. The balance of the incidents were on haulage roads or shop and plant areas, with one taking place at the delivery point for a load of crushed stone. Three of the dumping-area accidents involved "temporary" dump sites which differed from the usual locations for unloading. Figures 10 through 13 are sketches of several truck line-contact accident scenes [20].

Discharging a load and related activities (such as approach and exit of dump areas, spreading material, cleaning beds, and "shake-outs") were the most common operations in truck-related accidents, with only one maintenance-activity case (waxing truck). Table 9 is a breakdown of the dumping operations leading to contacts for 11 of the 12 fatal accidents. The twelfth accident was due to the bed being raised into an overhead line while truck was parked for waxing.

Overhead-Line Information. Accident descriptions indicate that the overhead lines contacted were usually owned by an electric utility and in most cases supplied power to the mining/material-handling facilities involved. Table 10 lists line ownership, voltage, and heights (at point of accident) as far as was available in reports. The completeness of accident data with respect to overhead-line circuit protection and results of contacts (to the power system) vary widely, but the following information is supplied for several cases.

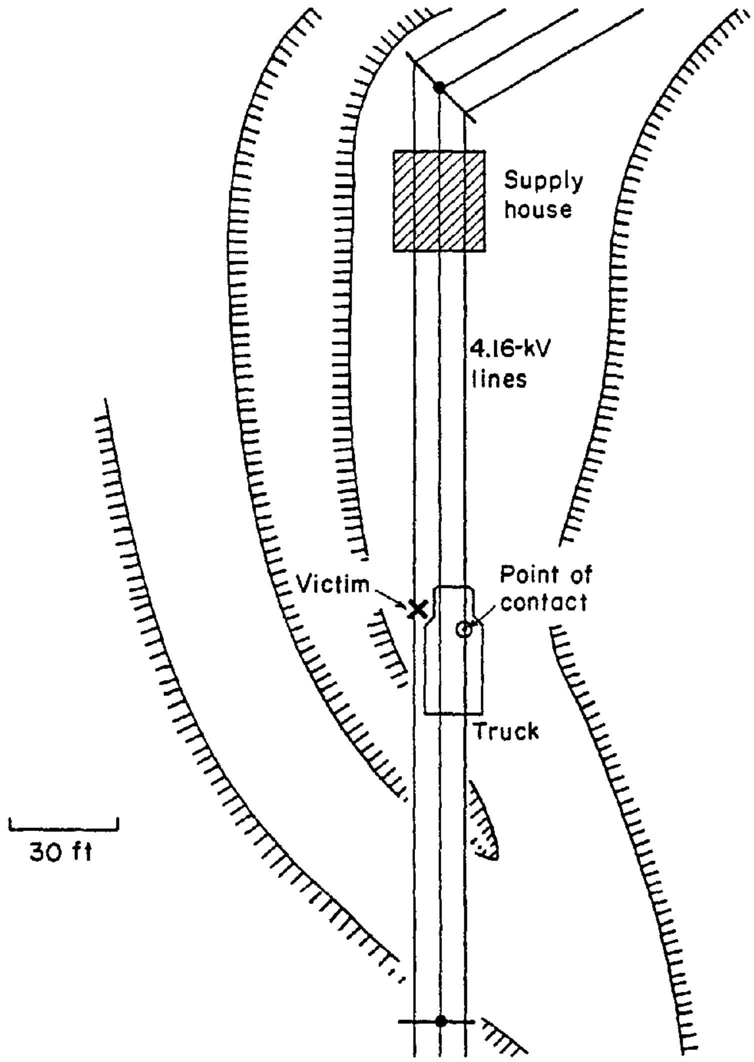

Figure 10. Accident scene involving a truck bed raised into lines while truck was parked for waxing near a coal company-shop area.

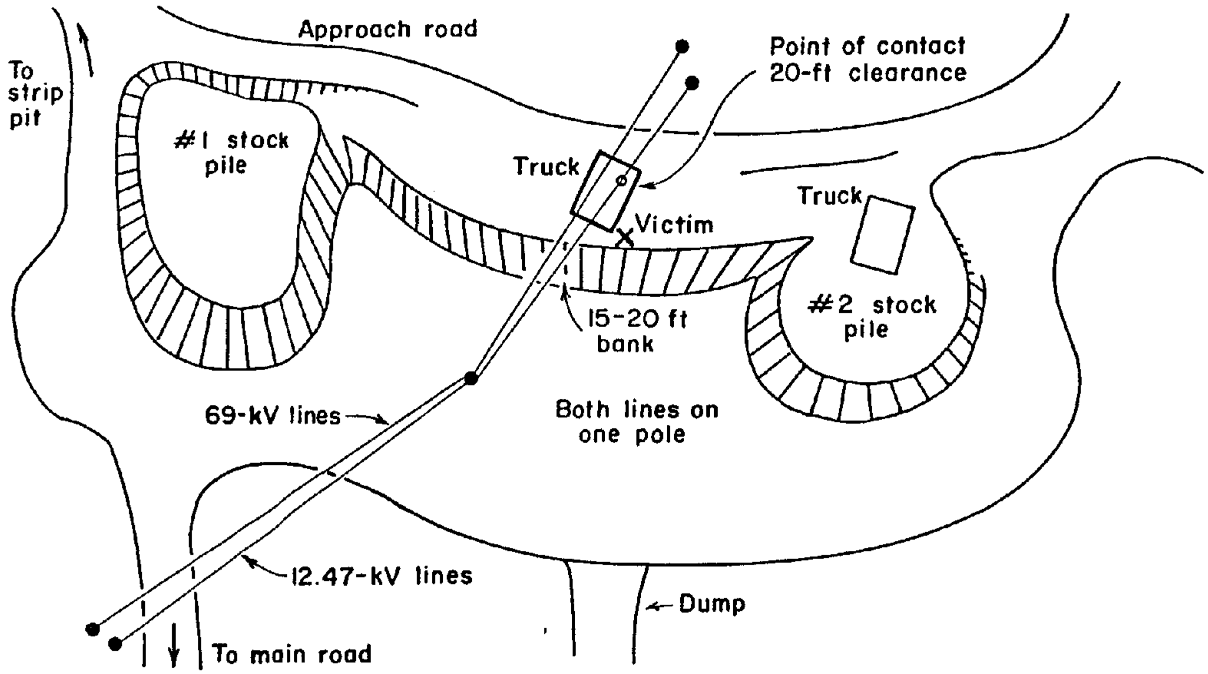

Figure 11. Accident scene where a truck bed was raised into lines while unloading at a coal stock-pile area.

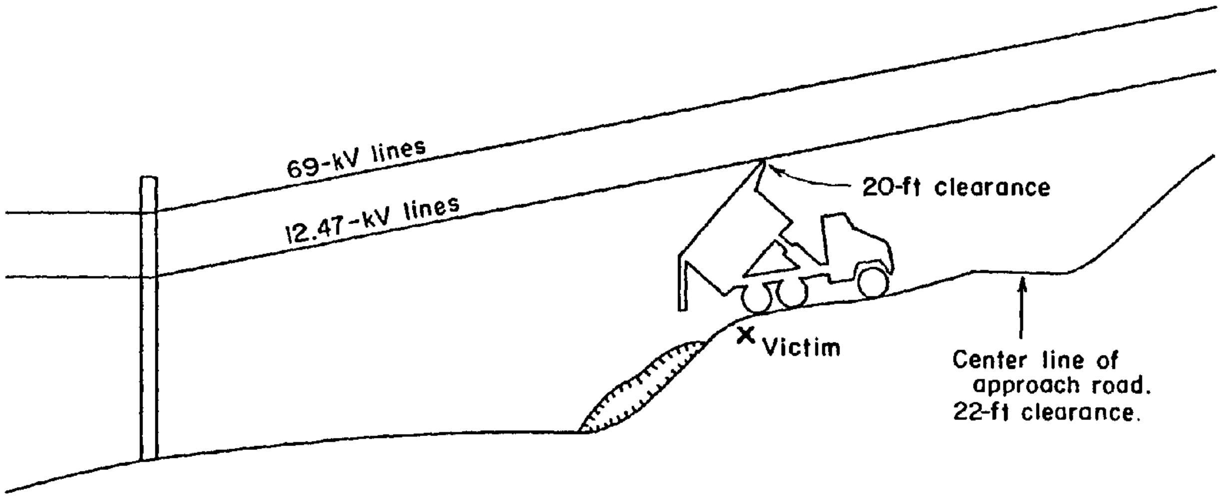

Figure 12. Side view of accident illustrated in Figure 11.

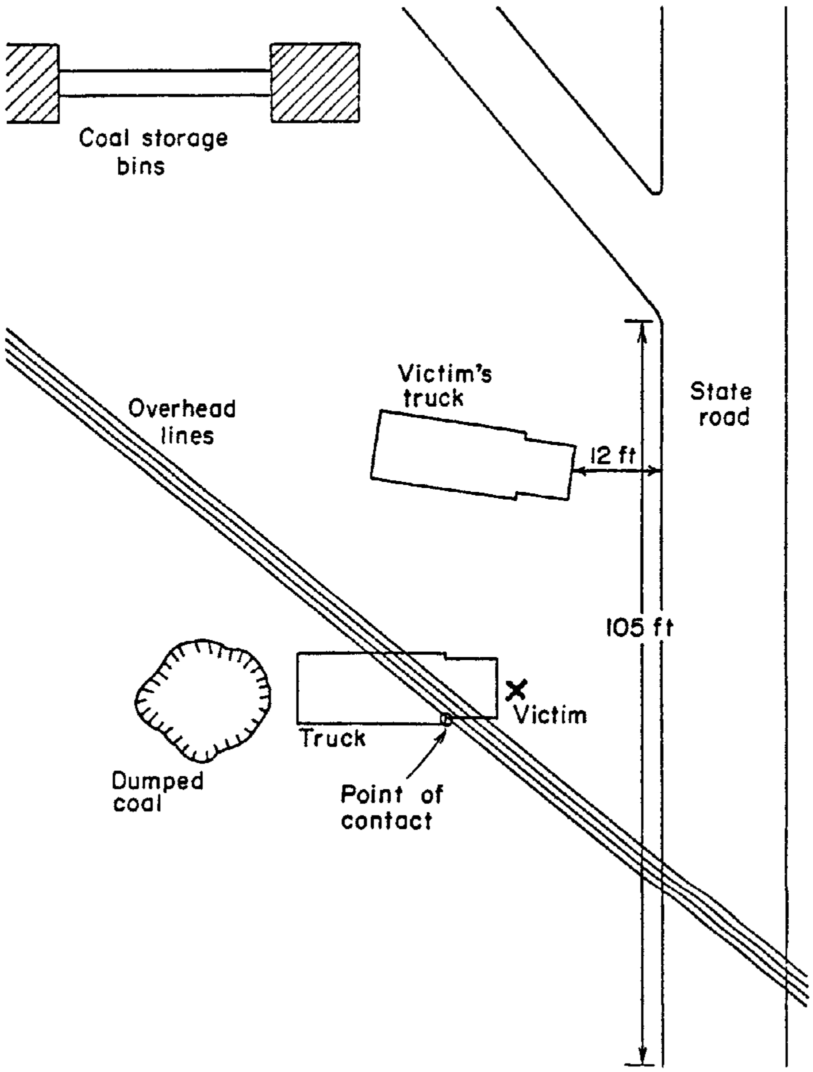

Figure 13. Accident scene showing a truck at a coal-tipple area which pulled into lines with the bed in the raised position. Victim was investigating smoke from beneath truck.

Table 9. Activities of trucks involved in overhead-line contact fatalities while dumping.

Description	Number of Accidents
Pulling away from dump site with bed raised, driving into overhead lines	3
Dumping load at dump site, raising bed into overhead lines	2
Driving into lines with truck bed down at a stockpile area	1
Driving into overhead lines while spreading reddog on a haulroad	1
Dumping stone in a plant parking lot, raising bed into overhead lines	1
Raising bed into lines while "shaking-out" bed	1
Cleaning residual material from the bed at a preselected location when wind swung lines into raised bed	1
"Gate spreading" gravel at a delivery point, drove into overhead line	1

Table 10. Overhead-line data for truck fatalities.

Line Owner	Voltage (Line to Line for Three Phase)	Height Above Ground
Coal		
n.g.*	4160-V three phase	20 ft 3 in.
Utility	12000-V three phase	<11 ft 3 in.
Utility	12470-V three phase	20 ft
A Neighboring Mining Co.	13200-V three phase	<19 ft 5 in.
Utility	12400-V three phase	27 ft 4 in. (neutral 22 ft 6 in.)
Utility	12470-V three phase	21 ft 1 in. (neutral 18 ft 0 in.)
Metal/Nonmetal		
Utility	7000-V n.g.	25 ft 6 in.
n.g.	13200-V three phase	22 ft 8 in.
n.g.	7200-V three phase	24 ft
Utility	4160-V three phase	28 ft 6 in.
Utility	7200-V n.g.	20 ft
Utility	7200-V three phase	20 ft

* n.g. indicates that data was not given in the accident report.

Three systems had breakers for overload and/or short-circuit protection but did not mention specific ground-fault protection. The first, fed from a wye secondary, had breakers set to interrupt at 400 A, which did not trip for the accident. Another was equipped with a reclosing oil circuit breaker which reclosed repeatedly, eventually locking out. The third system which was supplied from a solidly- grounded wye source had a time-rated fuse on each phase conductor and an automatic recloser set to operate at 200 A. Power was evidently not interrupted since the fuse was intact and no service outages were reported that would indicate recloser operation.

Two systems had exclusive provisions for ground-fault protection. The first had overload protection and residual ground-fault relaying both set to interrupt at 400 A. The residual relaying on this solidly-grounded wye system, however, was wired incorrectly. There was no tripping due to the accident, and the contacted conductor was burned in two. The second system was fed from a solidly-grounded wye secondary and was equipped with overload protection and some type of ground-fault protection set at 240 A. This system operated an oil circuit breaker which did not open for the accident in question.

The remaining accident reports give little or no detailed information on the power systems involved. One only notes a solidly-grounded power source, and several others mention arcing at equipment overhead-line contact points.

Conductor arrangement in the overhead-line installations as described in five reports was commonly a three-phase four-wire configuration with the phase conductors in a horizontal plane and the neutral directly below them.

Victim Information. A large diversity exists among victim characteristics for truck overhead-line contact accidents. Table 11 lists ages and work experience of truck line-contact victims, but the amount and types of work experience are not clear cut or exact due to incomplete information in reports.

Eleven victims were drivers of the trucks involved in the accidents, with the remaining victim being the driver of a nearby truck. Seven of these victims were fatally injured as they stepped from their trucks after contact with an overhead line, while five were outside of and contacting the truck when line contact occurred.

Four situations entailed the driver exiting the truck unaware of the overhead-line contact. However, it is difficult to determine if at any time prior to the accident they were aware of the hazard present. One driver exited the truck due to tire fires mistakenly attributed to hot brakes (actually due to current flow).

Two other cases appear to have resulted from drivers exiting cab while unaware of overhead-line contact, but the accidents were not witnessed.

The remaining six accidents had varying victim activities. One driver was electrocuted while exiting cab to check overhead-line clearance. Another was walking around the truck while the bed was raising and was in contact when the frame was energized. A driver was electrocuted while he operated

Table 11. Victim data for truck fatalities.

Age	Work Experience
43	- 20 years as a truck driver - 8 years with the company* - victim was familiar with site of accident
63	- at least 26 years as a truck driver - 26 years with the company - victim was familiar with site of accident
18	- two years as a truck driver - victim had two days experience at facility where accident occurred.
51	- at least six years in coal mining - eight months as a general laborer for company - assigned as a truck driver at time of accident - victim was a master electrician but was not certified by federal or state agencies
23	- six years as a truck driver - victim had hauled to the facility where accident occurred for approximately 2-1/2 wks
25	- five years as a truck driver
34	- 10 years as a truck driver - three years with the company - first trip to location of accident
35	- at least seven years as a truck driver - seven years with the company
46	- 14 years as a truck driver
21	- report description seems to indicate that victim had been at accident location before
22	- one year experience in mining
34	- 7-1/2 years as a truck driver - six months for the company

* Any use of "the company" refers to the company employing the victim at time of accident.

dump controls from alongside a dump trailer and contacted a line when "shaking-out" the bed. A mechanic was directing dumping operations in this particular case and shouted several warnings to the victim immediately before the accident. A driver was operating a gate latch on a dump trailer when a wind gust blew lines adjacent to the bed into contact with it. The truck was parked parallel and very close to the lines. Another driver was raising a truck bed from a position alongside the truck while watching bed clearance, but was electrocuted when the bed contacted a line not visible from his position. The final fatality resulted from a driver leaning over to check smoke from below a truck's engine (not his truck) and bracing himself on the bumper. The truck was in contact with an overhead line at the time, which actually caused the smoke due to a dangling light wire below the cab.

Overall, two drivers obviously recognized the overhead-line hazard present, and at least four to five others should have been aware of the potential danger due to their familiarity with the dump locations.

Seven drivers were employed directly by the mining company involved, while the remaining five provided contracted services. The safety training of the drivers is mentioned in four reports; in these cases they had received none.

Accident-Scene Information. Only one of the truck accidents had direct supervision or direction for dumping operations. Often, numerous individuals were in the vicinity of the accidents but failed to recognize the immediate danger. Five of the fatality reports clearly state that the respective accident locations were generally known to be hazardous due to overhead lines. These five cases follow.

1. A truck bed was raised into lines while waxing the truck in a location often used for this purpose (waxing).

2. The clearance of overhead lines above a coal stockpile varied according to the stockpile level. At the time of the accident, the lines were close enough to ground level to be contacted by an unraised truck bed (11 ft 3 in.). Workers at the stockpile had brought this condition to the attention of the victim immediately before the accident.

3. Lines in one case had been torn down by mobile equipment about one year prior to the fatal accident. At that time a meeting was held between the mining and power company involved, but no action was taken to alleviate the hazard.

4. In a stockpile area where a fatality occurred, the supervisor reported two earlier line contacts, but no injuries were involved.

5. At the scene of another fatal accident, the neutral conductor of the installation had been hit and damaged twice previously.

Other fatal accident reports elude to known dangeroussituations but give no details. In several cases, the overhead-line contacts also endangered individuals attempting to rescue or aid the victims. Four reports state that one or more workers were shocked while engaged in rescue or fire-fighting efforts. Two individuals felt current flow through their legs and lower body due to step potentials. One rescuer was seriously burned, requiring hospitalization.

Facility Information. Table 12 contains information on the type and size of the facility associated with each truck fatality. Again, data is somewhat incomplete in several cases. Coal-company sizes are expressed in relation to tons per day, and metal/nonmetal operations according to number of employees.

Fatal Accidents Involving Mobile-Drill Rigs

Equipment. Twelve indirect line-contact fatalities involving mobile drills were examined, six of which occurred in metal/nonmetal mining operations with the remainder in coal applications. All drilling rigs were pneumatic or hydraulic drilling units with masts capable of being carried in a horizontal position, then raised to vertical for drilling. All were mounted on rubber-tired trucks allowing travel over public highways. Rigs of this type usually have jacks for stabilization and leveling while drilling,

Table 12. Facility types and sizes associated with truck fatalities.

Type of Facility	Size
Coal-company trucking service	n.g.
Coke plant	n.g.
Railroad tipple for a strip operation (coal)	2000 tons/day
Coal mine and preparation plant	100 tons/day
River barge loading dock	n.g.
A coal-company tipple	2000 tons/day
Sand-and-gravel plant	200 employees
Lightweight-aggregate processing plant	31 employees
Kaolin/sand mine and mill operation	136 employees
Sand-and-gravel pit and plant	9 employees
Sand-and-gravel pit and plant	8 employees
Sand-and-gravel operation	10 employees

but most accident reports are unclear as to whether ground contact was through tires, jacks, or a combination of both. Regardless, tires were obviously in ground contact in several cases, with six cases reporting tire fires as a result of line contacts. Another report mentions evidence of tracking across rig tires.

The drill rigs associated with the fatalities in coal ranged in vertical-position height from 35 ft 5 in. to 43 ft. The heights in the metal/nonmetal cases were comparable, with mast lengths of 25 ft to 31 ft reported.

Location/Activity. Contacts in the metal/nonmetal accidents all resulted from rig masts being raised into overhead lines. Coal fatalities include three cases where masts were raised into lines, one where the mast was lowered into contact, and two cases of driving into lines with the mast raised. Each situation is slightly different, descriptions are brief, and each accident is therefore described in Table 13. Figures 14 through 18 are sketches of several drill-rig accident scenes [20].

Overhead-Line Information. Table 14 contains data for the overhead lines contacted by drill rigs in the 11 accidents in question. Missing entries are due to incomplete information in accident reports. Five of the drill-rig accident reports describe protection circuitry on the contacted overhead lines as follows.

1. A single-phase line servicing private residences was protected by a 25-A fuse which opened upon line-mast contact.

2. Another line installation, supplied from a solidly-grounded wye, was protected by a reclosing circuit breaker set to reclose two times before locking out. Ground-fault protection was provided by a directional overcurrent-relaying system. Timed settings were 30 cycles at 1.5 A for ground faults, and 50 cycles at 4 A for phase over-current. Instantaneous settings were 14 A and 8 A for phase and ground protection, respectively. Time to first reclose was 10 s, and time to final reclose 40 s. The system tripped and locked out as a result of the accident.

3. The 161-kV line listed in Table 14 was fed from two generating stations through a solidly-grounded wye system, and protected by zone-phase relaying and directional ground-overcurrent-relaying with instantaneous protection. The phase-to-ground currents at the two stations created by the accident were 600 A and 1560 A. For the accident location (zone), both phase relays operated, in one and 25 cycles for their respective fault currents. The recloser on this circuit was set to close three times, in 5, 30, and 60 s, successively. Relaying operated properly to isolate the fault, locking out after the third reclose. The phase conductor burned in two at the contact location.

(4) One single-phase system contacted was derived from a solidly-grounded wye and protected by an automatic recloser set to reclose twice before locking out. Minimum trip current was 280 A, but the system did not operate when the line was contacted.

Table 13. Drill-rig activities and locations associated with accidents.

Location	Activity
COAL	
Exploratory-hole site on a farm	Setting up for hole, raised mast into lines
Exploratory-hole site on a tree farm	Setting up for hole, raised mast into lines
Access road to a surface coal mine	Raising mast to replace drill steel in rack, raised into lines
Surface-mine drill bench	Lowering mast on bench, lowered into lines
Surface-mine drill benches	Moving drill from one bench to a lower bench, drove into lines with mast up
Surface-mine drill bench	Backing drill into position for the first hole of a new row, backed into line with mast raised
METAL/NONMETAL	
Exploratory-hole site on private land	Setting up for hole, raised mast into lines
Near fueling area of a quarry	Making a set up in order to tie down the stabilizing bushing, raised mast into lines
Near a fueling area (not a hole site)	Raising mast to remove a drill steel, raised into lines
Area where equipment was to be parked during an idle period	Raising mast in order to remove "mud pan," raised into lines
On a roadway from pit to an equipment parking area	Raising mast for some reason, raised into lines (double fatality, operator and rescuer)

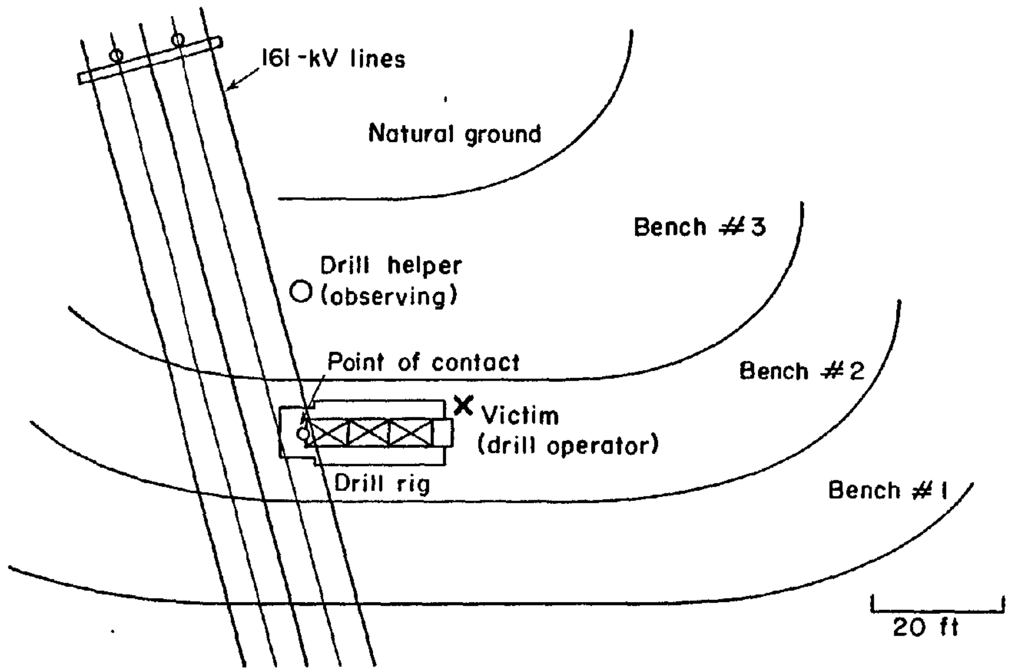

Figure 14. Accident scene where a drill-rig mast was lowered into a line while drilling blast holes at a surface coal mine.

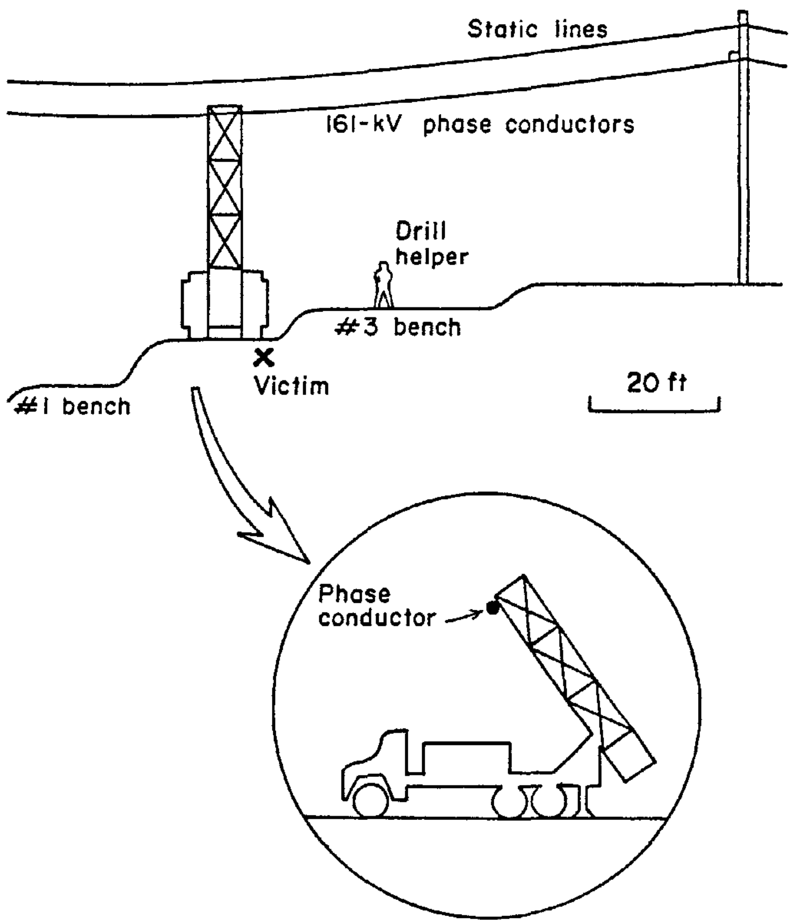

Figure 15. Side view of accident illustrated in Figure 14.

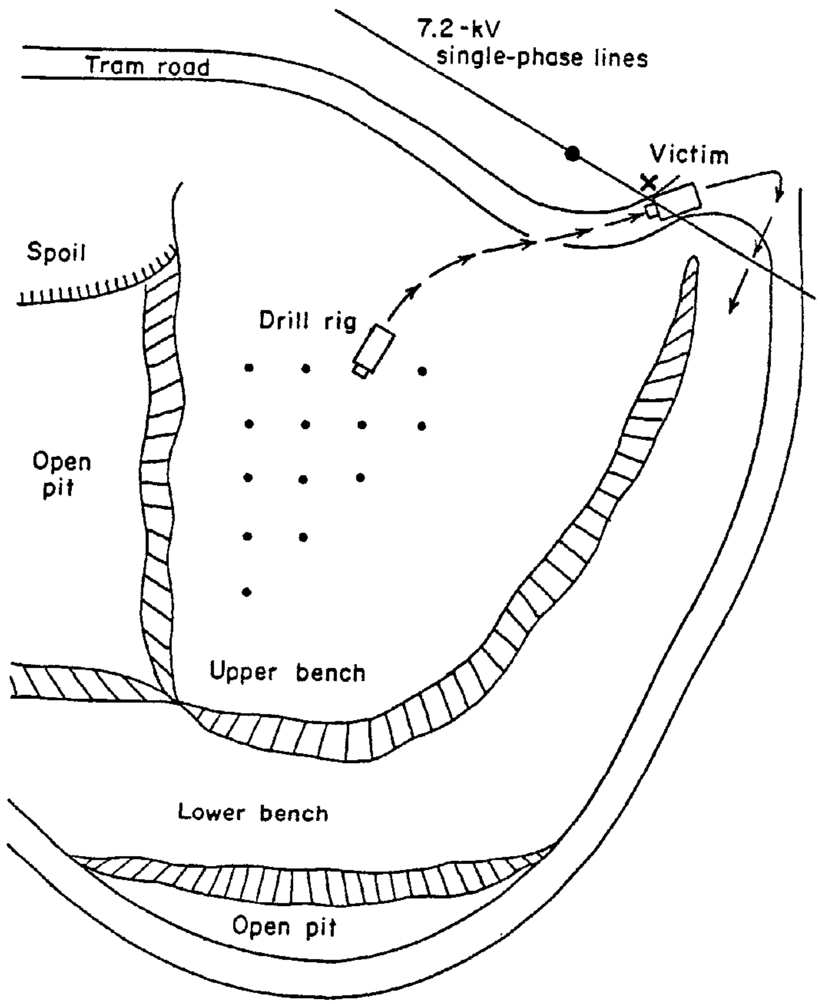

Figure 16. Accident scene involving a drill rig at a surface coal mine which contacted overhead lines while being moved with the mast in the raised position.

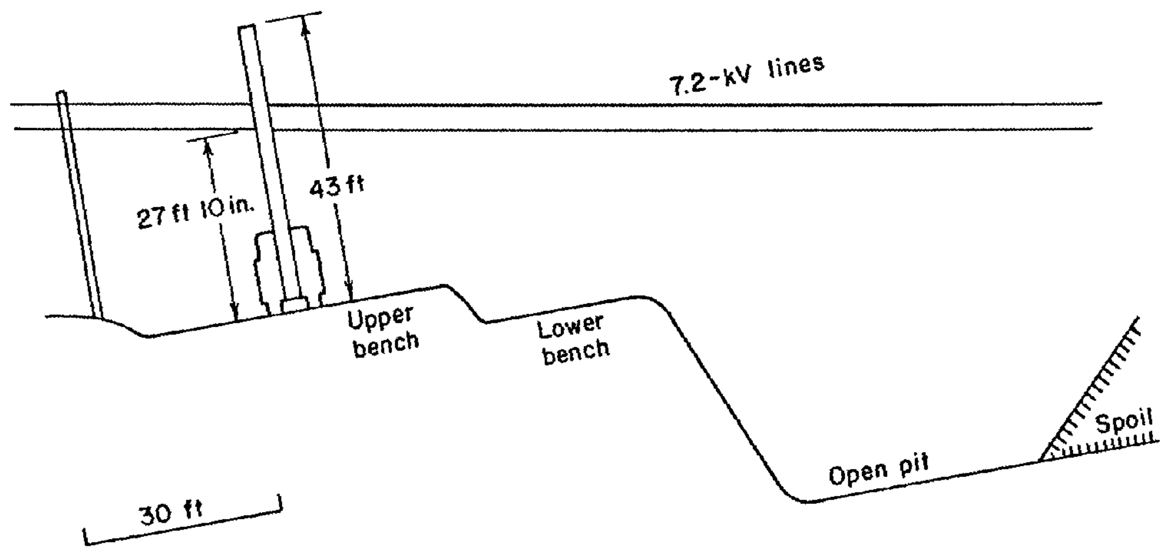

Figure 17. Side view of accident illustrated in Figure 16.

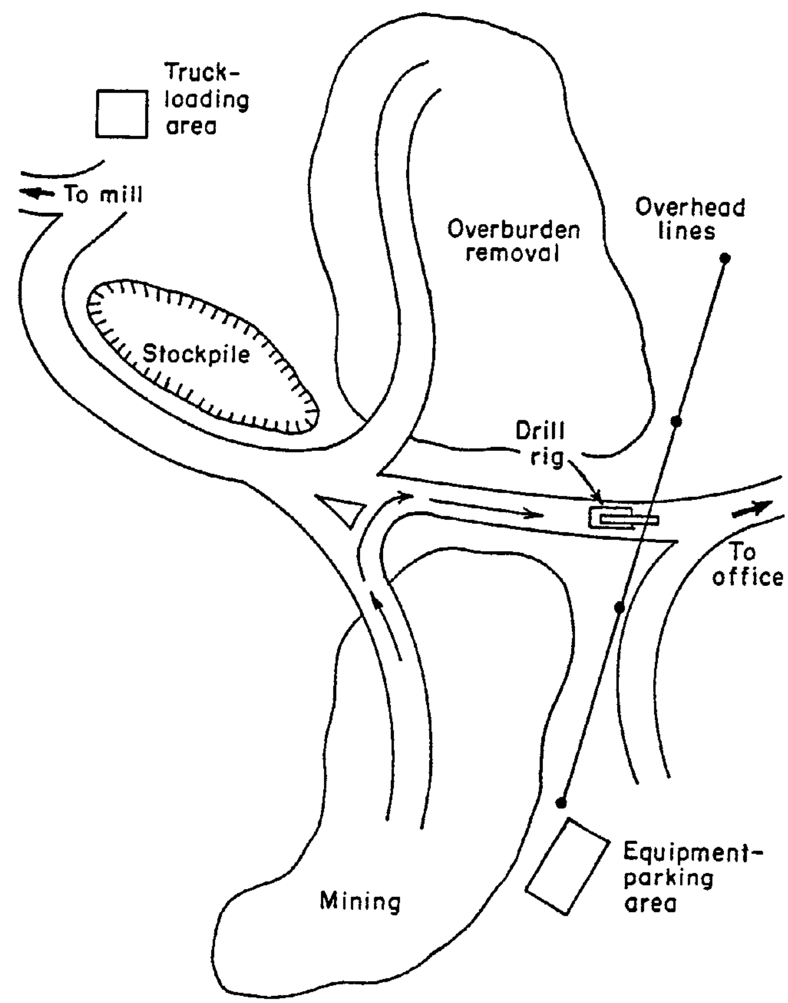

Figure 18. Accident scene involving a drill rig at an open-pit uranium mine which was driven into lines with the mast in the raised position.

Table 14. Voltage, height, and ownership of overhead lines contacted by drill rigs.

Ownership	Voltage (Line to Line for Three Phase)	Height Above Ground
Coal		
Utility	7200-V single phase	21 ft 7 in. (neutral 18 ft 4 in.)
Utility	7200-V single phase	25 ft 6 in.
Utility	23000-V single phase	37 ft
Utility	161000-V three phase	31 ft 5 in.
Utility	7200-V single phase	29 ft 10 in.
Utility	34500-V three phase	33 ft 10 in.
Metal/Nonmetal		
Utility	12000-V three phase	22 ft
Utility	13000-V n.g.	24 ft
n.g.	-V n.g.	n.g.
Utility	7620-V n.g.	20 ft

(5) A three-wire three-phase system contacted was fed by a delta secondary and protected by a circuit breaker set at 1140 A instantaneous and a recloser set at 300 A. Protection tripped and locked out the circuit due to drill-line contact, although the phase conductor burned in two.

The remainder of the accident reports gave little detail on line-protection systems, except for two additional cases where the contacted conductor was severed or burned in two.

Victim Information. The ages and work experience of the victims associated with the drill-rig accidents varies, but overall they tended to be younger and more inexperienced than was observed among the truck drivers described earlier. Table 15 outlines this information but, as before, it is only as complete as the accident reports.

The activities of the victims at the time of the respective accidents can be roughly concluded from information in Table 13, but the following details can be added. Eight of the victims were operating the controls of a drill when line contact was made; two of these were drill helpers. A laborer was electrocuted while he stood with his hand on the rig as the mast was raised into a line. An operator was killed as he walked alongside and in contact with his rig while the drill helper drove into an overhead line with the mast up. Another operator was electrocuted as he stepped from the cab of his rig after backing the upright mast into a line. A superintendent was killed as he attempted to rescue a drill foreman who had driven a raised mast into an overhead line.

As previously stated, it is difficult to determine if a victim recognized the potential and immediate danger present in an accident situation. It appears from the accident descriptions that the individuals drilling exploration holes and those who raised masts to make repairs or adjustments (at random locations) were not aware of the impending contact. In general, those drilling blast holes were cognizant of the overhead lines in their work areas. One operator was lowering his mast near overhead lines under the direction of the drill helper but, through some error or misjudgment, contacted the lines. Another operator and his helper discussed the hazard while eating lunch overlooking the drill site, just prior to the fatal accident. Another operator had drilled near the overhead lines for seven months prior to his fatal accident. Five of the twelve victims were employed by contractors working for the various mining companies. Safety training is mentioned for only one victim, this being first-aid instruction.

Accident-Scene Information. Supervision at the accident scene is indicated in two cases. In the first, a supervisor warned the drillers about the overhead-line hazard and then left just before the rig was backed into the lines. Another case involved an engineer observing as the drill mast was raised into the lines.

The danger to other workers and rescuers is well illustrated in a double fatality where a superintendent was killed attempting to aid a drill operator who had been shocked through indirect overhead-line contact. Three other workers sustained electric shocks and burns while attempting to help accident victims.

Table 15. Ages and work experience of drill-rig fatal-accident victims.

Age	Work Experience
18	- three months as a drill operator - worked several summers as a drill helper
21	- two years total in mining - 18 months as a drill helper - six months as a drill operator
18	- four months in mining as a laborer
19	- three months in mining as a drill operator
25	- one year in mining - seven months as a drill operator
23	- eight weeks in mining as a drill operator
34	- 4-1/2 years as a driller and blaster
47	- 1-1/2 years in mining as a drill operator
26	- one year experience as a (drill foreman?)
47	- mine superintendent at time of accident - 26 years experience (in mining?)
33	- one year experience as a drill helper
23	- n.g.

Facility Information. Table 16 lists available information on the size and type of facility associated with drill-rig line-contact accidents.

Fatal Accidents Involving Mobile Cranes

Equipment. Several different types of mobile cranes were involved in overhead-line accidents while performing various operations. Table 17 groups the 12 cranes in question according to type and also gives their boom length and application. Ground contact of cranes was by both rubber tires and crawlers, although mobile cranes often have manually or hydraulically-set stabilizers which offer some additional contact.

Four reports state that hoisting cables were burned at line-contact points, and one reports arcing from an outrigger to ground. Another report mentions tire fires as a result of the line contact.

Location/Activity. Nine of the crane accidents took place at construction sites. Of these, three were at coal-preparation facilities, four were at processing areas for quarry stone or sand-and-gravel, and two were at pipeline-installation sites. The three non-construction locations included two sludge-pond areas and a sand-and-gravel pit.

Activities tended to be similar within the location groupings given above. The four cranes in stone or sand-and-gravel processing areas were hoisting prefabricated components of processing equipment into place. Stone washing-and-sizing plants often have modular construction to facilitate relocation. Three of these four were moving conveyor sections. The three coal preparation-plant accidents occurred while hoisting sheet steel to upper floors of a plant, unloading concrete forms, and preparing to erect a belt frame. One pipeline-construction accident took place while moving pipe from a stockpile to a ditch, and another while loading excess pipe onto a lowboy trailer. The sludge-pond fatalities were a result of the hoist cable contacting an overhead line when the operator swung the boom to remove weight from an outrigger. The final incident involved a boom-line contact while the crawler mounted unit was in transit on a pit-access road. Figures 19 and 20 show two crane-contact situations [20].

Overhead-Line Information. Table 18 gives basic information for the overhead lines contacted by mobile cranes, including owner, voltage, and clearance.

The power systems involved and their protective circuitry are discussed, in varying detail, in five of the accident reports. Two of the systems, which had 7200-V single-phase service derived from solidly-grounded wyes, had ground-fault protection provided by reclosers set at 400 A. One did not trip for the line contact, but the other tripped three times then locked out. Another system having its source at a solidly-grounded wye did not trip when the accident occurred. Yet, when the phase wire which was contacted burned through, it dropped on a messenger wire tied to the system neutral which tripped instantaneous ground-fault protection. One coal company owned three-phase distribution system had a solidly-grounded-wye source and phase-overcurrent protection set to operate at 240 A. An overhead line owned by a sand-and-gravel plant ran 1.1 miles from the plant to where it joined utility lines, but the nearest disconnect was 6.5 miles away. Another case involved

Table 16. Facility type and size for drill-rig fatalities.

Type of Facility	Size
Exploration work on a farm (no active mine)	n.g.
Strip-mining operation (coal)(several pits)	800 tons/day
Exploration work for a coal company	250 tons/day
Strip-mining operation (coal)	400 tons/day
Strip-mining operation (coal)	300 tons/day
Coal-and-clay surface-mining operations (strip)	50 tons/day
Limestone quarry and mill	39 employees
Limestone quarry and mill	n.g.
Open-pit clay mine and brick plant	20 employees
Open-pit uranium mine	7 employees
Open-pit bauxite-and-clay operation	48 employees

Table 17. Crane information.

Crane Type	Total Number	Boom Length	Application
Open-truss cable-supported boom on a rubber-tired truck	4	- 31 ft 6 in boom	- construction
		- 51 ft boom	- used as a drag-line at a sludge pond
		- 71 ft boom	- used with a clamshell bucket at a sludge pond
		- 70 ft main boom & 15 ft jib boom	- construction
Cable-supported boom on a crawler-mounted frame	3	- 30 ft boom	- construction
		- 65 ft boom	- construction
		- n.g.	- used as a drag-line
Hydraulically-operated boom on a rubber-tired truck	2	- n.g.	- construction
		- >50 ft boom	- construction
Hydraulically-operated four-wheel mobile crane	2	- n.g.	- construction
		- n.g.	- construction
(Remaining crane was not described)			

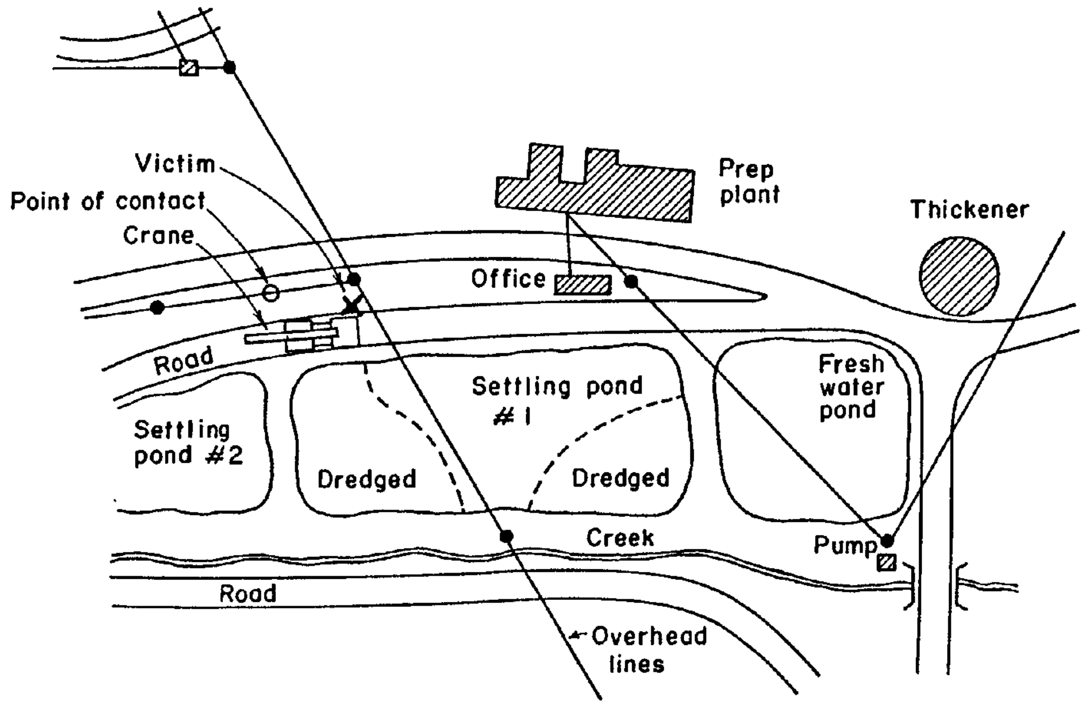

Figure 19. Accident scene showing a crane which had the hoist rope swung into a line while dredging a coal preparation-plant sludge pond.

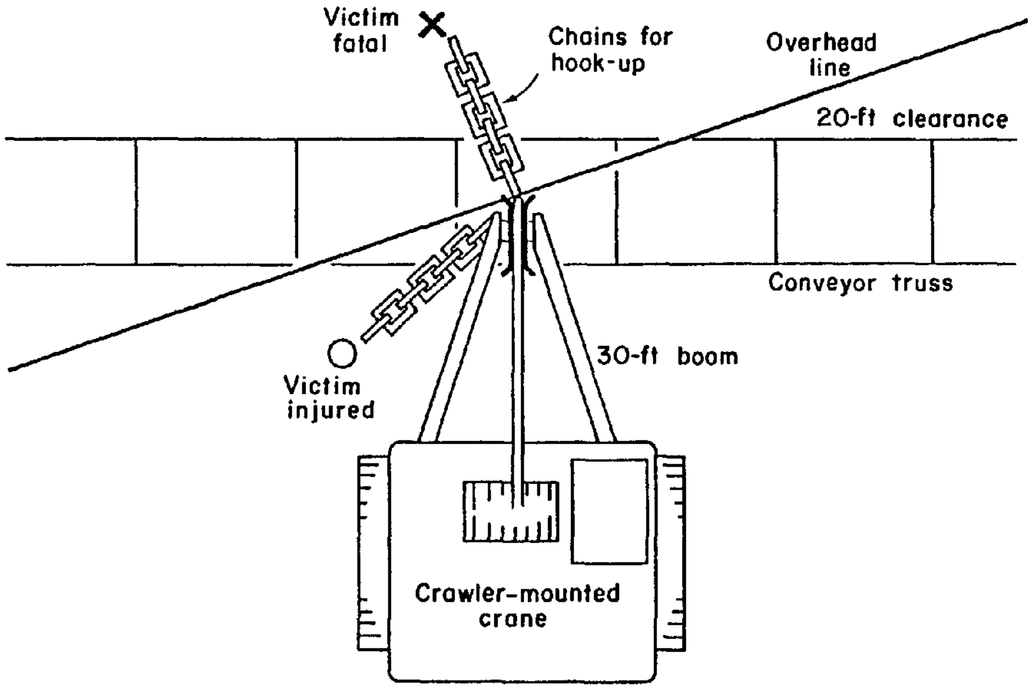

Figure 20. Accident scene where a crane hoist rope contacted a line while erecting a portable plant at crushed-stone quarry.

Table 18. Overhead-line data for mobile-crane fatalities.

Line Owner	Voltage (Line to Line for Three Phase)	Height Above Ground
Coal		
Utility	7200-V single phase	25 ft 0 in.
Coal Company	12470-V three phase	30 ft 0 in.
Utility	12470-V three phase	28 ft 8 in.
Utility	7200-V single phase	n.g.
Utility	7200-V single phase	n.g.
Metal/Nonmetal		
n.g.	7000-V n.g.	20 ft 0 in.
n.g.	7200-V three phase	n.g.
Utility	24900-V three phase	26 ft 5 in.
Sand-and-Gravel Pit	22520-V three phase	37 ft 3 in.
n.g.	33000-V three phase	n.g.
Utility	12000-V n.g.	30 ft 0 in.
n.g.	12500-V n.g.	n.g.

the contact of a line with fused disconnects only two poles away from the accident. A phase fuse opened upon contact. Other accident reports make occasional mention of arcing and line burns at points of equipment contact.

Victim Information. Ages and experience range widely among the victims of crane-line contacts. Characteristics of crane-contact accident victims do not have the same significance as those of truck and drill accidents since crane victims were usually not the operators involved, as in truck and drill cases. Table 19 lists the ages and work experience of the various victims and also their job or duty at the accident scene.

Some of the victims' activities at the time of accident can be seen in Table 19, but all situations involved can be divided into the five areas that follow.

1. In five cases, victims were guiding hoisted loads when the boom or cable of the crane contacted an overhead line, thereby energizing the load.

2. Three fatals resulted from two accidents in which the victims contacted the crane frame after the line contact. One victim touched the frame as he walked along side of the crane, unaware that he had driven the unit into an overhead line. Two others were hurridly dismounting crane truck after the line contact and apparently touched the truck and ground simultaneously.

3. Two fatals involved workers in contact with crane outriggers as the operators swung the hoisting ropes into overhead lines. Booms were swung to remove weight from the outriggers.

4. Two victims were pulling or guiding hoist rigging toward a load when contact occurred. In one case, the hoist rope was pulled into the overhead line by the victim, while the other hoist rope made contact due to crane motion.

5. Another fatal took place as a crane was trammed with a tow-assist out of a pit. At one point, the boom swung free, contacting a nearby overhead line. The victim, upon seeing the impending contact, began to run away and apparently touched the tow rope just as the boom made line contact.

Three of the crane accidents involved contractors and another included contracted and mining-company personnel. Safety training is mentioned in one report. The victim of the towed-crane accident had received 2-1/2 hours of refresher safety training within the last year, including a film entitled "Fires and Wires."

Accident-Scene Information. Whether the victim, or more importantly the crane operator, were aware of the overhead-line hazard in each case cannot always be determined from report information. In seven of the accidents, it appears as though neither the workers involved nor the crew collectively recognized the dangerous situation. In the five cases which follow, one or more of the individuals involved were aware of the overhead-line-hazard potential.

Table 19. Victim data for crane fatalities.

Age	Work Experience	Duty/Job at Accident
39	- seven yrs for the company as a mechanic, welder, and crane operator	- crane operator
34	- five years as a utility man around the prep plant - accident was first time he had worked as a hookman around a crane	- hookman
19	- one month in mining	- laborer
25	- three months on this construction job	- crane operator
30	- six years in mining - three years as a dozer operator	- assisting with out-riggers on a crane
54	- 28 years in mining - two years as a truck driver - worked occasionally as a helper around crane operations	- assisting with out-riggers on a crane
58	- 25 years in mining and construction - three years as a foreman	- foreman on job at time of accident
40	- two years as a laborer in sand-and-gravel mining	- laborer, helping guide a load
20	- six weeks experience with the company as a laborer	- laborer, helping guide a load
44	- self employed welding and construction contractor	- directing operations steadying load
50	- two years with the mining company	- helping with a crane move
23	- several summers as a laborer	- laborer, helping position load
50	- 22 years in mining - four years as a mechanic with the company	- mechanic, helping guide a conveyor section into place

1. When a hookman pulled a hoist rope into line contact, the operator knew the overhead lines were present.

2. The crane operator in a double fatality knowingly maneuvered his hydraulic crane near overhead lines, despite warnings from other crew members. He had been told by supervisors not to use a crane in that location.

3. A contractor directing construction activities had discussed the hazard before proceeding with the job, and supposedly adjusted the crane boom length so as to miss the overhead lines. He was electrocuted while steadying the load and directing the crane operator.

4. One report states that the mine superintendent requested that the utility de-energize the lines in question while work was carried out near them. When informed that they could not cut the power until three days later, he proceeded with work near the energized lines.

5. Another fatality resulted when a crew hoisted a conveyor section near a newly installed overhead line they thought to be de-energized.

Because crane work normally requires at least a small crew, multiple workers are often exposed to shock hazards when an overhead line is contacted. In almost every case where a load was being guided or steadied by workers, an individual other than the fatally injured victim was shocked or injured. In one case, a worker was knocked unconscious and severely burned. At least three other accidents had workers exposed to shock hazards but not injured.

Supervisory personnel were present at six of the contact accidents. In three cases, the supervisor was assisting with work on the ground, including one in which he was the victim. In one other incident the foreman was operating the crane.

Facility Information. Facilities at which the crane accidents took place are listed in Table 20, along with their size.

Proximity-Warning Devices. In no accident report involving cranes is the use of a proximity warning device mentioned. Upon examining the contacts involved, it is questionable if the use of such devices would have prevented many of these accidents. In seven cases, hoisting ropes made the actual contact, and in one the load hit the line. Two other contacts occurred while the crane was in transit and not hoisting material. In only four or five crane-contact incidents does it appear likely that a correctly operating proximity-warning device would have indicated the impending line contact. More importantly, as stated before, workmen in nearly half the accidents knew they were near overhead power lines.

Table 20. Facility type and size for crane fatalities.

Facility	Size
Coal-preparation plant	200 tons/day
Coal-preparation plant	2600 tons/day
Coal-preparation plant under construction	n.g.
Coal-preparation plant sludge-pond area	1000 tons/day
Coal-preparation plant sludge-pond area	50 tons/day
Quarry	7 employees
Sand-and-gravel pit	8 employees
A large mill (type not given)	982 employees
Sand-and-gravel pit and plant	24 employees
Sand-and-gravel pit	15 employees
Sand-and-gravel sizing and stockpiling facility	12 employees (250000 tons/year)
Quarry and mill	n.g.

Dragline Fatal Accident

This accident is classed separately because in the report of investigation, the unit is designated as a "crawler-mounted dragline." It is likely though that it was a crawler-mounted crane serving as a dragline, much the same as one case in the mobile-crane section.

Regardless of designation, the crawler-mounted unit had a cable-supported open-truss boom of unknown length raised to a maximum vertical height slightly above 24 ft. The unit was traveling along an access road to a sand-and-gravel pit, as the operator stopped to lower the boom for clearance of the 7200-V power line in question. He apparently stopped with his point shieve (tip of boom) less than one foot from a 24 ft-high phase conductor. When the dragline stopped, a 26-year-old utility man with three years and three months experience, helping with the move, walked to the unit and placed his hand on the drag rope to lean over and check if the drive chain had fallen off (evidently he did not realize why the unit stopped). It is believed that an arc from the line to the point shieve energized the drag rope. The operator, thinking that he was a safe distance from the line, did not realize the utility man had been shocked. The operator was also shocked while attempting to aid the victim.

Non-Equipment-Related Accidents

Compiled listings of indirect-contact electrocutions in mining not involving mobile equipment are not complete, but Table 21 gives several examples of representative cases, for 1970-1980. Three accident-investigation reports were examined, one involving a construction worker and two dealing with surveying accidents.

In the first case, a 35-year-old mason with 12-years experience contacted a 12.47-kV three-phase line with a 1/2-in. reinforcing rod. Because of a three-tier scaffold used for the job, the lines were only seven ft above the work surface. The victim was a contractor working for a small garnet-milling company. The contact tripped some form of protection to de-energize the circuit.

The surveying accidents represent two situations likely to create shock hazards, these being the use of a long level rod and a metal chain (tape) near overhead lines. In one case, a 19-year-old chainman with three months experience contacted a 13.8-kV line with an extended level rod, 13 ft 4 in. long, which he was carrying in a vertical position. The overhead line in this location sloped downward toward its entrance to a nearby substation, being 14 ft 9 in. above ground level at the point of contact. The victim had worked in this area earlier the same day, but it is not clear if he recognized the hazard. Another chainman, 32-years old with 15 months in mining, was electrocuted when a chain (tape) contacted a 46-kV mine-owned power line. The victim was at head-chainman position with the chain running below the lines. He gave the 222-ft length a hard jerk to clear it from vegetation, at which time it flipped into the air and contacted the overhead line. The back chainman was also shocked. The transitman had warned the men about the chain and power-line hazard just prior to the accident. The overhead lines were installed correctly but, as can be seen in Figure 21, the terrain and station positions allowed the chain to easily snap up into the lines [20].

Accident-Analysis Findings

Upon examination of the preceding material, general statements can be made describing indirect line-contact fatalities in mining over the past decade. The list presented here outlines factors associated with these accidents along with supporting detail when necessary. These characteristics will provide part of the basis of recommendations to be made in Chapter IV.

Table 21. Non-equipment indirect line contacts.

Description	Number of Cases
Victim raising a metallic bar or pipe into an overhead line	3
Surveyor contacting a line with a rod or chain	4
Contacting a line with a ground ladder	1
Contacting a line by way of a blasting cable	1

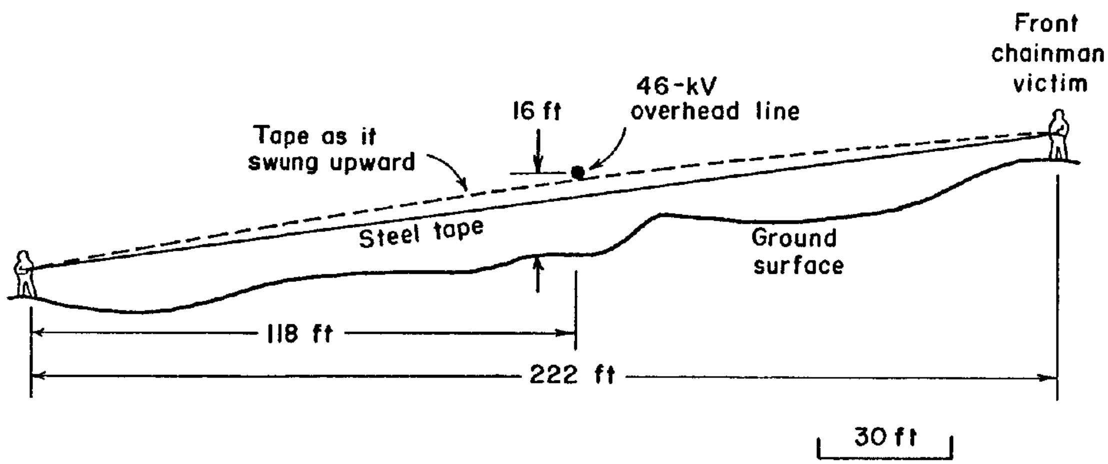

Figure 21. Accident scene where a steel measuring tape was snapped-up into a line.

Equipment and Overhead Lines. Overhead-line contacts are by far, most common among trucks, mobile-drilling rigs, and mobile cranes. Other high-reaching equipment is found in mining such as walking draglines and shovels, but are usually not as mobile or as frequently moved. Trucks involved in fatal contacts were all tandem, triaxle, or tractor-trailer highway-legal dumps. Notable is the absence of any accidents with large off-highway ore trucks which are commonly found in open pit mines with overhead mine-power distribution. Several crane fatalities have shown that crawler ground-contact can offer sufficient resistance to create dangerous frame potentials.

Arcing across and through a tire carcass can cause tire fires. These fires are dangerous not only due to the fire hazard, but because they can divert attention from the line-contact conditions.

Clearances specified in NESC standards do not place lines above the working heights of much equipment used in mining surface operations. Tandem and triaxle trucks can contact legal line installations, and most trailer-dumps, drill rigs, and mobile cranes are substantially higher than minimum line heights.

Facilities and Locations. Truck accidents reveal that potentially hazardous conditions are allowed to exist at tipples, stockpiles, and other loading facilities. This is basically overhead lines exposed to approach and exit truck traffic, and dumping operations. Drill contacts are likely in random locations where masts are raised for reasons other than drilling, or on pit benches traversed by power lines. Construction sites are the usual location of crane contacts, and preparation-plant areas are also fairly common.

Facilities at which accidents occurred are normally small to moderate in size. With respect to past accident location, most metal/nonmetal operations employed less than 30 to 40 personnel, and most coal facilities handled less than 400 tons/day.

Activity. Trucks normally raise beds into lines or drive into them with the bed up. Drill accidents usually involve raising the mast into a line. As may be expected in construction, cranes are normally hoisting loads at time of contact. An apparently high-risk area is around sand-and-gravel processing plants where a combination of modular construction and overhead lines supplying the plant create conditions for crane-line hazards [29]. Accidents also occur while cranes are in use as excavators.

All truck-contact victims in the accidents examined were drivers, among whom experience seemed to have little influence. Contacts when the driver is in the truck cab may be attributed to limited vision, but fatalities with the operator outside the vehicle often represent inattention to surroundings and dumping operation.

Inexperience seems to be a contributing factor in drill rig-line contacts, with the victim most often operating the drill controls. In crane contacts, experience of the operators may be more relevant than that of workers on the ground who are normally the victims. Hookmen and others contacting crane or load have the highest risk of electric shock.

Victims. Nearly half the victims of past line contacts were contracted workers, rather than mining company employees, and safety or work hazard training was almost non-existent among victims. A conservative estimate indicates that 35 to 40% of the victims knew they were near overhead lines.

Circuit Protection. Protection for overhead-line circuits is normally intended to prevent equipment damage, but can still allow lethal current levels to flow. These devices will hopefully de-energize a line after contact, but current flow is often not high enough to activate protective devices. Lines contacted are commonly single-phase or three-phase systems with solidly-grounded neutrals at their source. Utilities use solidly-grounded systems with high phase-to-neutral current trip levels to accommodate phase-to-neutral loading on the system (such as single-phase residential services).

Either phase protection or ground-fault protection can operate to clear a line-contact fault. Often systems have "reclosers" which try to reclose a cleared circuit at preset time intervals, to avoid "lock-outs" due to temorary faults. This can lead to the momentary re-energization of an apparently de-energized line, possibly causing further electrical shock-exposure and system damage. Contacted lines can burn through causing the additional hazard of downed lines.

Accident Scene. Most accident scenes of past fatalities had no immediate supervision. Supervisors were present in several crane accidents, but were usually helping with the work. Few cases had a workman specifically assigned to watch line clearances during operations. Those which did involved warnings which were given too late or were unheeded by the operator or victim. Shock to multiple workers, such as non-victim hookmen, bystanders, and rescuers, is a serious problem in overhead-line contacts. Accidents occurring at sites of previous line contacts, or in areas known to be hazardous, are common in truck-contact cases.

Proximity-Warning Devices. No proximity-warning devices were in use in the accidents examined. Regardless, the possibility of preventing a significant number of line contacts through the use of such devices is questionable due to device limitations as outlined in Chapter II, as well as the large number of past victims who knew they were near overhead lines.

Summary

The findings contained in this chapter are an important addition to the background information outlined in Chapter II. Line-contact accident characteristics specific to mining are a vital basis for the recommendation of measures to reduce line hazards at mining operations. These recommendations will be presented in Chapter IV.

Chapter IV

RECOMMENDATIONS OF METHODS TO REDUCE INDIRECT-CONTACT OVERHEAD-LINE ELECTROCUTIONS

General

This chapter sets forth recommendations of methods that can prevent electrocutions due to the indirect contact of overhead power lines in mining. The measures described are based on present techniques which can be used to reduce these fatalities and the recognition of problem areas as outlined in an analysis of such accidents (Chapter III). Particularly, hazardous locations are identified, and then solutions to the problem are proposed, accompanied by formal recommendations. Proposed solutions are general in applicability and, together, cover a wide range of situations and represent varying degrees of effectiveness. Further description and examples are provided in an appendix.

Many sources of information were consulted during the development of recommendations for this chapter. Rules and recommendations proposed here may therefore be the same or similar to those found in other writings. The extent to which outside sources were used, however, was too varied and sporadic to allow exact referencing for their contributions, therefore the following sources are referenced for any recommendations in this chapter which by design or by coincidence contain similar material [6,9,10,11,17,19,42].

Problem Overview

Indirect contact of overhead lines is responsible for a significant number of electrocutions in the mining industry. In response to this problem, various solutions have been proposed and implemented, and have been detailed in Chapter II. These include efforts to avoid line contact, such as line installation standards, minimum clearance distances, warning devices, and work-force training; methods to reduce the effect of contacts such as the insulation of booms and loads; and effective grounding of equipment frames. Also reviewed in Chapter II were the inadequacies of these solutions. In brief, the continuance of indirect-contact electrocutions can be attributed to either not applying available prevention measures or inherent drawbacks of the solutions. This suggests that the removal of overhead-line hazards is a more desirable answer to the problem, even though it may be more difficult to achieve.

The elimination of overhead line hazards may prove more feasible in mining operations than in a general situation involving high equipment and utility lines. This is due to the fact that mining is a relatively specific activity, often with well-defined operations, facilities, and equipment. Overhead-line safety can therefore be taken into account in mine-plant design, and also considered in relation to pre-existing utility lines, mine-facility power, or pit distribution.

The elimination of overhead-line hazards will not always be practical or possible due to physical conditions, line ownership, or economics. Because of this, it is essential that attention also be given to less extreme methods of overhead-line hazard reduction, ranging from warning devices to work-force education. Ideally these efforts should result in a program including sound design and personnel safety.

Possible solutions which will require attention in an attempt to substantially reduce indirect-contact electrocutions in mining will be discussed in this chapter. Each major area will be presented with consideration of the theory of the solution, advantages, problems, specific specific applications (equipment, facility), and relation to points discussed in Chapter III. Solutions will also include recommendations for their implementation with specific examples when appropriate.

Hazardous Areas

Before discussing possible means of prevention, areas and situations which pose the greatest overhead-line hazard will be outlined. This listing is important since it represents the target areas for most of the solutions which follow. The first three groups discussed are primarily mining surface facilities and associated areas, while the last refers to the active excavation of a surface mine.

Mining surface facility is a very general term, but most possibilities can be covered in a few general categories. The areas that will follow may be considered hazardous due to a combination of equipment traffic and line exposure, depending on the type and height of equipment and overhead congestion

Loading and Dumping Facilities. This category includes stockpiles, loading bins/hoppers, and material-transfer areas. Not only these particular points but also adjacent areas, yards, and roads are hazardous locations for truck operation when overhead lines are present. Some contributing factors to the risk are unfamiliarity with the dump, use of a temporary dump point, fluctuation in the edge of a stockpile, and fluctuation in the height of a stockpile.

Mine Plant Areas. Trucks and cranes can easily be exposed to line hazards near various mineral processing, storage, and handling installations. Included here are large and small plants for coal preparation; metal/nonmetal ore milling; various crushing, washing, and sizing operations; storage areas; transport structures; refuse dumps; and settling ponds. Sand-and-gravel processing facilities, which also fall into this category, were shown in Chapter III to be a frequent contact location and will therefore be described in more detail.

Sand-and-gravel operations require electric power for crushers, conveyors, washers, screens, and pumps, and often use "unitized" equipment such as mobile conveyor-hoppers. A common configuration has utility service to one or more centrally located poles, with lines dropping radially from pole-mounted transformers to clusters of equipment. Utility service is normally bare overhead conductors to the transformers, while drops to equipment may be cables run overhead on messengers, along equipment frames, or in conduit underground to avoid congestion. These drops are typically 440 V, but the real hazard exists with the incoming utility lines which range from 4.16 to 13.8 kV [29].

Construction Sites. These may or may not be near permanent facilities, but often present a hazard involving construction cranes and pre-existing overhead lines.

Active Workings. Another potentially dangerous situation involves overhead lines traversing active surface-mine workings. The fatalities that have occurred in these areas were due to lines other than pit-power distribution. Hazards exist primarily over mine benches as well as access and haulage roadways.

Although not responsible for any electrocutions in the group of accidents examined, pit-power distribution can create a hazard when overhead lines are used, such as for strip-mine base lines or for open-pit ring mains.

Preventive Measures

The solutions proposed will be grouped according to the manner in which they attempt to prevent overhead-line contact fatalities, beginning with those that, in theory, would be most effective in reducing the shock hazard. This organization causes some overlapping, but it allows the recommendations to be followed from the most effective and desirable, to those which should be considered minimum precautions. The following solutions, because of this organization, will cover roughly the same hazardous situations just listed, with each successive group proposing less extreme corrective techniques. Although this format may in some respects seem disjointed, it should allow the reader to consider a specific line-hazard situation and progress through the possible solutions, adapting those which are feasible and discarding those which do not apply. An attempt has been made to keep recommendations general in nature to allow a wide coverage of situations, although detailed descriptions of some hypothetical line-hazard cases have been included in an appendix to further illustrate the intent of these proposed solutions. The areas presented have been arranged as follows:

1. elimination of overhead lines:
    a. with respect to mining surface facilities
    b. with respect to active surface-mine workings;

2. limiting access to overhead lines:
    a. surface facilities,
    b. active workings,
    c. construction sites or exploration drilling;

3. overhead-line modification:
    a. raising existing lines,
    b. neutral conductor installation,
    c. disconnect switches;

4. protective devices:
    a. proximity-warning devices,
    b. insulating devices;

5. safe work practices and personnel training:
   a. guidelines for working near overhead lines,
   b. passive-warning techniques,
   c. personnel training; and

6. other methods.

Discussions and recommendations for each group are intended for general application but, by the nature of most overhead-line contacts and their characteristics, most solutions tend to highlight the "hazardous areas" discussed earlier in this chapter.

Elimination of Overhead Lines. This is a rather broad category and represents what can be considered the most effective means of eliminating equipment-line contacts. This group will be divided into two areas of application, mining surface facilities and active mine workings, with the first area further split according to the technique of line elimination.

Mining surface facilities have been described as permanent or semi-permanent installations that serve some support function to a mining operation. The primary concern is eliminating lines in these areas which will cause a hazard to high-reaching mobile equipment. The two techniques considered will be the physical relocation of lines and alternatives to bare overhead conductors.

The first technique consists of the placement of new overhead-line installations and relocation of existing lines in and around mining surface facilities so as not to pose a contact hazard to equipment in that area. The locations in question tend to be of permanent nature and definite limits and will often allow routing of lines in less hazardous positions. Dump areas, processing plants, and supply yards would primarily encounter truck and crane exposure, although shops and fueling areas could also include drill-rig traffic. Moving overhead lines to avoid equipment contact may seem an obvious course of action, but the circumstances of past accidents reveal that correctable hazardous situations are often allowed to exist at mining operations.

An estimation of overhead-line rerouting costs were supplied by the Pennsylvania Power and Light Company. The approximate cost for rerouting a 12-kV overhead line around a one-half mile square area includes removing one-half mile of line and installing one and one-half miles [30]:

REMOVAL COST (0.5 mile):	$ 9,550
ADDITIONAL COST (1.5 mile):	99,600
TOTAL:	$109,150.

Similar costs for the removal and addition of lines were given by the West Penn Power Company [31]. These prices could change substantially depending on line ampacity and installation conditions, but they represent a mid-1982 cost for a typical utility three-phase distribution pole line. This situation could represent rerouting of a line around a processing plant and its associated facilities or around the active excavation of a strip mine. (The latter case will be covered later in this section.)

If rerouting of lines is feasible, it is inherently the most effective technique since it eliminates the hazard and, after line placement, does not rely on the human element. This method can be implemented by initial safe facility placement, by safe line placement, or by line relocation. Practicality can easily rule out overhead-line elimination, however. For example, it may be difficult or impossible to find an alternate location for the plant or lines due to topography, right of ways, or operation layout; or it may be too expensive to use a different location for the plant or to relocate lines.

Recommendations for line elimination must center on locations presenting the most potential for equipment contact. Where there is frequent dump-bed truck traffic, lines must be restricted from dump sites and approach/exit roads. Unless the lines are in a location inaccessible to trucks, a safety margin should be allowed outside the normal truck routes. A distance of 100 ft would allow for limited movement of trucks outside of normally traveled areas to account for mechanical problems, bed cleaning, back-ups, and temporary dump sites. Roads leading away from dump locations should not be crossed by lines for at least 250 ft beyond the dump-site, since beds may not be completely down as trucks leave the area. This distance would give additional time for the bed to lower or for the driver to recognize the condition.

A 100-foot margin would also increase safety for equipment movement about shops, supply yards, and similar areas. These areas require this additional distance beyond normal equipment-travel limits to account for extension and movement of booms and masts beyond parking areas and yards, as well as truck movement.

Overhead-line equipment exposure should also be a consideration in and around material-processing facilities. These facilities, however, often have more definite boundaries for areas used by equipment, and will not always require the 100-foot safety margin for line placement.

The following are recommendations for the elimination of bare overhead power conductors posing a contact hazard in mining surface installations and associated facilities. Section 1 of Appendix B presents more detailed explanations of these recommendations and hypothetical situations implementing various solutions.

1. Areas encountering frequent truck traffic and dumping operations or loading equipment such as stockpiles, transfer areas, hoppers, bins, and other dumping sites, should not be located within 100 ft of overhead high-voltage lines. "Area" is defined as that region where truck traffic can normally be expected, including the extreme limits of stockpile edges, truck scales, and locations where trucks line-up, clean, and shake-out beds. This 100-foot zone can be reduced to 20 feet if the said zone is impassable to the equipment involved. Also, high-voltage overhead lines should not cross over dump-area approach and exit roads within 250 feet of the dump point.

2. Areas in and around mine shops, maintenance yards, fueling areas, supply yards, equipment-parking areas, and similar locations

normally traveled and used by high-reaching equipment should not be located within 100 ft of overhead high-voltage lines.

3. Material-processing facilities and their associated installations such as preparation plants; mills; crushing, washing, and sizing facilities; storage and transfer facilities; and refuse handling/disposal installations should be located with respect to overhead high-voltage lines so equipment operating in and about these facilities shall not be exposed to high-voltage line-contact hazards.

One situation in which line relocation may not be feasible is where the lines supply power to the facility in question or a nearby installation. For the elimination of these bare overhead conductors, some alternate method must be used to supply power. One alternative suitable for permanent installations is underground cable. Cables in conduit or directly buried are suitable for such applications as lines entering plants, dump facilities, shops, supply yards, and support buildings. Cables similar to those found in mine-power distribution, such as MPF and SHD types, are used for buried applications. Further information on underground cable installations is found in Appendix C.

Pennsylvania Power and Light supplied comparative cost estimates for 12-kV overhead lines and 12-kV direct buried underground cable for a 500-foot run entering a building. These costs assume no transformer or transformer vault cost and good ground conditions for trenching [30]:

12-kV overhead:	$ 9,950
12-kV underground:	$21,200.

These costs can vary depending upon the cable ampacity required, and underground costs can increase substantially if difficult trenching conditions exist.

West Penn Power Company supplied a rough breakdown of the labor costs involved in underground line installation. These are mid-1982 figures and assume good trenching conditions [31]:

TRENCHING AND BACKFILLING LABOR:	$ .40/ft
CABLE INSTALLATION LABOR:	$2.00/ft
ADDITIONAL LABOR:	$ .30/ft
TOTAL:	$2.70/ft.

An approximate value for the cost increase of three-conductor cable is $5.00/ft more than ACSR [32].

If the ground is unsuitable for cable burial or a less permanent installation is desired, shielded cable can be used either overhead, suspended from a messenger cable, or supported along structures in ducts or trays. MPF or SHD type cable is commonly used although specifically designed overhead cable can be purchased with a three conductor cable pre-bound to a steel messenger [33,34]. Aerial-cable installations require closer and stronger support structures than comparable ACSR lines due to their additional weight [31]. Also, aerial cables are susceptible to extreme ice and snow loading due to their large surface area, and can sustain insulation damage from metallic shields in the cable, due to wind motion. These factors may lead to early cable failure [26].

In addition to cable cost ($5.00/ft more for cable than ACSR lines) West Penn Power Company has indicated that costs for installation and additional materials for an aerial cable will be approximately $17.00/ft, mid-1982 [31]. Pennsylvania Power and Light estimates show that the total cost of a shielded-aerial cable installation is approximately twice that of a bare-conductor installation, which makes it slightly less expensive than a comparable underground line [30].

Cables present a safe alternative to bare overhead conductors in areas where high-reaching equipment must travel. Underground service removes line exposure completely, but overhead cable may be preferable due to cost, ground conditions, or expected installation life. In either method, the cable should completely span the hazardous area, or its purpose will have been defeated. Such cable runs should continue for a short distance beyond the hazard area to allow for equipment extensions protruding beyond area limits.

The following recommendation deals with the use of cables as an overhead-line alternative. Further discussion and an example are found in Section 2 of Appendix B.

4. In such cases where overhead high-voltage lines cannot be eliminated from in or about mining surface facilities, primarily when the lines supply power to the facility or a nearby installation, those lines presenting a contact hazard should be replaced by underground or overhead shielded cables. Transition from overhead bare conductors to underground or shielded-aerial cables should be at least 20 ft outside of the hazardous area, and such cables should continue to the building or installation in question.

Overhead lines traversing active surface mine workings present a hazard to high-reaching equipment operating therein. Whether they are pre-existing utility lines or part of mine-power distribution, hazards can result for trucks and drills on benches or on haulage and access roads. The present concern is the elimination of these lines, thus their removal from the work area is the most direct solution. This may involve the permanent relocation of a utility line over a proposed open pit, or temporarily rerouting a line about a strip operation. Elimination of overhead lines in a pit-power distribution system would likely involve replacement by cable. Operations such as strip mines can and commonly do use all cable distribution with good results, if proper cable-handling techniques and equipment are used [35]. Open-pit operations normally use overhead distribution to switchhouses in the pit, and shielded trailing cables to mobile equipment. However, as mentioned earlier, of the fatal accidents examined, none were due to contact of these overhead-distribution lines. In large open-pit mines, overhead distribution is the most practical due to the long distances and cable protection requirements but, where frequent equipment operation poses a contact hazard, cable may be more desirable.

A representative cost for the rerouting of a line around a one-half mile square area was given earlier in this chapter. Actual costs will vary widely depending on line size and distance involved, with alternate routes normally being over twice the original line length [36].

Use of cable to replace overhead lines in mine-power distribution systems will incur $5.00/ft additional cost for cable over ACSR as well as the cost of cable-handling equipment.

When rerouting lines around surface-mine work areas, all aspects of the operation should be considered, including surface clearing, reclamation, access roads, and haulage roads, as well as actual mining activities. A safety margin should again be provided beyond normal work areas to account for occasional abnormal truck traffic, excavator booms, and similar situations. The following recommendations cover the elimination of overhead lines from active surface mine workings.

5. Overhead high-voltage lines traversing an area of proposed surface mining should be relocated at a time well enough in advance so they will not be exposed to contact by equipment in and about the mining operation. This should include areas of active mining as well as adjacent traveled areas and haulage or access roads. Relocated lines should be at least 100 ft from the extreme limits of mine-equipment operation.

6. Surface mines using overhead pole lines for pit-power distribution should evaluate their systems for possible equipment-line contact hazards. Cable should be used in place of overhead lines in locations where substantial contact hazards exist.

<u>Limiting Equipment Access to High-Voltage Overhead Lines</u>. Contact of overhead lines can be avoided by removing equipment operation from the hazardous area as opposed to moving the lines. Although in theory this would be a very effective method, it is not applicable in many locations where equipment movement is necessary. Access cannot be restricted, for instance, for cranes in supply yards or trucks in dump areas. However, there are situations where such a technique could substantially reduce the danger of contact, such as where lines traverse active surface-mine workings. In this case, equipment could be kept out of any contact-hazard area while working in its vicinity, given that its function does not require it to work within the dangerous area. Obviously, in such a situation, restricting access attempts to reduce the role of worker safety and common sense in avoiding accidents. The concept of limiting access to lines is important, since for example a very small strip operation may be unable to sustain the cost of relocating even a small overhead distribution line [37]. Any efforts to restrict mobile equipment must be carefully planned and implemented so as not to hamper normal operations or antagonize the work force.

Some permanent surface facilities may be suitable for the restriction of high-reaching equipment. Where this is possible, it provides an effective and less costly alternative to relocating overhead lines, so long as normal operations are not hindered. Restriction could be accomplished by posting the area, or using barriers such as steel cross-bars which allow only low vehicles (cars and small trucks) into the area. Provisions could be included to easily allow occasional entrance of higher equipment.

7. Areas about mining surface facilities where high-voltage overhead lines are present and where high-reaching mobile equipment will have no need to operate, should be restricted to entrance of such equipment by physical barriers and public notice.

Mentioned earlier was the problem of overhead high-voltage lines over active surface-mine workings. Possibly due to mine size, line-installation size, or relocation costs, overhead lines that are over projected mine excavations may not be movable.

One option for the operator is to leave the overhead-line right-of-way undisturbed to avoid the hazard. Leaving the area undisturbed, will result in a loss of resource as well as a disruption in the continuity of mining. Such a disruption may involve only a single pass as in a contour-strip operation, or may play a major part in mine layout as with a large area-strip mine traversed by a major transmission line. For instance, consider a contour mining operation with an overhead powerline across the projected path. To continue through the right-of-way but not mine below the lines, the towers or poles beyond the pit-width limits would be guyed. The cables could then be removed or lowered into trenches, and all large equipment trammed or walked over the right-of- way. The lines would then be replaced and mining operations resumed on the far side of the overhead lines [38].

West Penn Power Company supplied a cost estimate for a temporary line removal similar to that just described. At mid-1982 prices, one hour of power outage will require 6 to 12 man-hours at $30.00/man-hour. Each additional hour would require six man-hours. This, of course, assumes that the utility is able to de-energize the line [31].

Another alternative for a mine operator is the questionable practice of mining under lines. Operating under overhead lines may be physically possible, but extensive precautions will be needed if worker safety is to be maintained. If mining proceeds beneath lines, the operation of high-reaching equipment should be restricted so that at no point in mining activities will line contact be possible. The most positive method of restriction would be physical barriers erected around the overhead lines in question. For barriers to be effective they should be highly visible to equipment operators and difficult to move and replace quickly. Suitable construction would include: substantial wood or steel posts set in the ground, possibly spanned with steel cable, or pre-formed concrete barriers such as oil drums filled with concrete. Free-standing wooden barriers may prove more convenient for short-term work near lines, but can also be easily moved. If barriers are difficult to relocate, workers will be less likely to move them and negate the protection they provide.

Limiting access to overhead lines at surface-mine workings is covered in the following recommendations. An example with additional details is included in Section 3 of Appendix B.

8. If high-voltage overhead lines over projected surface-mine workings will remain in place, mining operations should be altered to minimize the exposure of mining equipment to the lines.

9. When surface-mining operations will proceed under existing high-voltage overhead lines, the following precautions should be implemented. When any mobile high-reaching mining equipment will operate in the vicinity of high-voltage overhead lines, physical barriers should be erected to limit machine-line clearances to legal minimums as set forth in 77.807-2, 55.12, 56.12, and 57.12, CFR, Title 30. "Vicinity" shall mean an area wherein equipment, in normal operation, could move to a position of line-contact exposure. Such barrier positions will account for the extreme reach of booms and masts out over the barriers. The barriers used should be easily visible to equipment operators and should extend the width of the given work area, bench, and so on, parallel to the overhead lines. Barriers will remain in place until all work has been completed in the area in question.

In situations involving mining facilities and mine workings, there is a degree of control over the immediate surroundings, but in short-term mining-related activities like light construction and exploration drilling, the circumstances usually do not offer the options of relocating or altering dangerous overhead lines. Such circumstances may dictate working with the hazard present and indicate the need for some type of equipment operating restrictions. As with the other cases in this "limiting access" section, the construction, exploration drilling, or other activities under consideration are assumed to be in the vicinity of overhead lines, but are not required to be adjacent to the lines where contact is possible. This again means that the restrictions will serve as artificial common sense.

Construction cranes which will remain stationary while operating at a project site can be positioned so that line contact cannot occur at any position. Cranes which will travel during operation will require barriers around hazardous areas, such as were described for active mine workings. When determining a safe distance from overhead lines, contact by hoist cables and swinging loads should be considered. These criteria are expressed in the following recommendations.

10. Cranes used for construction and other projects on and about mine property should be positioned so, at any point in their full range of motion, minimum legal line-equipment clearances as set forth in 77.807-2, 55.12, 56.12, and 57.12, CFR, Title 30 are maintained. Hoist-rope contact, load contact, and hook-men pulling hoist ropes from vertical should be considered.

11. If in normal operations a crane will be required to travel to reposition or transport loads, physical barriers should be erected adjacent to high-voltage overhead lines so that at all times legal line-equipment clearances as set forth in 77.807-2, 55.12, 56.12, and 57.12, CFR, Title 30 are maintained. Hoist rope and load clearances should be considered. Barriers should be highly visible, extend the width of the work area, and remain in place until work is completed.

Exploration drilling commonly requires operation in unfamiliar surroundings often under minimal supervision. However, it usually has the flexibility of drill-site relocation to avoid overhead-line hazards, therefore, lending itself to restriction of drill-rig placement as a safety precaution. Management and engineering personnel have the responsibility to locate exploratory test holes in safe locations with respect to overhead lines. Holes will sometimes though, necessarily be near overhead lines, and further precautions will be required. One hundred fifty feet should constitute being "near" an overhead line since a drill-rig could easily move this distance while finding a suitable set-up location. One hundred fifty feet, however, is still somewhat arbitrary since rig relocation depends on terrain and hole-site surroundings. Should the rig be within 150 ft of an overhead line, physical barriers should prevent entrance into areas of possible line contact. The barriers serve the same purpose as those described earlier but, should be of more portable construction to facilitate quick set-up and transport. Simple steel rods set in the ground spanned with rope and flagging or wooden horse type barricades would be suitable. Engineering crews (surveyors) should see that necessary barriers are installed prior to drilling activities.

12. Supervisory and engineering personnel in charge of exploration-drilling operations should locate hole sites at least 150 ft from any high-voltage overhead lines. If holes must be drilled within the 150-foot limit, physical barriers should be erected at appropriate locations along the overhead lines so the drill-rig mast will at all times maintain legal clearances as set forth in 77.807-2, 55.12, 56.12, and 57.12, CFR, Title 30.

Overhead-Line Modification. Solutions discussed prior to this point have tried to isolate overhead lines from mobile equipment to eliminate the chance of contact. Courses of action exist, however, that can substantially reduce line-contact hazards without some of the extreme measures proposed earlier. Such techniques are important because, as stated previously, many cases will arise where an operator cannot eliminate overhead-line hazards or limit access to them.

Some hazard situations can be improved by raising the overhead line in question, depending on the equipment involved. This method could be applied to areas where dump-bed truck traffic is the main concern. Lines over roadways, for example, could be raised to easily clear most dump-bed units without extensive support structures. A line height of 45 ft would place lines above most highway legal dump-bed trucks, even with their beds fully raised. This height would also clear most other high-reaching equipment such as drills and cranes, when in transit with their booms and masts lowered. Except in special cases, it would be impractial to try to place lines high enough for any eventuality such as cranes and drills with raised booms. It is possible though, if necessary, to raise lines to heights of more than 65 ft, using single wood pole supports. Line heights attainable depend upon line spans, cable sag, and surrounding terrain, but in most cases 45 ft would be a sufficient and achievable height.

Information on raising overhead lines was obtained from West Penn Power Company [31]. Line clearance can be increased five ft by using fiberglass pole extensions, but larger increases will require the installation of new poles. The cost to install one pole at mid-1982 prices is approximately $2000 for labor and materials plus the pole cost. The following are typical pole costs:

Pole Height (above ground)	Cost/pole
35 ft	$ 250
65 ft	$ 700
80 ft	$1600.

Depending on the situation, raising of overhead lines can be recommended as a feasible, relatively economical, and effective method to reduce line-contact hazards.

13. Where high-voltage overhead lines cross roadways and areas traveled by high-reaching equipment, ground-to-line clearance should be at least 45 ft.

Another modification of line installations which lends itself to road crossings is the guarding of phase conductors by effectively-grounded neutral conductors. If it can be ensured that any accidental contact with phase conductors will be simultaneous with the contact of a grounded conductor, a low-resistance path for phase-to-ground current will likely be provided. This not only reduces current flow via an equipment-ground contact but increases the chances of rapid fault clearing by protective devices on the circuit. To effectively guard phase conductors, several grounded conductors will be necessary to ensure simultaneous contact. In some cases, the need for multiple grounded conductors may make this method impractical due to the cost of materials and installation, as well as mechanical strength limits of the line supports. Under these circumstances, West Penn Power Company recommends the use of rubber guarding on overhead lines at hazardous crossings [31]. Cost for installation of such guarding would be approximately $250 plus materials, at mid-1982 prices.

These guarding techniques are less desirable than preventing the line contact initially, but they do hold a cost advantage in many situations. Recommendations for overhead-line-guarding techniques follow.

14. High-voltage overhead phase conductors exposed to frequent mobile-equipment traffic should be guarded by neutral conductors tied to earth through a low-resistance earth (ground bed) connection. "Guarded" means that any mobile equipment extension which contacts a phase conductor will normally have simultaneous contact with a grounded conductor.

15. When high-voltage overhead phase conductors are difficult or uneconomical to protect by grounded conductors, insulating guarding (rubber goods) should be used to protect lines in equipment-contact hazard areas.

When power must be supplied to a mining facility substation, utilities will commonly run a branch overhead line from their distribution lines to the substation. If such a branch line creates a contact hazard on or around the mine property, a disconnect switch should be provided external to the utility system and upstream from any contacthazard area. Should the need arise to work in close proximity to these lines, power could be cut with no disturbance to other utility customers. Disconnects which are quickly accessible from mine work areas would also encourage de-energization prior to work about lines, although this depends upon ownership of the lines, availability of qualified personnel (to cut power), and utility policy. Close disconnects would also be useful for emergency de-energization. The following recommendation primarily targets lines feeding mine installations, which are or may become hazards to personnel.

16. High-voltage overhead lines run from a utility distribution system to supply power to mine facilities, should have a disconnect switch which can isolate the line from the distribution system. If mine personnel are authorized and qualified to disconnect the feeder line in question, the switch should be readily accessible from mine work areas, to facilitate and encourage its use.

Protective Devices. This section will address the use of proximity-warning devices and boom/load insulation devices.

As stated previously, the idea of a proximity-warning device is sound in theory, but their use cannot be recommended without qualification. With proper application they are a safety feature but can easily become ineffectual and even hazardous if their limitations are not considered. The primary use of such devices has been on cranes, although the protection of drill-rig masts is also a possibility. The drawbacks of proximity-warning devices have been outlined in Chapter II and so will not be covered at this time.

Recommendations for the use of proximity-warning devices take the form of requirements which should be satisfied for safe application of these devices.

17. When proximity-warning devices are used to protect high-reaching equipment from line contact, the following criteria should be considered and applied. No device should be counted on as the only line of defense against overhead-line contacts, in place of safe system design and work-force training. The work force should understand the theory of operation, proper field operation, and limitations of the units in question. The use of warning devices does not relieve the operator from his responsibility to maintain line-equipment minimum clearances as specified in 77.807-2, 55.12, 56.12, and 57.12, CFR, Title 30 even if such devices are required by state or local laws. All proximity-warning devices should be kept in good operating condition, should be calibrated before operating equipment, and should not be used as an indicator to determine distance from an overhead line.

Devices such as boom cages and insulating load links also have sound theories of operation but problems in implementation. As detailed in Chapter II, major drawbacks stem from flashover due to insulator surface conditions.

The following recommendation outlines requirements for the use of such devices.

18. When insulating devices are used to protect high-reaching equipment from line contact, the following criteria should be considered and applied. No device should be counted on as the only line of defense against overhead-line contacts, in place of safe system design and work-force training. The work force should understand the theory of operation and the limitations of the devices in question. The use of insulation devices does not relieve the operator from his responsibility to maintain line-equipment minimum clearances as stated in 77.807-2, 55.12, 56.12, and 57.12, CFR, Title 30 even if such devices are required by state or local laws. Insulating links and boom cages should be regularly inspected for insulator damage and mechanical integrity, and should be thoroughly cleaned when necessary or on a regular basis to ensure maximum insulation properties.

Safe Work Practices and Personnel Training. Recommendations to this point have more or less emphasized techniques which will have some degree of effectiveness irrespective of safe operating procedures and work-force common sense.

However, any attempt to reduce overhead-contact hazards at a mining operation should involve efforts in several areas, one of which should be the development of safety awareness within the work force. Training of personnel in safe operation of mobile equipment near overhead lines will compliment any other method previously discussed and, in some cases, may be the only effort made toward preventing indirect-contact electrocutions. Therefore, this category is extremely important when operating near overhead lines.

Even where measures have been taken to eliminate overhead-line hazards, situations can still easily arise where it becomes necessary to operate equipment within an area of possible line contact. The following recommendations are directed toward these circumstances and include guidelines for work near overhead lines, some passive-warning techniques, and safety training of personnel.

The topic of safe work practices near energized overhead lines primarily targets activities which are of short duration and at random locations, such as light construction. These activities often cannot be foreseen in initial layout of mine facilities and overhead lines, nor do they justify extreme measures such as line relocation. The recommendations developed therefore, do not focus on line hazards which endanger equipment in routine operations, such as at stockpiles or supply yards, for these conditions should be rectified by line elimination, line modification, or some other permanent prevention technique. Rather, these guidelines apply to atypical and temporary operations which are inadvertently near overhead lines.

The following recommendations cover procedures for working near energized overhead lines, and guidelines for work crews should an overhead-line contact accident occur.

19. The following are recommended guidelines for working near high-voltage overhead lines.
    a. Areas in question should be thoroughly examined by supervisory supervisory personnel and workmen to determine if any overhead-line hazards are present.
    b. All overhead lines should be considered energized unless an authorized representative of the line owner indicates otherwise.
    c. If work is to be carried out near utility-owned overhead lines, the utility should be contacted for assistance with planning safe operating procedures for the project.
    d. Equipment operating near energized overhead lines must maintain minimum clearances as set forth in 77.807-2, 55.12, 56.12, and 57.12, CFR, Title 30 and comply with any state or local requirements.
    e. Equipment in question should be operated only by a competent, experienced, qualified operator.
    f. Operations near overhead lines should be observed by a reliable worker, watching for maintenance of minimum clearances and unsafe conditions. This job (observation) should be the worker's designated and only task.
    g. A competent worker should be designated to direct the equipment operator, and only this worker should give directions. Standard signals should be agreed upon and used.
    h. Booms, masts, beds, and so forth should be in a lowered position when equipment is in transit. Exceptions arise for cranes transporting loads, trucks spreading material, and similar situations.
    i. Minimum legal clearances as specified in 77.807-2, 55.12, 56.12, and 57.12, CFR, Title 30 should also be maintained for equipment in transit.
    j. If for the activities necessary, minimum clearance cannot be provided, the overhead lines in question should be de-energized and visibly grounded.
    k. The use of safety devices such as proximity-warning devices, boom cages, or insulating links does not allow closer operation to energized overhead lines than legal minimums as set forth in 77.807-2, 55.12, 56.12, and 57.12, CFR, Title 30.

20. The following procedures should be followed if an energized overhead line is contacted.
    a. If contact was momentary and no lines are down, a calm and experienced crew member should be <u>certain</u> that the equipment is no longer in contact and then assign members of the crew to check for injuries among work party; if necessary, administer first aid (basic life support, cardio-pulmonary resuscitation) and send for an ambulance immediately; notify supervisory personnel; check for dangerous equipment damage (i.e., hoist rope burns); and secure area for possible accident investigation.
    b. If contact is made and maintained, a calm and experienced crew member should instruct personnel aboard the equipment to remain in place and <u>not</u> to contact the ground, and have the

operator move equipment out of contact if possible. He should assign crew members to keep all other personnel clear of area, including equipment, hoisted loads, and fallen lines; notify appropriate mine supervisory personnel and/or utility to have lines de-energized; and send for an ambulance if needed. The crew should not contact any victims still in contact with energized frames, loads, etc. When victims can be safely rescued, the crew should administer first aid (basic life support, cardio-pulmonary resuscitation), move equipment to a safe position, check for damage, and secure area for possible accident investigation.

Note: The response by work crews involved in past overhead-line electrocutions displays a need for familiarization with the above procedures, and the importance of training in cardio-pulmonary resuscitation (CPR).

Passive-warning techniques as described here refer to any overhead-line danger warning or reminder method which relies on worker recognition and response. This includes signs, stickers, posters, and line indicators. Any such signs or devices should have visibility and appropriate color schemes to draw worker attention. They should be to-the-point and simple to understand. Signs in hazardous areas should be large enough to be easily read from approaching equipment and should warn operators well in advance of the danger.

Recommendations for several examples follow, but variations and extensions of these are possible. Several examples are listed in Section 4 of Appendix B.

21. In locations where lines cross frequently traveled areas or roads, a large (at least 5 ft x 6 ft) highly visible sign should warn equipment operators of the nearby high-voltage overhead lines and give minimum vertical clearance. Such signs should precede lines over roadways by at least 50 ft from both directions. Where overhead line visibility may be a problem in these locations, line markers such as high-visibility spheres or flagging should be used to draw attention to overhead-line positions and aid with distance judgment.

22. Conspicuous warning signs or stickers should be placed in the cabs and at the operating controls of all mobile mine equipment capable of overhead-line contact. Such notices should alert operators to the dangers associated with overhead lines and possibly give minimum and maximum heights of the equipment in question.

Part 48, Sections 25 through 28, and 31, CFR, Title 30, provide for the initial training and periodic retraining of mine personnel with respect to the occupational hazards of mining. Within this framework is one opportunity to inject high-voltage overhead-line safety. New employees at surface operations may often be placed as laborers assisting on or about mobile equipment and should in their initial training (48.25 and 48.26) be alerted to the danger presented by overhead lines. Hazards specific to the mining facility in question can be brought out in initial training (48.25 and 48.26) and retraining (48.28), as well as in the hazard training required for workers assigned to new jobs (48.27) (particularly new equipment operators). Frequent reviews of safe practices regarding overhead lines would be advisable for all operators of high-reaching equipment, regardless of the minimum legally required training. Particularly important is the review of safety guidelines with crews which are about to begin operations with exposure to overhead lines. The familiarization of supervisory personnel with safety guidelines and company policies is also essential if they are to safely direct the work force under hazardous conditions.

23. All new and experienced personnel who may be required to work where overhead-line hazards exist should be trained in safe work procedures with respect to same. The following are areas that should be covered in this training.
    a. Personnel should be familiarized with the electrical aspects of an overhead-line contact and the electrocution hazard involved. Personnel should be informed of federal and local regulations, and company policies regarding work near overhead lines, as well as the guidelines outlined in recommendations 19 and 20.
    b. Hazards specific to truck drivers should be covered, including: inattention to surroundings at dump sites, unfamiliar dump locations, gate spreading of material, shaking out or cleaning beds, and moving a truck with the bed raised.
    c. Hazards specific to mobile drill-rig operators should be covered, including: inattention to surroundings when raising the drill mast, and moving a rig with the mast raised.
    d. Hazards related to crane operation should be covered, including: the flexibility and quick operation of hydraulically-operated cranes, the tendency of operators to neglect boom and cable position while watching hoisted loads, hoisting cable-overhead line contacts, danger to crews working around cranes, and transporting hoisted loads.
    e. Instruction should cover the shock hazard to workers and operator helpers assisting around mobile equipment (i.e., hookmen and drill helpers), as well as the importance of reducing unnecessary worker contact of equipment frames and keeping unnecessary personnel clear of the work area.
    f. Personnel should be taught to recognize possible line contacts by indications such as: arcing and flashing, humming noises, and tire fires and smoke.
    g. Warning should be given regarding the danger to personnel attempting to rescue shock victims.
    h. Training should also cover overhead-line hazards not associated with mobile equipment, such as: work on scaffolding, work on roofs or elevated structures, the handling of bars, pipes, cables, or ladders near overhead lines, and the danger to surveyors related to long level rods and metallic tapes.

Other Methods. Beyond the general recommendations made thus far, more novel and specific solutions can be imagined for the reduction of indirect-contact electrocutions. These ideas, most of which are not in general use, represent new solutions to particular situations, as well as the use of common devices in new applications. The following are random examples of some machine/situation-specific schemes to reduce the shock hazard from overhead-line contacts.

Boom cages and proximity-warning devices are commonly associated with mobile cranes but may also be applicable to mobile drill rigs. Although proximity-warning devices would still have limited effectiveness, problems encountered with hoisting-cable protection and boom-length changes would be eliminated. Some type of insulating shield on the upper half of a drill mast may be effective because of the shorter length of most masts (compared to crane booms) and the limited range of mast movement (an arc in one plane).

Equipment with extendable and articulating extensions (booms, masts, arms) may benefit from an alarm which would sound any time the extention is in motion. Such an alarm would warn non-operating personnel to stand clear of machine parts that would become energized in the event of a line contact. This would only be desirable for equipment on which the extension is positioned and remains stationary for extended periods of time, such as with drill rigs and bucket trucks [39].

An alarm that indicates an overhead-line contact after-the-fact, may be useful for equipment where personnel often step from the unit and are electrocuted, trucks being a common example. If some type of current-sensing device could monitor a path along the equipment frame, contact could be indicated by an alarm in the cab or near the controls [40].

Another device that would be applicable to dump-bed trucks is a simple "bed-up" position indicator. Drivers, through neglect, or due to a faulty hydraulic power take off, may be unaware of a raised bed, and a light or audible alarm to indicate the condition would help solve the problem.

A large number of indirect-contact fatalities result from the victim's simultaneous contact with a hot frame and ground while dismounting equipment. In such a case, insulated side steps and grab rails or handles may be of possible use but, as evidenced by insulating load links, it is difficult to insulate for the high potentials in question, particularly under dirty conditions [8].

One method of protecting lines at road crossings is by guarding them with grounded neutral conductors. This method, discussed earlier, allows the phase conductor to be contacted though, and relies on the operation of protective circuitry. If mechanical trip wires are used to guard the lines, such wires could activate a local audible alarm, and this may avoid the contact completely [40].

Summary

The recommendations presented have ranged from extensive and costly relocation of overhead lines to simple verbal warnings to a machine operator. These solutions have widely varying degrees of effectiveness and target many aspects of the overhead-line contact problem. They represent a collection of ideas from which can be compiled an organized attempt to reduce the danger presented by high-voltage overhead lines at a mining or mining-related operation. Chapter V will conclude the report by relating the development of these recommendations to the original goals of this research.

Chapter V

CONCLUSIONS

General

This chapter summarizes the coverage of the foregoing research with respect to the research goals set forth in Chapter I.

The problem of electrocutions due to indirect contact of overhead lines was reviewed in general terms, examining the hazard in mining and non-mining fields as well as methods currently used to prevent such accidents. Chapter II covered this background material.

Indirect line-contact fatalities in mining were analyzed to examine the problem as it exists in coal and metal/nonmetal mining operations. This analysis involved compiling characteristics of applicable fatal accidents from 1970 to 1980, and identifying similarities and trends. The analysis comprised Chapter III, which ended with a listing of findings regarding line-contact accidents in mining.

The primary goal of the research herein, was to establish and verify recommendations for the reduction of line-contact fatalities in mining. Chapter IV contained the recommendations formulated. Solutions to the problem were organized according to the prevention method employed and presented with respect to their relative effectiveness. Each solution area presented specific recommendations along with supporting information and justifications. Several of the recommendations are further detailed in an appendix.

Research Conclusions

Indirect contact of overhead power lines is a potential hazard to any activity utilizing high-reaching tools or mobile equipment, and is a major cause of electrocutions in the mining industry. Attempts to reduce this hazard exist in numerous regulations covering line installation and equipment operation, electric-utility-sponsored safety programs, and various warning and insulation techniques. However, efforts to date have failed to reduce line-contact fatalities in mining. Through a detailed examination of past indirect-contact fatalities, it has been determined that an effective effort to reduce these accidents, must focus on the elimination of line-contact hazards through their recognition in the planning and layout of mining operations and facilities. In addition to the elimination of overhead-line hazards whenever possible in initial mine and plant design, line-contact prevention efforts must also be directed toward more effective implementation of currently available hazard-reduction techniques (laws, safety programs, protective devices, and training) within the framework of mining operations. It is to these ends that recommendations set forth in this research have been developed.

Suggestions for Further Research

Through research of overhead-line contacts, areas were identified which merit further examination.

It may be beneficial to determine why no fatal accidents occurred in open-pit mines involving overhead lines used for distribution of power in the pit. For example, off-road ore trucks in large open-pit operations may have avoided line contacts due to better system layout or personnel training; or contacts may have occurred without fatalities due to the limited fault current on high-resistance grounded systems.

Although almost half of the mining accidents studied involved victims who knew they were near overhead lines, an effective and reliable means of line proximity warning would help to reduce line-contact fatalities. Research has been conducted in this area but, to date, has not overcome the inherent problems of electrostatic-field detection units, or developed a feasible alternate method of line-proximity detection.

A solution of limited applicability, but potentially effective, is the after-the-fact indication of line contacts. Available technology could possibly be used to develop a warning device (primarily for dump-bed trucks) which would activate an alarm upon line contact.

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APPENDIX A

CRANE AND BOOM SAFETY LITERATURE

This appendix contains examples of material included in the Pennsylvania Power and Light Company's "Crane and Boom Safety Program" packet. Figures 22 through 28 exhibit sample transmittal letters, a safety pamphlet, an equipment warning sign, and posters [18]. This material is included by written permission of the Pennsylvania Power and Light Company.

CRANE AND BOOM SAFETY PROGRAM
SAMPLE LETTER TO CONTRACTORS, CATV COMPANIES, RAILROADS, FIRE COMPANIES, EQUIPMENT DEALERS, SCRAPYARDS, WELL DRILLING COMPANIES, OUTDOOR SIGN COMPANIES AND EQUIPMENT RENTAL AGENCIES

Dear ____________________:

Once again Pennsylvania Power & Light Company is promoting its safety campaign: PP&L's Crane Contact Program. The material prepared will help to understand the regulations concerning distances to be kept with high reaching equipment from electric lines set up under the Occupational Safety and Health Act (OSHA).

The purpose of the program is to reduce the number of contacts, between crane booms and electric wires, to the lowest number humanly possible. To help keep your operators alert while on the job, we are enclosing a sample permanent adhesive vinyl sticker. We recommend it be placed in plain view of equipment operators.

In addition to the sticker, we are enclosing a sample pamphlet, bulletin board poster and reminder of the regulations regarding crane boom and hoist operation in the proximity of electric lines. Please use the enclosed, postage-paid card to order sufficient copies of these materials, so you may post them, hand them out, and discuss their meaning with your employees.

The OSHA regulations state the distance that you may operate cranes, trucks, hoist elevators and conveyors from electric lines as:

KV Line	Working Clearance	Clearance In Transit
Up to 50	10 ft.	4 ft.
66	10 ft. 6 in.	10 ft.
115	12 ft. 2 in.	10 ft.
138	13 ft.	10 ft.
230	16 ft.	10 ft.
500	25 ft.	16 ft.

We realize that it may be difficult for you to determine the voltage carried by an overhead line; therefore, PP&L representatives are available to advise you of the voltage of the line and safe distances to keep with your equipment. Feel free to contact the local PP&L office.

We hope you'll join us in our safety campaign again this year. By keeping your equipment at OSHA regulated distances, needless injury or death resulting from equipment contact with electric lines can be avoided.

Very truly yours,

Figure 22. Sample letter to accompany the crane and boom safety packet, addressing parties involved with the use of high-reaching equipment [10].

CRANE AND BOOM SAFETY PROGRAM
SAMPLE LETTER TO UNION OFFICIALS

Dear ___________:

Once again at Pennsylvania Power & Light Company we are intensifying our safety efforts and asking for your help in assuring the success of one phase of our safety campaign: PP&L's Crane Contact Program.

Last year, various types of high-reaching equipment contacted our electric lines, putting in danger the lives of not only the operators of this equipment, but also the people working nearby. Regulations under the Occupational Safety and Health Act (OSHA) state that certain safe distances must be observed while operating cranes, derricks, hoists, elevators and conveyors near electric power lines. They are:

KV Line	Working Clearance	Clearance In Transit
Up to 50	10 ft.	4 ft.
66	10 ft. 6 in.	10 ft.
115	12 ft. 2 in.	10 ft.
138	13 ft.	10 ft.
230	16 ft.	10 ft.
500	25 ft.	16 ft.

Realizing that it may be difficult for you or your members to determine the correct voltage carried by an overhead line, PP&L representatives are available to advise your people on the job of the voltage and required distances to keep with equipment. Feel free to contact the local PP&L office.

Please use the enclosed postage-paid card to order sufficient copies of the enclosed safety materials. We urge you to display the poster where it will be read, distribute the pamphlet among your membership and make available the warning stickers for posting in equipment.

We would also appreciate it if you would promote this safety campaign in your meetings and personal contacts. By working together, we can cut down the number of crane contacts with power lines thus avoiding a needless risk of death or injury.

Very truly yours,

Figure 23. Sample letter to accompany the crane and boom safety packet, addressing union officials [10].

CRANE AND BOOM SAFETY PROGRAM
SAMPLE LETTER TO MUNICIPALITIES

Dear _____________:

Once again at Pennsylvania Power & Light Company, we are intensifying our safety efforts and asking for your help in assuring the success of one phase of our safety campaign: PP&L's Crane Contact Program.

In order to help prevent injury or even death to equipment operators which can result when contacts are made with electric lines, we are notifying various groups in the Company's service area who work with high-reaching equipment. Union officials are being told of our efforts. All of these groups are receiving the enclosed safety materials. PP&L employees are being alerted to be on the lookout for equipment being operated near power lines.

You can be of great help in a cooperative effort to substantially reduce the number of electric line contacts in the future by promoting our safety campaign through your meetings and numerous personal contacts at the local level. If you and your employees see work underway near electric lines, please contact the nearest PP&L office. We will then visit the work location and make arrangements for the equipment operators to proceed safely. Working together like this, we may save someone's life.

Very truly yours,

Figure 24. Sample letter to accompany the crane and boom safety packet, addressing municipalities [10].

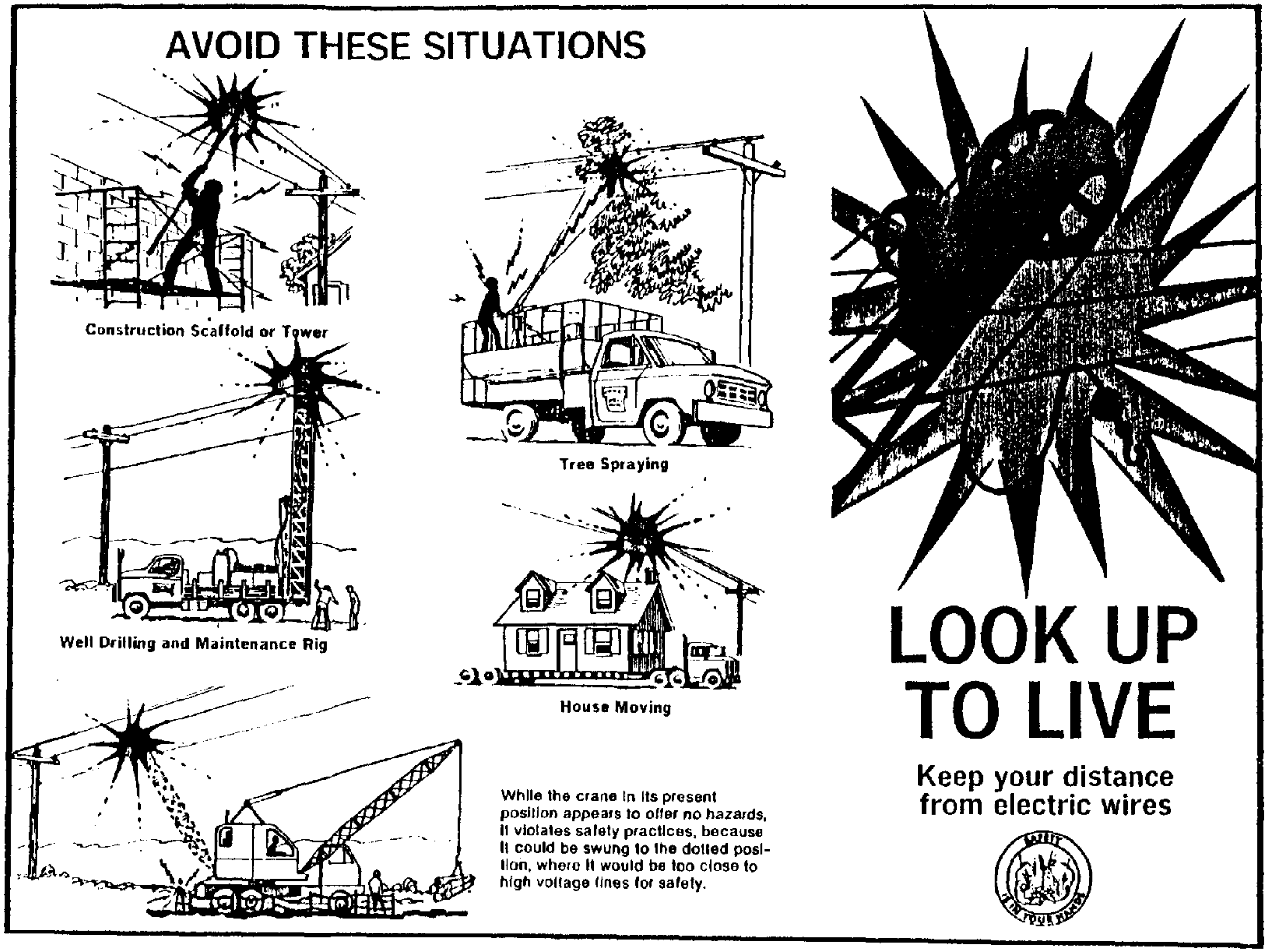
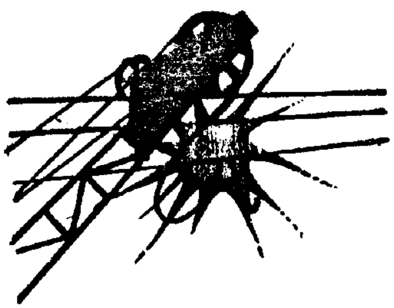


Figure 25. Pennsylvania Power and Light "Look Up to Live" pamphlet [10].



LOOK OUT! LOOK UP!

Power lines can be killers if you don't play it safe

Overhead power lines are normally safe . . . you can help keep them that way. If you operate any kind of high-reaching rig, don't risk tragedy to yourself, fellow workers or other persons at the scene.

Remember, electric lines are powerless only in one respect . . . they cannot avoid dangerous contact with your equipment. Only you can control that -- keep a safe distance away and prevent needless additions to "hot wire" fatalities and injuries which occur every year.

Thanks to the equipment operator's growing awareness of such accident potential, the number of crane and boom contacts with power lines is becoming fewer in PP&L's service area. Nevertheless, last year some of these unfortunate incidents did take place. Some due to open disregard . . . others simply the result of one forgetful moment. The ideal answer? Absolute prevention! Even one death or serious injury is one too many!

WHEN YOU WORK NEAR ELECTRIC LINES

- Provide for safe clearances . . . "look up" . . . keep those lines in sight!
- Arrange for proper safeguards through Pennsylvania Power & Light Company.
- Consider all wires "hot" even though they may appear harmless.
- Never touch a rig in motion near electric lines.
- Keep bystanders well away.

IF A POWER LINE CONTACT IS MADE

- Keep everyone clear of the rig, its load or fallen wires.
- Call the Pennsylvania Power & Light Company.
- Instruct the rig operator to stay on his rig and to move it away from the line if possible. He's safe if he doesn't step to the ground.
- Don't touch anyone who is in contact with the rig, the load or fallen wires.
- Have the power company de-energize the lines.
- If victim is not breathing, start artificial respiration* as soon as electrical contact is broken. Don't give up.

SECONDS COUNT!

*For your own safety and that of the people you work with, be sure you and your fellow workers learn the proper methods of resuscitation.

Important

To stay within the Occupational Safety and Health Act (OSHA) Regulations for the operation of cranes, booms and hoists (including power shovels, elevators and conveyors), WE URGE YOU TO FOLLOW THE OSHA REGULATIONS:

No person shall operate a crane or hoist so that any part of the equipment or the load is closer to an electric line than OSHA regulations permit except where, as a result of appropriate arrangements with the owner or operator of the electric line, (a) adequate insulating barriers have been erected or (b) the line has been de-energized.

OSHA regulations specify safe distances from electric lines depending on their voltage as:

KV	Working Clearances	Clearance In Transit
Up to 50	10 ft.	4 ft.
66	10 ft. 6 in.	10 ft.
115	12 ft. 2 in.	10 ft.
138	13 ft.	10 ft.
230	16 ft.	10 ft.
500	25 ft.	16 ft.

Help in determining the voltage of electric lines is available by calling a local Pennsylvania Power & Light Company office. PP&L will be happy to assist at the job site with voltage of line and distance you must keep away with equipment. If you will require this service please give the local PP&L office advance notice.

Figure 25. (Continued)

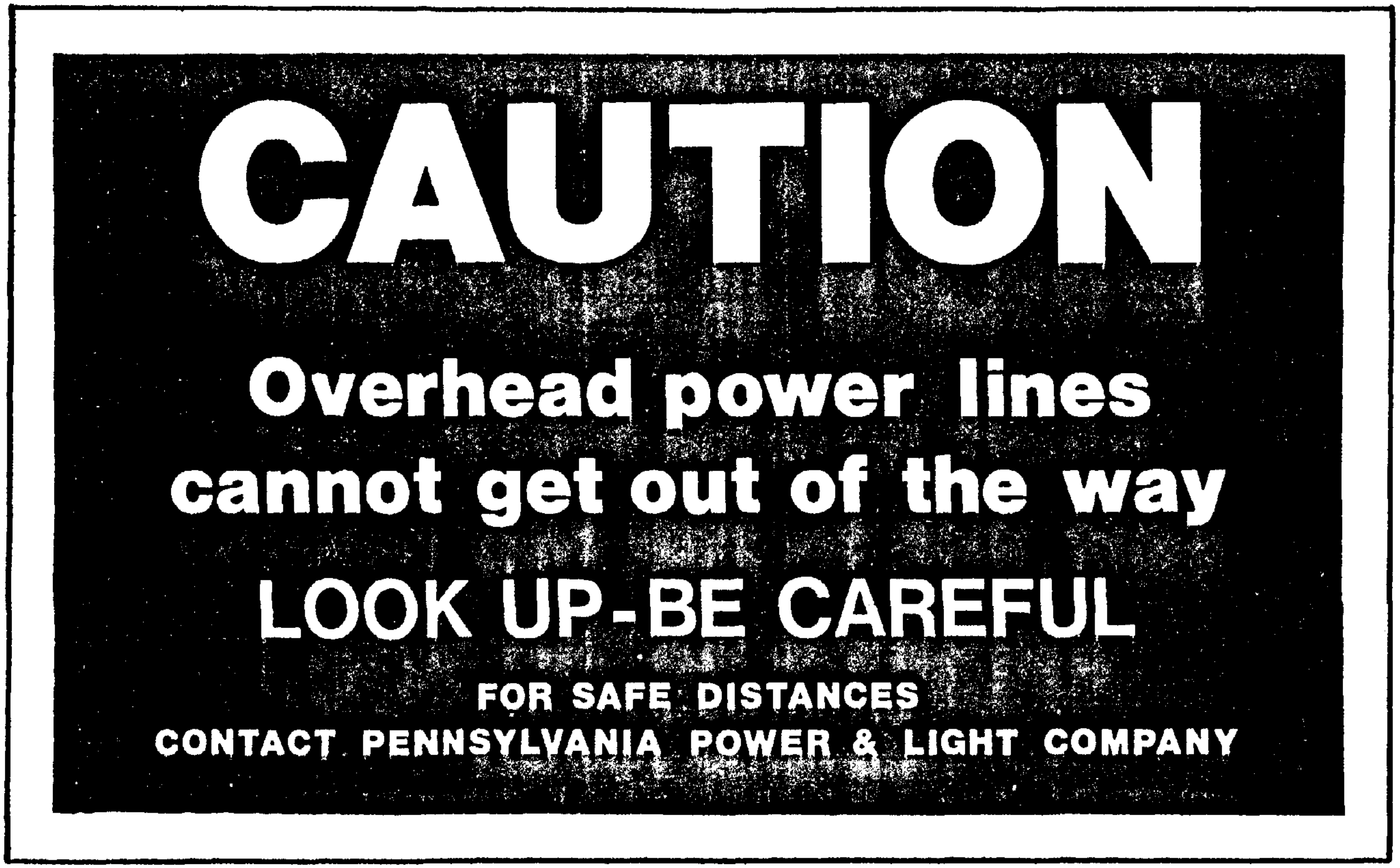


Figure 26. Self-adhesive warning sign for cabs and operating-control areas of mobile equipment [10].

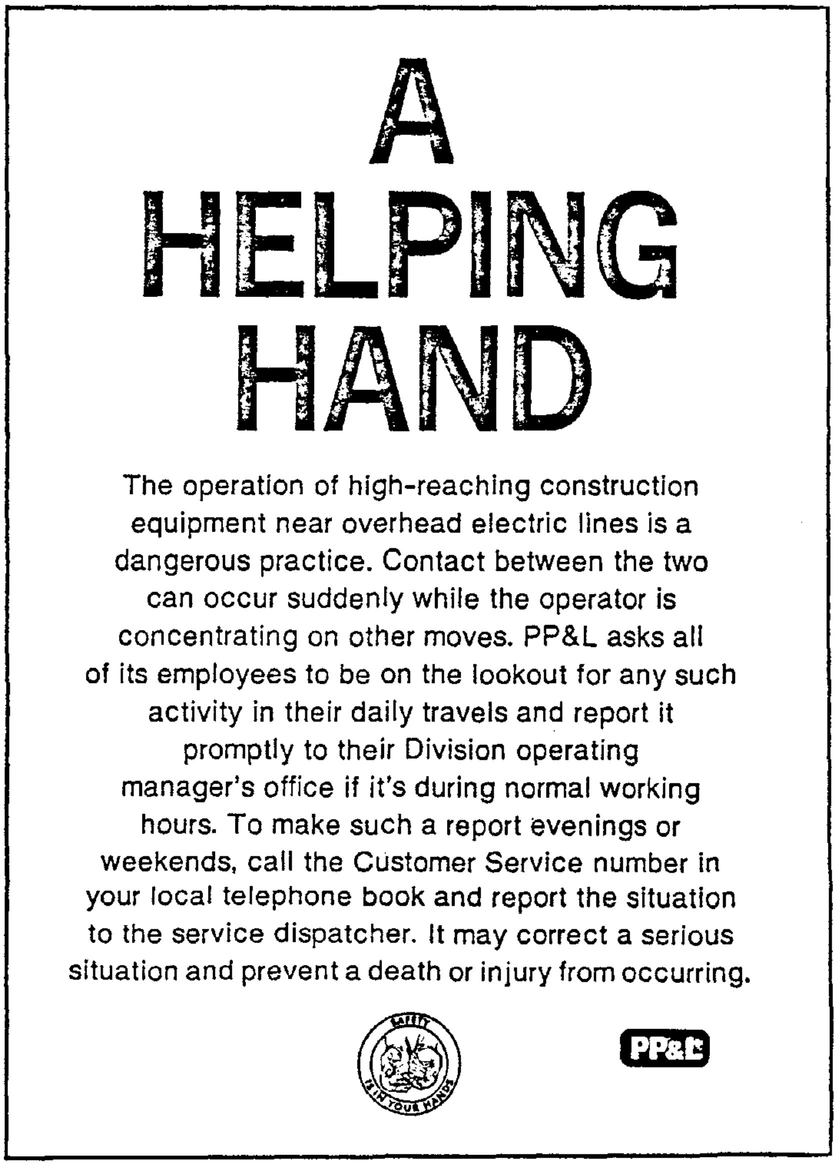


Figure 27. Overhead-line safety poster, directed toward utility employees [10].

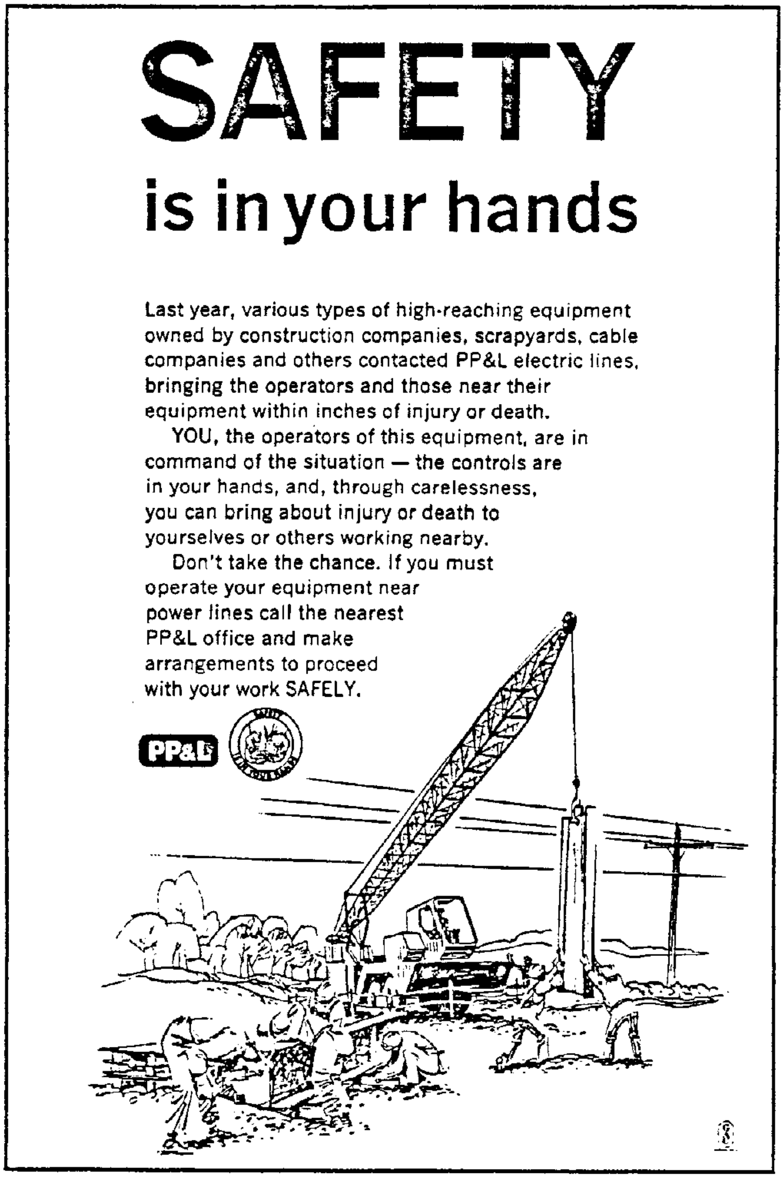


Figure 28. Overhead-line safety poster directed toward high-reaching equipment operators [10].

APPENDIX B

EXAMPLES OF SELECTED CHAPTER IV RECOMMENDATIONS

Section One

Figure 29 is a generalized plan view of a stockpile/railroad-loadout installation that could be a centralized dump for a number of small strip operations. In this figure are examples of recommendations 1, 2, and 3 of Chapter IV, showing a danger zone wherein overhead lines should be excluded. Areas of concern are the 100-foot limits about the truck scale, stockpile, and shop, and the exclusion of lines about the hopper, belt line, and rail-car loader. Notice also the line exclusion for the first 250 ft of the exit road, to allow for truck beds that have not been lowered completely.

Section Two

Figure 30 shows a sand-and-gravel processing installation such as may be located near a major construction project. This sketch illustrates the use of a 140-ft run of messenger-supported shielded-aerial cable for the approach to the plant area, as suggested in recommendation four. The shielded cable carries a primary distribution voltage of 12.4 kV to three, pole-mounted transformers. Insulated conductors either in buried conduit or run overhead, supply the various units at utilization voltage (likely 440 V). A plant as shown may often be of unitized portable construction and so the use of overhead shielded cable may be more appropriate for such a temporary situation than a buried high-voltage line [41]. The installation as shown greatly reduces the hazard to mobile equipment involved in erecting, altering, or repairing the plant structure.

Section Three

Figures 31 and 32 illustrate the use of barriers to restrict a truck-mounted vertical drill on a mine bench from the area below a 138-kV overhead line crossing the bench. Figure 31 shows the position of the line relative to the mine benches, and that the minimum vertical clearance over bench two will be 30 ft. The barriers are 24 ft horizontally from the nearest phase conductor, which is the distance required so that no part of the drill being used can come within 15 feet of a line (15 ft is the minimum clearance specified in 77.807-2, CFR, Title 30, for a line of this voltage). Figure 32 shows that 24 ft was chosen by considering the arc of mast movement which extends beyond the truck's front-most point. Therefore, the front bumper pulled against a barrier is the worst case, and 24 ft is required to keep the mast more than 15 ft from the lines.

This obviously leaves a short section of bench intact, and some alternate method may be required for fragmentation, such as using a smaller drill rig, angle drilling, or ripping (dozer). Another possibility is de-energizing the lines and/or drilling under direct utility-company supervision.

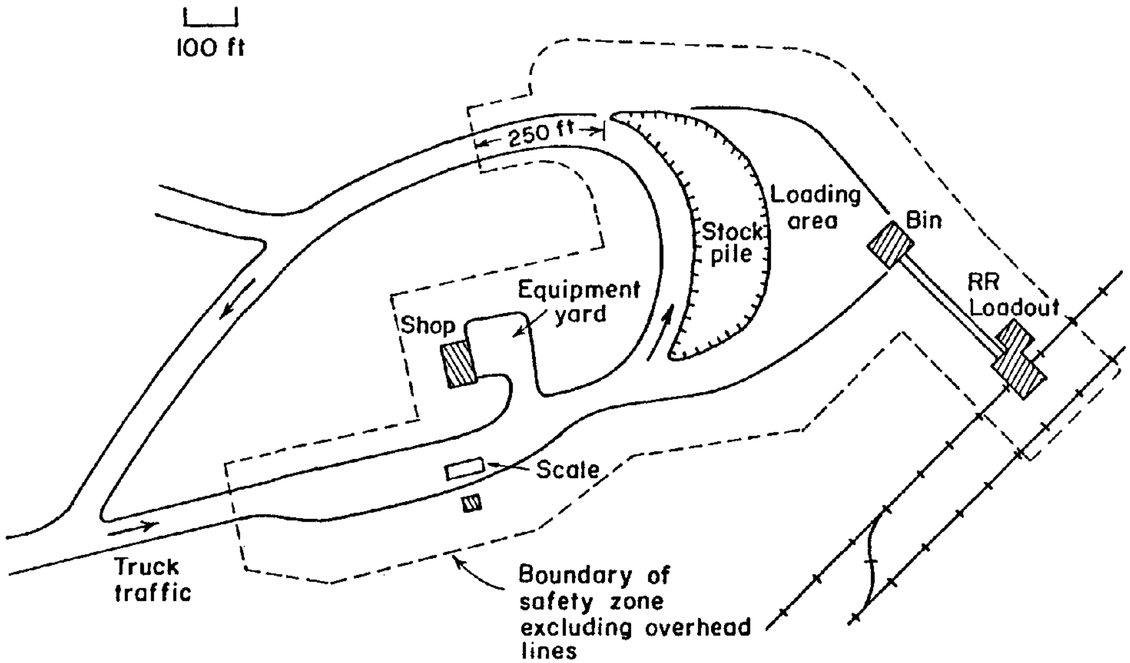


Figure 29. Coal-stockpile/railroad-loadout installation illustrating a recommended zone for exclusion of overhead lines.

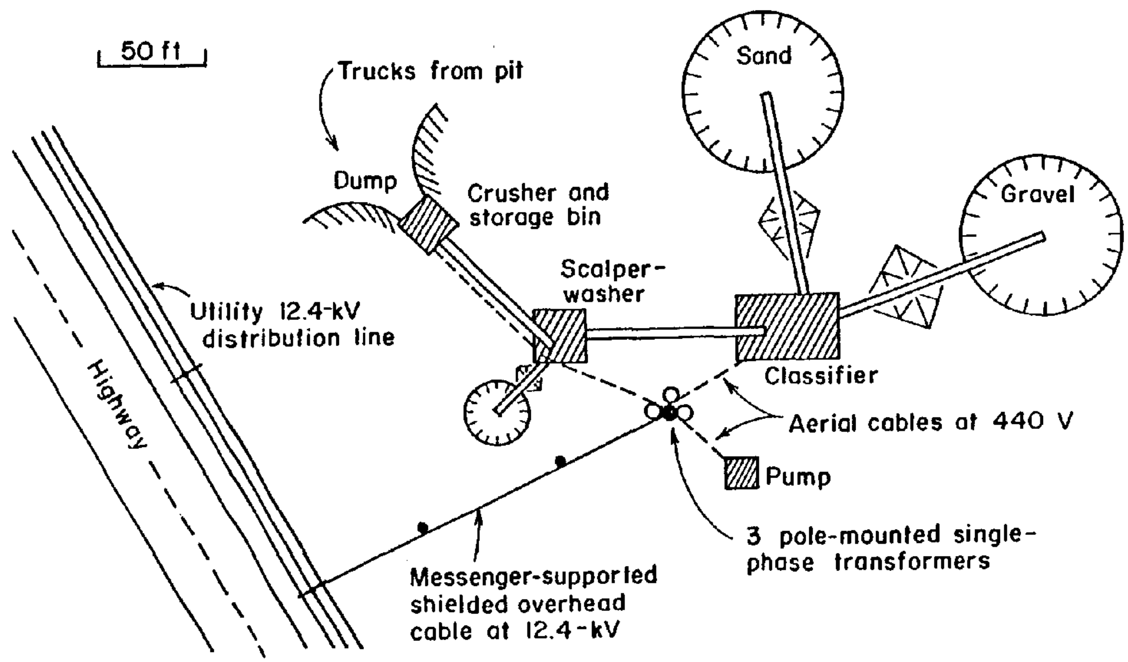


Figure 30. Layout of a sand-and-gravel processing plant with power supplied by a messenger-supported high-voltage shielded overhead cable.

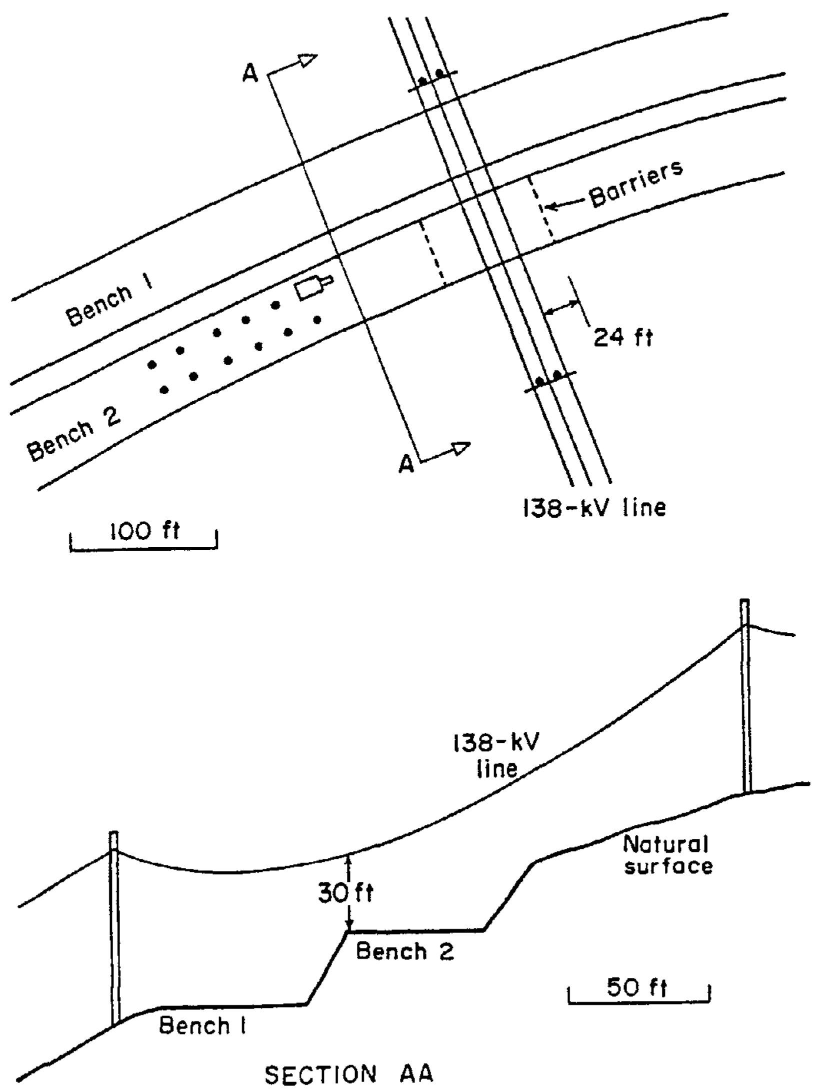


Figure 31. Mine benches shown with barriers to restrict equipment from area below overhead lines.

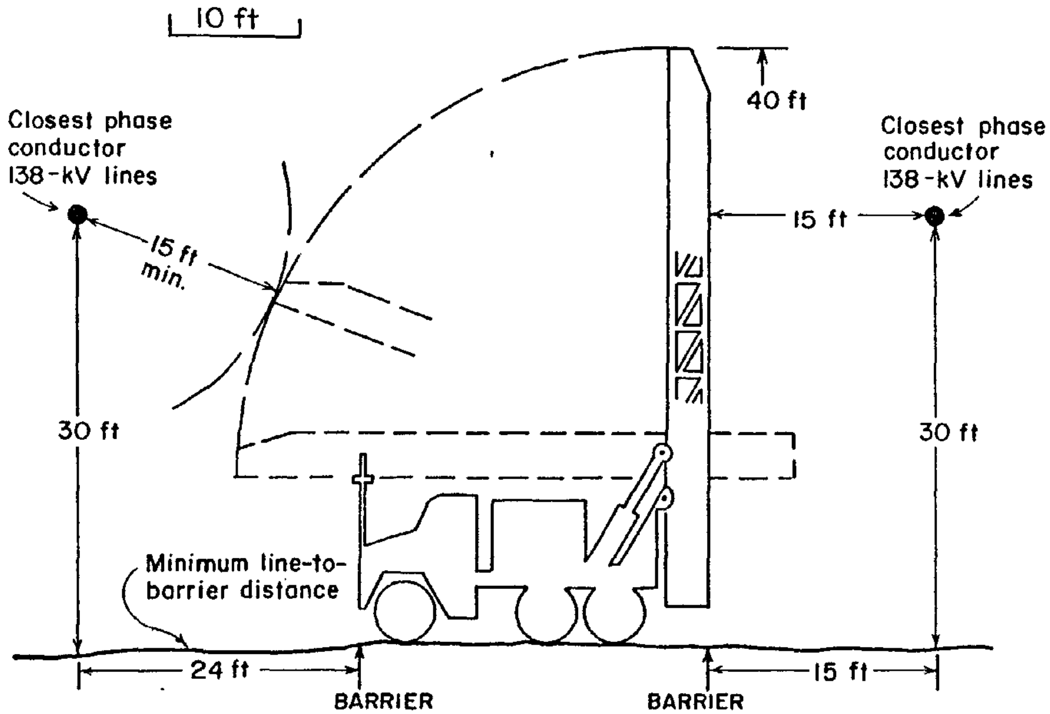


Figure 32. Determination of minimum line-to-barrier distance for the mine benches in Figure 31 and a given mobile drill rig.

Section Four

The application of passive warning is illustrated for several cases in Figures 33 and 34. Although notices and signs seen everyday lose their effect after a time, continual reminders to stay alert may help to prevent the electrocution of normally safe workers who may fail to concentrate on their job due to routine.

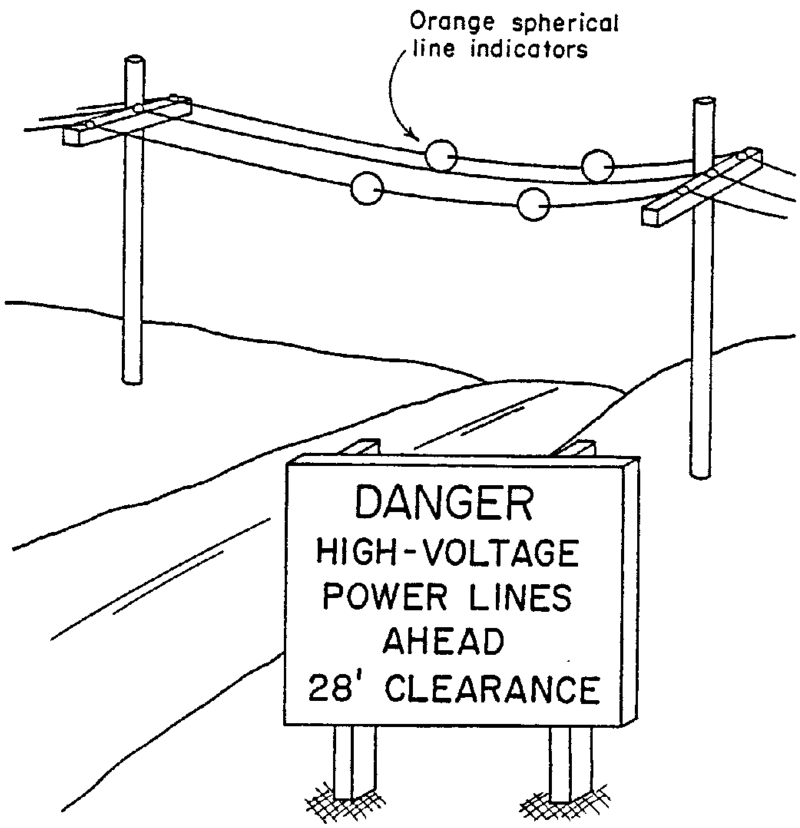


Figure 33. The use of warning signs and line indicators at an overhead-line road crossing.

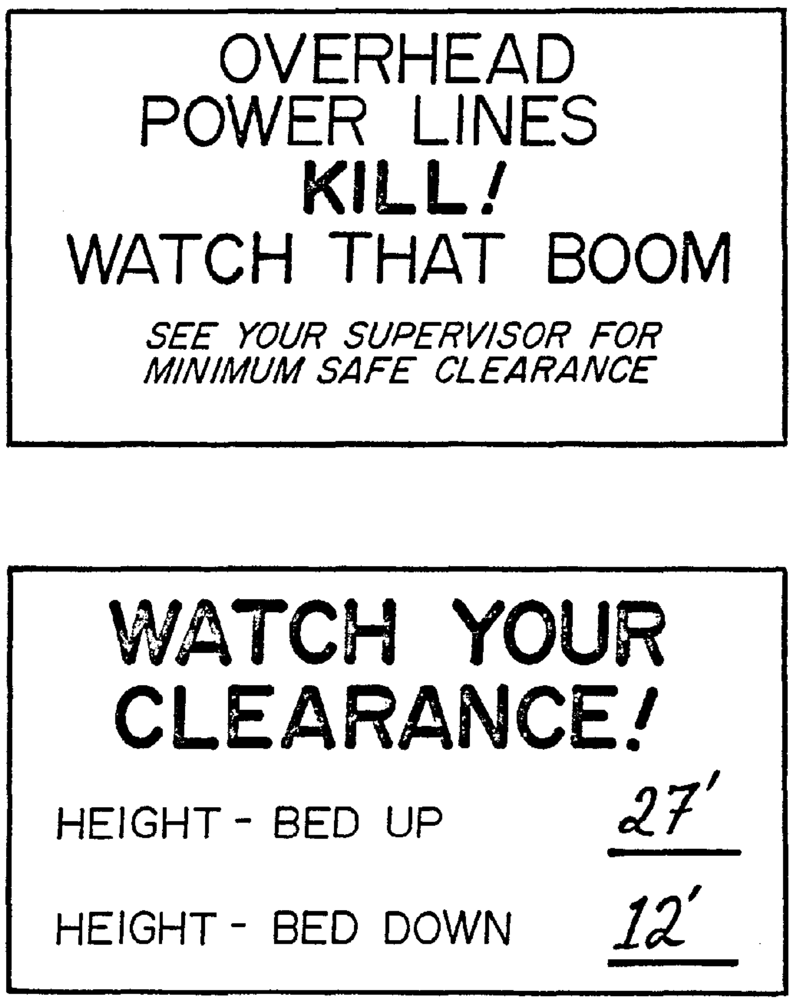


Figure 34. Examples of signs for cabs and control areas of mobile equipment.

APPENDIX C

BURIAL OF UNDERGROUND POWER CABLE

Where underground lines are used to supply power to a mining surface facility, a common method of installation is direct burial. In this method the cable is laid or drawn into an excavation which is then backfilled with the removed material or some filler to prevent cable damage. A concrete slab or some other nonmetallic shield is sometimes placed above the cable to prevent damage from future excavation. If the cable requires further protection from the backfill, ground movement, pressure, or moisture, direct burial can be replaced by the use of some type of cable duct, or conduits housing several ducts. Often these conduits are stone, tile, or fiber ducts surrounded by concrete [2].

Standards for the design and installation of underground power lines are found in Sections 30 through 38 of the National Electrical Safety Code [12]. These guidelines concern line location, clearances, depths, burial techniques, line protection, and associated equipment and installations. Figure 35 is a cross-section of a direct-buried cable installation.

Lines run are commonly multi-conductor shielded cables such as mine-power-feeder cable (MPF). Where additional protection is needed, as in wet direct-burial conditions, lead-jacketed cable can be used.

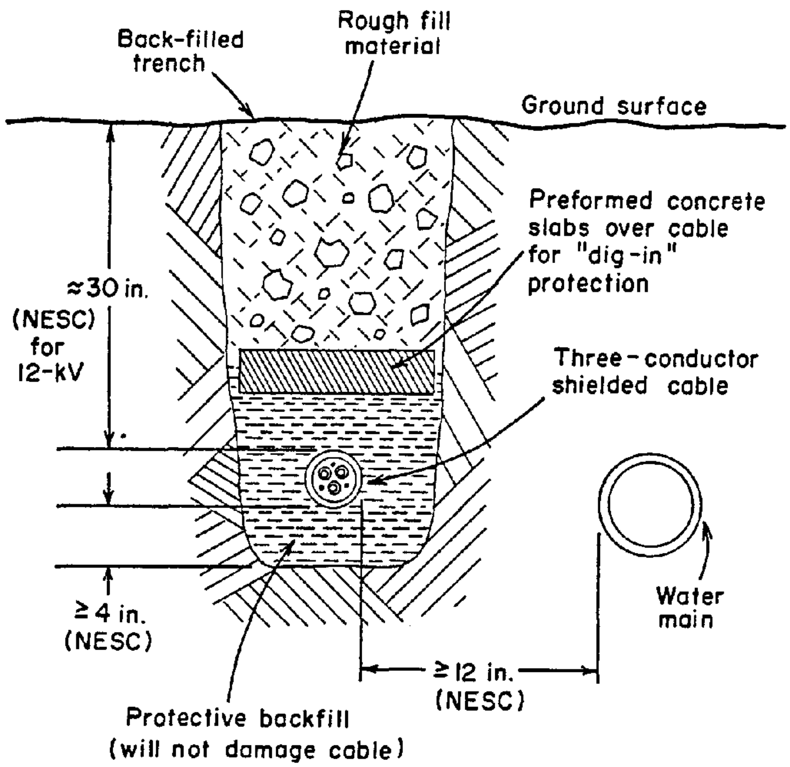


Figure 35. An example of a direct-buried cable installation, showing recommended practices and several NESC requirements.

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