WORKER DEATHS BY ELECTROCUTION

A Summary of NIOSH Surveillance and Investigative Findings

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
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PUBLIC HEALTH SUMMARY

What are the hazards?
Based on data from the NIOSH National Traumatic Occupational Fatalities (NTOF) surveillance system, electrocutions were the fifth leading cause of death from 1980 through 1992. The 5,348 deaths caused by electrocutions accounted for 7% of all fatalities and an average of 411 deaths per year.

How can a worker be exposed or put at risk?
Electricity is present at most jobsites, and many American workers, regardless of industry or occupation, are exposed to electrical energy daily during the performance of their tasks. These hazardous exposures may exist through contact with an object as seemingly innocuous as a broken light bulb to an energized overhead powerline.

What recommendations has the federal government made to protect workers' health?
The Occupational Safety and Health Administration (OSHA) addresses electrical safety in Subpart S 29 CFR 1910.302 through 1910.399 of the General Industry Safety and Health Standards. The standards contain requirements that apply to all electrical installations and utilization equipment, regardless of when they were designed or installed. Subpart K of 29 CFR 1926.402 through 1926.408 of the OSHA construction safety and health standards contain installation safety requirements for electrical equipment and installations used to provide electric power and light at the jobsite. These sections apply to both temporary and permanent installations used on the jobsite. Additionally, the National Electrical Code (NEC) and the National Electrical Safety Code (NESC) comprehensively address electrical safety regulations. NIOSH recommendations focusing on prevention are included in this Technical Document.

Where can more information be found?
The references at the end of this document provide a useful inventory of published reports and literature. Additional information from NIOSH can be obtained by calling the following number:

1-800-35-NIOSH
(800-356-4674)

INTRODUCTION

Nancy A. Stout, Ed.D.

Many American workers are exposed to electrical energy daily during the performance of their tasks. This monograph highlights the magnitude of the problem of occupational electrocutions in the U.S., identifies potential risk factors for fatal injury, and provides recommendations for developing effective safety programs to reduce the risk of electrocution.

This monograph summarizes surveillance data and investigative reports of fatal incidents involving workers who contacted energized electrical conductors or equipment. The surveillance data were derived from the National Traumatic Occupational Fatalities (NTOF) surveillance system maintained by the National Institute for Occupational Safety and Health (NIOSH). The NTOF data are based on death certificates of workers 16 years or older who died from a traumatic injury in the workplace. The fatality investigations were conducted as part of the NIOSH Fatality Assessment and Control Evaluation (FACE) program. FACE is a research program for the identification and investigation of fatal occupational injuries. The goal of the FACE program is to collect information on factors that may have contributed to traumatic occupational fatalities using an epidemiologic approach, and to develop and disseminate recommendations for preventing similar events in the future.

Based on the NTOF surveillance data for the period from 1980 through 1992, 5,348 workers died from contact with electrical energy (an average of 411 deaths per year). Electrocutions were the fifth leading cause of death, accounting for 7% of all workplace fatalities. In the 12 year period from 1982 through 1994, NIOSH investigated 224 electrocution incidents which resulted in 244 worker fatalities.

Part I of this monograph provides: an overview of electrical hazards, including the effects of electrical energy on the human body; a comprehensive summary of the epidemiology of occupational electrocutions based on NTOF and FACE data which identifies common risk factors for fatal injury due to contact with electrical energy; and recommendations for elements of an effective electrical safety program for the prevention of workplace electrocutions. Part II includes a summary abstract for all 224 FACE electrocution investigative reports prepared by NIOSH for further information and reference.

Our hope is that this monograph will serve as a valuable resource for safety and public health professionals, safety and health trainers, researchers, and others who can affect the prevention of occupational electrocutions.

PART I

ELECTROCUTION-RELATED FATALITIES

OVERVIEW OF ELECTRICAL HAZARDS

Virgil Casini, B.S.

Electricity is a ubiquitous energy agent to which many workers in different occupations and industries are exposed daily in the performance of their duties. Many workers know that the principal danger from electricity is that of electrocution, but few really understand just how minute a quantity of electrical energy is required for electrocution. In reality, the current drawn by a tiny 7.5 watt, 120-volt lamp, passed from hand to hand or hand to foot across the chest is sufficient to cause electrocution.[1] The number of people who believe that normal household current is not lethal or that powerlines are insulated and do not pose a hazard is alarming. Electrocutions may result from contact with an object as seemingly innocuous as a broken light bulb or as lethal as an overhead powerline, and have affected workers since the first electrical fatality was recorded in France in 1879 when a stage carpenter was killed by an alternating current of 250 volts.[2]

The information in the following two sections (**DEFINITIONS** and **EFFECTS OF ELECTRICAL ENERGY**) is intended as a basic explanation of electricity and the effects of electrical energy. Unless otherwise indicated, information in these sections is derived from OSHA electrical standards,[3,4] the National Electrical Code (NEC),[5] and the National Electrical Safety Code.[6] Official definitions of electrical terms can be found in these same documents.

DEFINITIONS

Electricity is the flow of an atom's electrons through a conductor. ***Electrons***, the outer particles of an atom, contain a negative charge. If electrons collect on an object, that object is ***negatively charged***. If the electrons flow from an object through a conductor, the flow is called ***electric current***. Four primary terms are used in discussing electricity: voltage, resistance, current, and ground.

Voltage is the fundamental force or pressure that causes electricity to flow through a conductor and is measured in volts. ***Resistance*** is anything that impedes the flow of electricity through a conductor and is measured in Ohms. ***Current*** is the flow of electrons from a source of voltage through a conductor and is measured in amperes (Amps). If the current flows back and forth (a cycle) through a conductor, it is called ***alternating current (AC)***. In each cycle the electrons flow first in one direction, then the other. In the United States, the normal rate is 60 cycles per second [or 60 Hertz (Hz)]. If current flows in one direction only (as in a car battery), it is called ***direct current (DC)***.

AC is most widely used because it is possible to step up or step down (i.e., increase or decrease) the current through a transformer. For example, when current from an overhead powerline is run through a pole-mounted transformer, it can be stepped down to normal household current.

Ohm's Law (Current=Voltage/Resistance) can be used to relate these three elements mathematically.

A ***ground*** is a conducting connection, whether or not unintentional, between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth.

EFFECTS OF ELECTRICAL ENERGY

Electrical injuries consist of four main types: electrocution (fatal), electric shock, burns, and falls caused as a result of contact with electrical energy.

Electrocution results when a human is exposed to a lethal amount of electrical energy. To determine how contact with an electrical source occurs, characteristics of the electrical source before the time of the incident must be evaluated (pre-event). For death to occur, the human body must become part of an active electrical circuit having a current capable of overstimulating the nervous system or causing damage to internal organs. The extent of injuries received depends on the current's magnitude (measured in Amps), the pathway of the current through the body, and the duration of current flow through the body (event). The resulting damage to the human body and the emergency medical treatment ultimately determine the outcome of the energy exchange (post-event).[7]

Electrical injuries may occur in various ways: direct contact with electrical energy, injuries that occur when electricity arcs (an arc is a flow of electrons through a gas, such as air) to a victim at ground potential (supplying an alternative path to ground), flash burns from the heat generated by an electrical arc, and flame burns from the ignition of clothing or other combustible, nonelectrical materials. Direct contact and arcing injuries produce similar effects. Burns at the point of contact with electrical energy can be caused by arcing to the skin, heating at the point of contact by a high-resistance contact, or higher voltage currents. Contact with a source of electrical energy can cause external as well as internal burns. Exposure to higher voltages will normally result in burns at the sites where the electrical current enters and exits the human body. High voltage contact burns may display only small superficial injury; however, the danger of these deep burns destroying tissue subcutaneously exists.[8] Additionally, internal blood vessels may clot, nerves in the area of the contact point may be damaged, and muscle contractions may cause skeletal fractures either directly or in association with falls from elevation.[9] It is also possible to have a low-voltage electrocution without visible marks to the body of the victim.

Flash burns and flame burns are actually thermal burns. In these situations, electrical current does not flow through the victim and injuries are often confined to the skin.

Contact with electrical current could cause a muscular contraction or a startle reaction that could be hazardous if it leads to a fall from elevation (ladder, aerial bucket, etc.) or contact with dangerous equipment.[10]

The NEC describes high voltage as greater than 600 volts AC.[5] Most utilization circuits and equipment operate at voltages lower than 600 volts, including common household circuits (110/120 volts); most overhead lighting systems used in industry or office buildings and department stores; and much of the electrical machinery used in industry, such as conveyor systems, and manufacturing machinery such as weaving machines, paper rolling machines or industrial pumps.

Voltages over 600 volts can rupture human skin, greatly reducing the resistance of the human body, allowing more current to flow and causing greater damage to internal organs. The most common high voltages are transmission voltages (typically over 13,800 volts) and distribution voltages (typically under 13,800 volts). The latter are the voltages transferred from the power generation plants to homes, offices, and manufacturing plants.

Standard utilization voltages produce currents passing through a human body in the milliampere (mA) range (1,000 mA=1 Amp). Estimated effects of 60 Hz AC currents which pass through the chest are shown in Table 1.

Table 1. *Estimated Effects of 60 Hz AC Currents*

1 mA	Barely perceptible
16 mA	Maximum current an average man can grasp and "let go"
20 mA	Paralysis of respiratory muscles
100 mA	Ventricular fibrillation threshold
2 Amps	Cardiac standstill and internal organ damage
15/20 Amps	Common fuse or breaker opens circuit*

*Contact with 20 milliamps of current can be fatal. As a frame of reference, a common household circuit breaker may be rated at 15, 20, or 30 amps.

When current greater than the 16 mA "let go current" passes through the forearm, it stimulates involuntary contraction of both flexor and extensor muscles. When the stronger flexors dominate, victims may be unable to release the energized object they have grasped as long as the current flows. If current exceeding 20 mA continues to pass through the chest for an extended time, death could occur from respiratory paralysis. Currents of 100 mA or more, up to 2 Amps, may cause ventricular fibrillation, probably the most common cause of death from electric shock.[11] Ventricular fibrillation is the uneven pumping of the heart due to the uncoordinated, asynchronous contraction of the ventricular muscle fibers of the heart that leads quickly to death from lack of oxygen to the brain. Ventricular fibrillation is terminated by the use of a defibrillator, which provides a pulse shock to the chest to restore the heart rhythm. Cardiopulmonary resuscitation (CPR) is used as a temporary care measure to provide the circulation of some oxygenated blood to the brain until a defibrillator can be used.[23]

The speed with which resuscitative measures are initiated has been found to be critical. Immediate defibrillation would be ideal; however, for victims of cardiopulmonary arrest, resuscitation has the greatest rate of success if CPR is initiated within 4 minutes and advanced cardiac life support is initiated within 8 minutes (National Conference on CPR and ECC, 1986).[6]

The presence of moisture from environmental conditions such as standing water, wet clothing, high humidity, or perspiration increases the possibility of a low-voltage electrocution. The level of current passing through the human body is directly related to the resistance of its path through the body. Under dry conditions, the resistance offered by the human body may be as high as 100,000 Ohms. Wet or broken skin may drop the body's resistance to 1,000 Ohms. The following illustrations of Ohm's law demonstrates how moisture affects low-voltage electrocutions. Under dry conditions, Current=Volts/Ohms = 120/100,000 = 1 mA, a barely perceptible level of current. Under wet conditions, Current=Volts/Ohms = 120/1,000 = 120 mA, sufficient current to cause ventricular fibrillation. Wet conditions are common during low-voltage electrocutions.

High-voltage electrical energy quickly breaks down human skin, reducing the human body's resistance to 500 Ohms. Once the skin is punctured, the lowered resistance results in massive current flow, measured in Amps. Again, Ohm's law is used to demonstrate the action. For example, at 1,000 volts,

Current=Volts/Ohms = 1000/500 = 2 Amps, which can cause cardiac standstill and serious damage to internal organs.

CONCLUSIONS

Electrical hazards represent a serious, widespread occupational danger; practically all members of the workforce are exposed to electrical energy during the performance of their daily duties, and electrocutions occur to workers in various job categories. Many workers are unaware of the potential electrical hazards present in their work environment, which makes them more vulnerable to the danger of electrocution.

The Occupational Safety and Health Administration (OSHA) addresses electrical safety in Subpart S 29 CFR 1910.302 through 1910.399 of the General Industry Safety and Health Standards.[3] The standards contain requirements that apply to all electrical installations and utilization equipment, regardless of when they were designed or installed. Subpart K of 29 CFR 1926.402 through 1926.408 of the OSHA Construction Safety and Health Standards[4] contain installation safety requirements for electrical equipment and installations used to provide electric power and light at the jobsite. These sections apply to both temporary and permanent installations used on the jobsite.

Additionally, the National Electrical Code (NEC)[5] and the National Electrical Safety Code (NESC)[6] comprehensively address electrical safety regulations. The purpose of the NEC is the practical safeguarding of persons and property from hazards arising from the use of electricity. The NEC contains provisions considered necessary for safety and applies to the installation of electric conductors and equipment within or on public or private buildings or other structures, including mobile homes, recreational vehicles, and floating buildings; and other premises such as yards; carnival, parking, and other lots; and industrial substations. The NEC serves as the basis for electrical building codes across the United States.

The NESC contains rules necessary for the practical safeguarding of persons during the installation, operation, or maintenance of electric supply and communication lines and associated equipment. These rules contain the basic provisions that are considered necessary for the safety of employees and the public under the specified conditions. Unlike the NEC, the NESC contains work rules in addition to installation requirements.

EPIDEMIOLOGY OF ELECTROCUTION FATALITIES

Suzanne Kisner, B.S., Virgil Casini, B.S.

Occupational fatalities associated with electrocutions are a significant, ongoing problem. Data from the NIOSH National Traumatic Occupational Fatality (NTOF) surveillance system indicated that an average of 6,359 traumatic work-related deaths occurred each year in the United States from 1980 through 1989; an estimated 7% of these fatalities were due to electrocutions.[12] In 1995, the Bureau of Labor Statistics reported that electrocutions accounted for 6% of all worker deaths.[13] For the year 1990, the National Safety Council reported that electrocutions were the fourth leading cause of work-related traumatic death.[14]

A review of hazards in the farming industry showed that electrocutions accounted for about 7% of all agricultural work-related deaths.[15] The specific hazards involved in these electrocutions include internal wiring in farm buildings, buried electrical cables, and overhead powerlines.[15] A study of work-related electrocution deaths was conducted using data from the Occupational Safety and Health Administration (OSHA) Integrated Management Information System (IMIS).[16] This study identified 944 work-related electrocutions for the period 1984 to 1986; 61% of these fatalities were caused by contact with high-voltage powerlines. From 1980 through 1989, NIOSH reported an average of 15 electrocutions each year were caused by contact between cranes or some other type of boomed vehicles and energized, overhead powerlines.[17]

NTOF ANALYSIS

Methods

The National Traumatic Occupational Fatalities (NTOF) surveillance system is composed of information taken from death certificates for decedents 16 years of age or older with a positive response to the "Injury at Work?" item, and an external cause of death (International Classification of Diseases, Ninth Revision [ICD-9]; E800-E999).[18] Electrocutions which occurred from 1980 through 1992 were identified by selecting those cases which had an ICD-9 code of "E925-accident caused by electrical current."

An initial manual review identified certain events that occurred with greater frequency. Based on this review, 17% of the cases with specific circumstances were grouped through keyword searches of the literal information from the death certificates. A keyword search was done for "crane," "boom," "hoist," and "rigging" to identify electrocutions involving boomed vehicles. Electrocutions involving ladders and scaffolds were identified through a search for "ladders" and "scaffolds." A keyword search was conducted for "short cir," "faulty," "shorted," "defective," "malfunctioning," "short," and "damaged," to identify those electrocutions involving contact with a short-circuited, damaged, or improperly installed wire or equipment. Contacts with a truck or other vehicle were located using the keywords "truck" and "vehicle." Electrocutions involving grain augers and elevators were found through a search for "auger" and "elevator." Because of the level of detail contained on death certificates, specific circumstances surrounding most of the deaths were not as easily categorized. For most of the remaining cases, the circumstances surrounding the electrocutions were missing, incom-

plete, or vague. While these cases were not removed from the analysis, to assign them to specific groups would involve a much more detailed review, which is not possible with death certificate data alone.

Industry was coded into division-level industry categories using the 1987 Standard Industrial Classification System.[19] Occupation was grouped into major occupation divisions according to the 1980 and 1990 Bureau of the Census Occupational Classification System.[20,21] Employment estimates used to calculate fatality rates were extracted from the Bureau of Labor Statistics' *Employment and Earnings* annual average employment data.[22] The employment data from *Employment and Earnings* are based on the annual averages from the Current Population Survey, a sample survey of the population 16 years of age and over.

A detailed description and the limitations of the NTOF surveillance system have been reported previously.[12] Because the amount of detail on death certificates is sometimes limited and death certificates are known to capture approximately 81% of all work-related deaths,[23] the number of electrocutions presented should be considered the minimum number of deaths.

Results

A total of 5,348 workers were electrocuted in 5,180 incidents from 1980 through 1992. One-hundred fifty-three (3%) of the fatal incidents resulted in multiple fatalities: 140 incidents involved 2 victims each, 11 incidents involved 3 victims each, and 2 incidents involved 4 victims each.

An average of 411 workers were electrocuted each year, with an average annual rate of 0.4 per 100,000 workers. Figure 1 provides the frequency and rate per 100,000 workers of electrocutions by year of death. The substantial decrease is noteworthy, but it varies by industry. While total work-related fatalities decreased 23% from 1980 to 1989,[24] the number of electrocution deaths have decreased by more than 50% from 1980 to 1992.

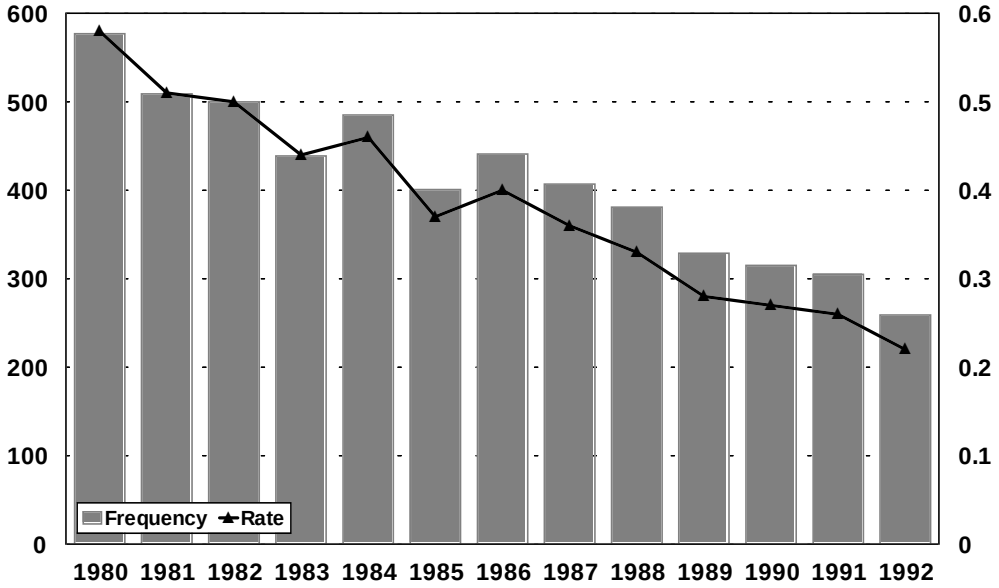

Figure 1. *Frequencies and Rates of Electrocution Deaths Identified by NTOF by Year, 1980-1992*

Sixty percent of the electrocutions occurred to workers less than 35 years of age. Figure 2 provides frequencies and rates per 100,000 workers of electrocutions by age group.

Ninety-nine percent of the electrocutions occurred among men. Whites accounted for 86% of the electrocutions, followed by Blacks (7.1%), Hispanics (5.3%), Asians (0.4%), Native Americans (0.3%), and other and unknown races (0.8%).

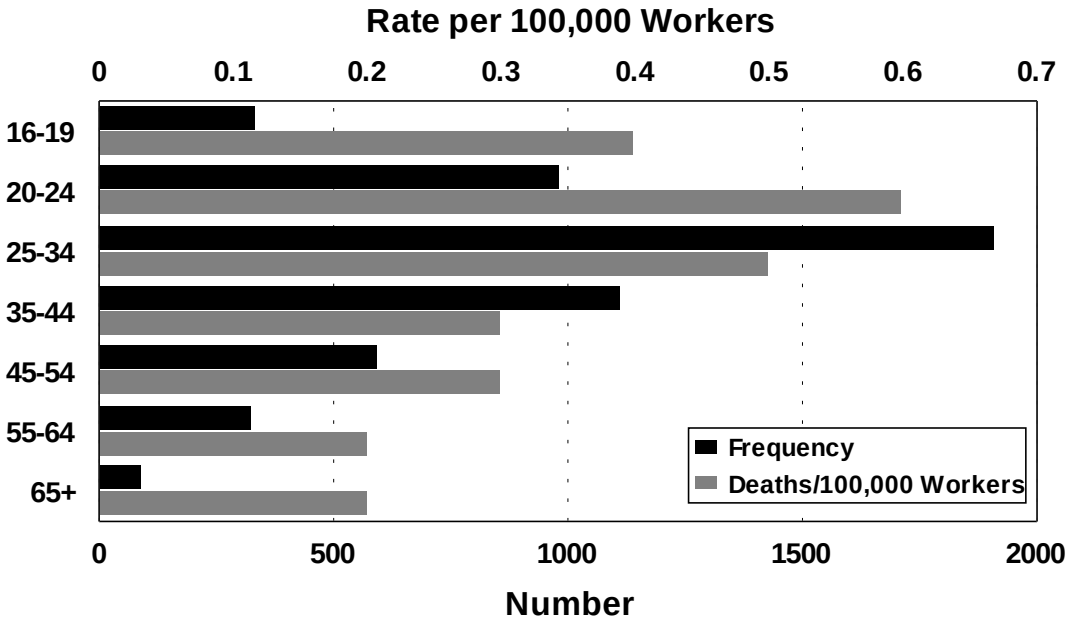

Figure 2. *Frequencies and Rates of Electrocution Deaths Identified by NTOF by Age Group, 1980-1992*

The industries with the highest percentage of electrocutions were construction (40%), transportation/ communication/public utilities (16%), manufacturing (12%), and agriculture/forestry/fishing (11%) (Figure 3). The construction industry had a rate of 2.4 per 100,000 workers, followed closely by mining which had a rate of 2.2 (Figure 3).

Over the 13-year period, 61% of the electrocutions occurred in two occupation divisions: 46% among craftsmen and 15% among laborers (Figure 4). These two groups also had the highest rates of electrocution death: 1.4 per 100,000 workers each (Figure 4).

Much of the information from death certificates for decedents involved in electrocutions is vague. However, certain circumstances were easily identifiable. Three-hundred thirty-seven (6%) of the victims contacted a boomed vehicle that was in contact with an energized power source. Two-hundred seventeen (4%) contacted a ladder or scaffold that was in contact with an energized power source. One-hundred fifty-three (3%) contacted short-circuited, damaged, or improperly installed wire or equipment. One-hundred twenty-nine (2%) contacted a truck or other vehicle, other than a boomed vehicle, which was in contact with an energized power source. Eighty-two (2%) contacted an energized grain auger or grain elevator. As previously described, the specific circumstances surrounding the electrocutions in the remaining 83% of the deaths were not categorized in these data.

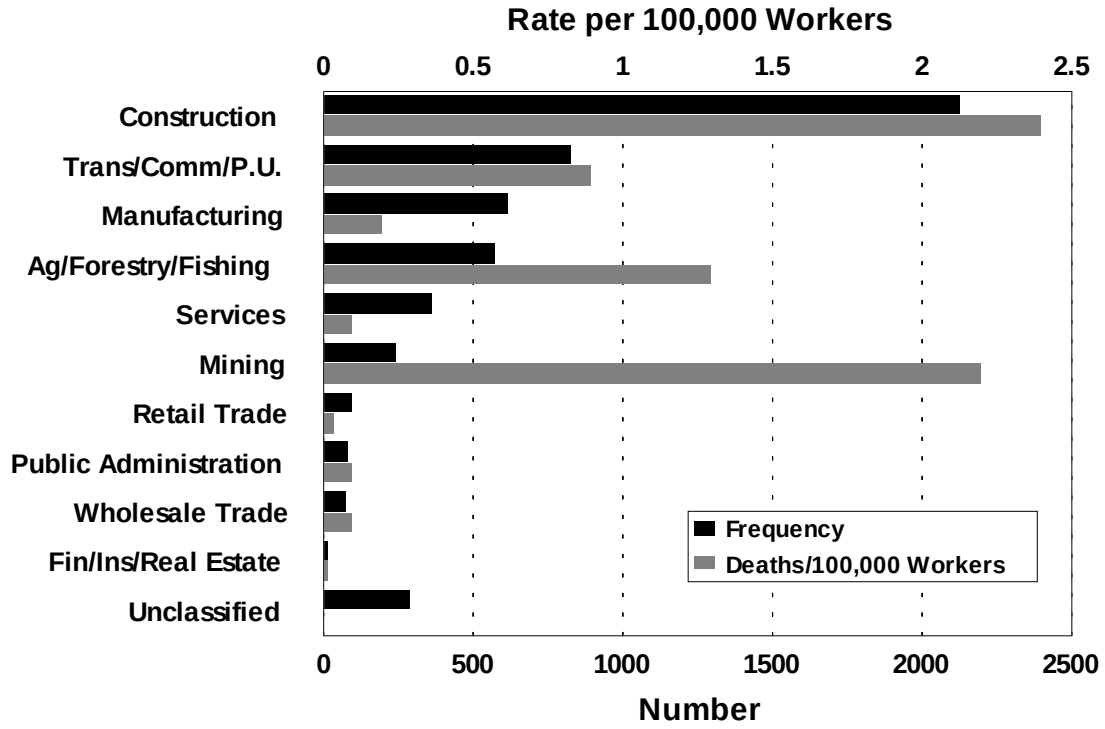

Figure 3. *Frequencies and Rates of Electrocution Deaths Identified by NTOF by Industry, 1980-1992*

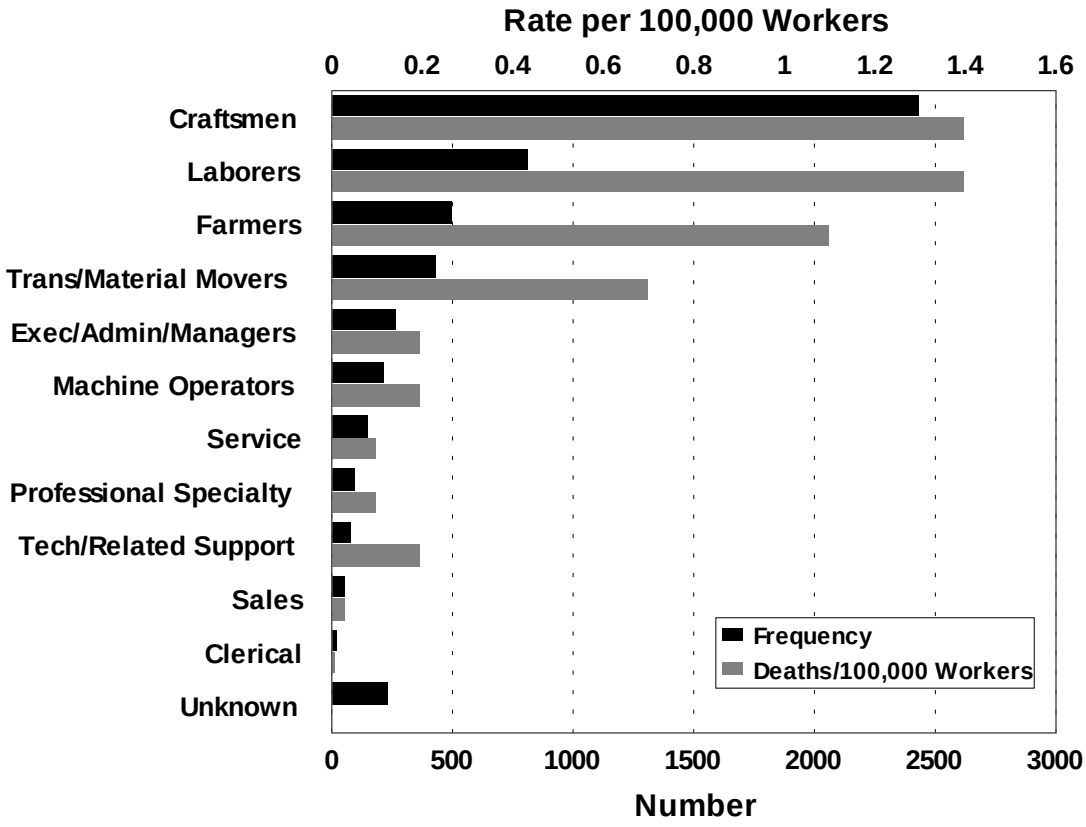

Figure 4. *Frequencies and Rates of Electrocution Deaths Identified by NTOF by Occupation, 1980-1992*

FATALITY ASSESSMENT AND CONTROL EVALUATION (FACE) INVESTIGATIONS

Methods

During the period from November 1982 to December 1994, NIOSH investigated 224 electrocution incidents resulting in 244 occupational fatalities.[25] These investigations were undertaken as part of the Fatality Assessment and Control Evaluation (FACE) program conducted by (NIOSH). The FACE program was initiated in 1982 and directed from its inception by the NIOSH Division of Safety Research. FACE is a research program for the identification and investigation of fatal occupational injuries.

Derived from the research conducted by William Haddon, Jr. (the Haddon model), this approach reflects the public health perception that the etiology of injuries is multifactorial and largely preventable.[26] For each case, factors associated with the agent (mode of energy exchange), the host (the worker who died) and the environment are identified during the pre-event, event, and post-event time phases. These contributory factors are investigated in detail in each FACE incident, and are summarized in each FACE summary report, along with recommendations for preventing future incidents of a similar nature.

Investigators conducted investigations at the incident sites, evaluating each event's circumstances, including agent, host, and environmental characteristics. When an incident involved multiple fatalities, data were collected for each victim. Percentages presented here describe frequencies of incident characteristics. Rates could not be calculated due to the lack of comparable denominator data. Percentages do not necessarily reflect the risk to workers, but rather describe the problem's proportional magnitude.

Industry was coded into categories using the 1987 Standard Industrial Classification System[31] and occupations were grouped using the 1980 Bureau of the Census Occupational Classification System.[32]

Results

The victims (243 men and 1 woman) ranged in age from 17 to 70 years, and the mean age was 34 years. The loss of years of potential life before age 65 was substantial; for the 244 victims discussed in this analysis, the years of potential life lost (YPLL) equaled 7,903 years or an average of 33 years per victim. Sixty-four percent of the victims died prior to age 35 (Figure 5).

The industries with the highest number of electrocutions were Construction (121); followed by Manufacturing (40); Transportation, Communications, Public Utilities (30); and Public Administration (19) (Figure 6).

Figure 7 shows the 10 job classifications (occupations) with the highest number of fatalities. Although utility line workers (linemen) typically receive extensive training in electrical safety and the hazards associated with electrical energy, they had the highest number of fatal injuries. Twenty-six (55%) utility line worker fatalities were due to the failure to utilize required personal protective equipment (gloves, sleeves, mats, blankets, etc.). Laborers, who generally receive little or no electrical training, were the next highest classification.

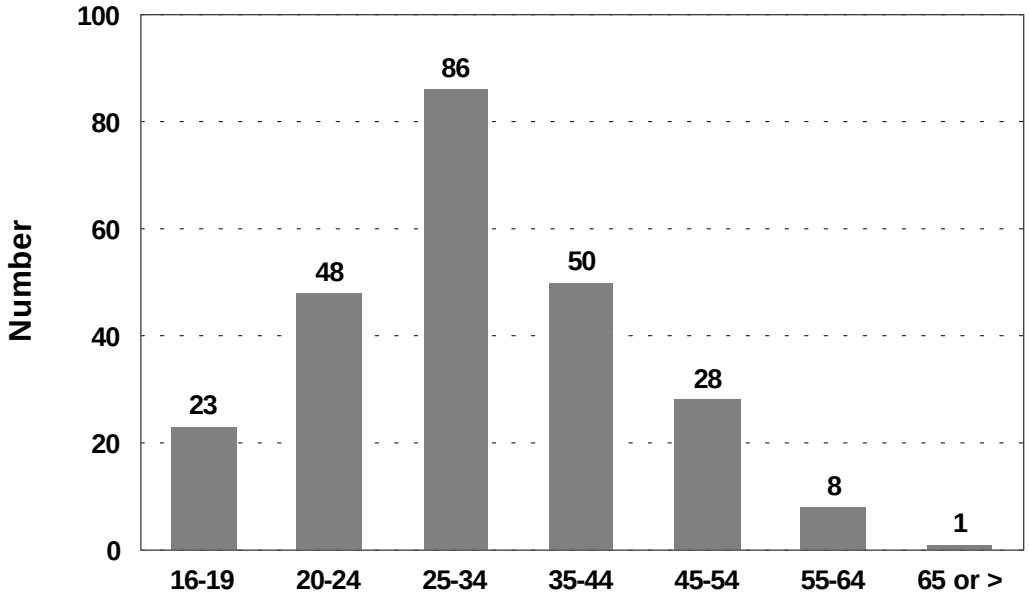

Figure 5. *Frequencies of Electrocution Deaths Identified by FACE by Age Group, 1982-1994*

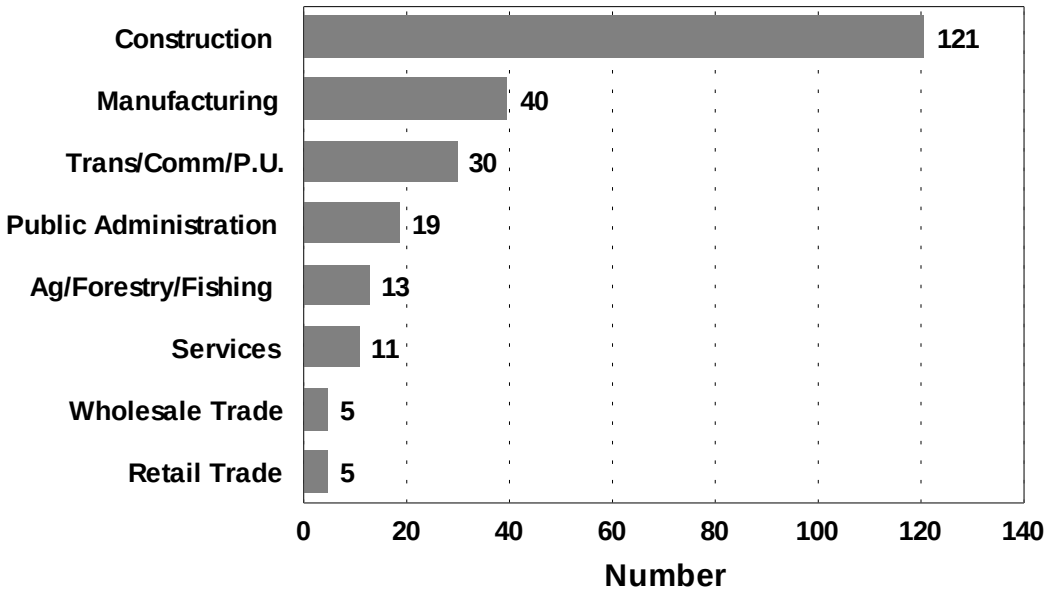

Figure 6. *Frequencies of Electrocution Deaths Identified by FACE by Industry, 1982-1994*

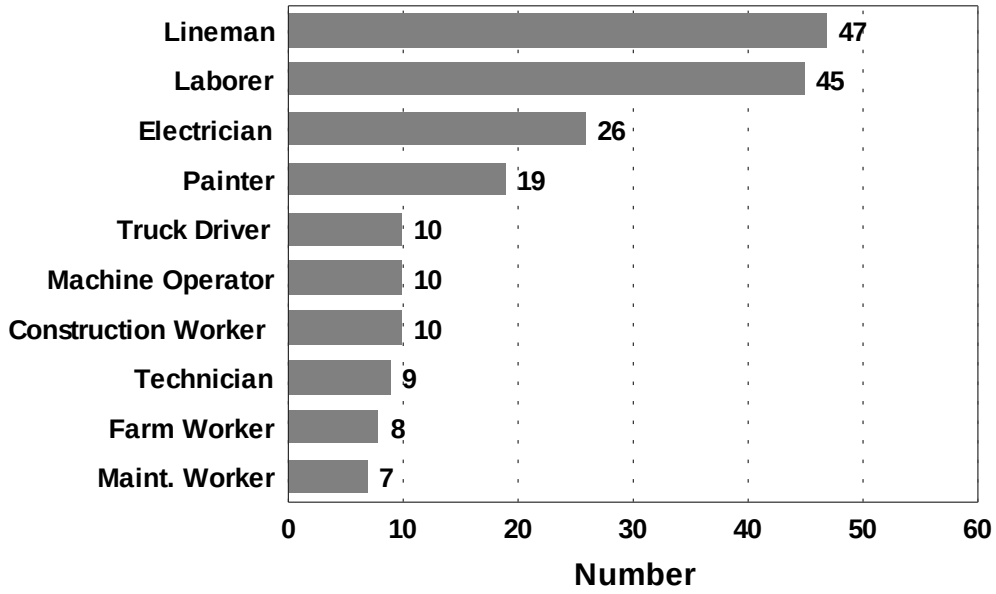

Figure 7. *Frequencies of Electrocution Deaths Identified by FACE by Occupation, 1982-1994*

The number of investigated electrocution incidents by month of occurrence are provided in Figure 8. The largest number of incidents occurred in months where weather conditions were most favorable for the highest level of outside activity.

In 79 (35%) of the incidents, no safety program or established, written safe work procedures existed.

Factors common to these incidents included the lack of enforcement of existing employer policies concerning the use of personal protective equipment, and the lack of supervisory intervention when existing safety policies were being violated. Supervision was present at the site in 120 (53%) of the incidents, and 42 victims were supervisors.

Of the 244 victims, 194 (80%) had some type of electrical safety training. On-the-job training, received by 102 victims, was the most common type of training. Thirty-nine victims received no training at all. One hundred (41%) of the victims had been on the job for less than 1 year.

Fifty-one (23%) of the incidents occurred at establishments that employed 500 or more workers. Eighty-five (38%) of the incidents occurred at establishments that employed less than 50 workers.

Two hundred twenty-one (99%) of the incidents involved alternating current (AC). One incident involved direct current (DC). Two incidents involved AC arcs. Of the 221 AC electrocutions, 74 (33%) involved less than 600 volts and 147 (66%) involved 600 volts or more. The number of electrocutions by voltage level is listed in Figures 9 and 10. Forty (54%) of the lower-voltage electrocutions involved household current of 120 to 240 volts. Manufacturing companies accounted for 40 (54%) of the lower-voltage incidents. This is particularly disturbing due to safety features such as electrical safety interlocks, emergency stop devices, and electrical guarding inherently designed into manufacturing equipment.

Of the 147 higher-voltage incidents, 111 (76%) involved distribution voltages (7,200-13,800 volts) and 21 incidents involved transmission voltages (above 13,800 volts). Of the incidents involving at least 7,200 volts, 41 (28%) resulted from contacting an energized powerline with a boomed vehicle. Thirty-five incidents occurred when conductive equipment such as an aluminum ladder or scaffold contacted an energized powerline. The weight of this equipment sometimes required more than one worker to move or position it, resulting in multiple fatalities. Thirteen deaths occurred in six separate incidents when workers erected or moved scaffolds that came in contact with energized, overhead powerlines. Electric powerline line mechanics were victims in 47 (36%) of the incidents involving transmission and distribution voltages.

Almost all American workers are exposed to electrical energy at sometime during their work day, and the same electrical hazards can affect workers in different industries. Based on the analysis of these cases, NIOSH identified five case scenarios that describe the incidents resulting in the 244 fatalities: (1) direct worker contact with an energized powerline (28%); (2) direct worker contact with energized equipment (21%); (3) boomed vehicle contact with an energized powerline (18%); (4) improperly installed or damaged equipment (17%); (5) conductive equipment contact with an energized powerline (16%).

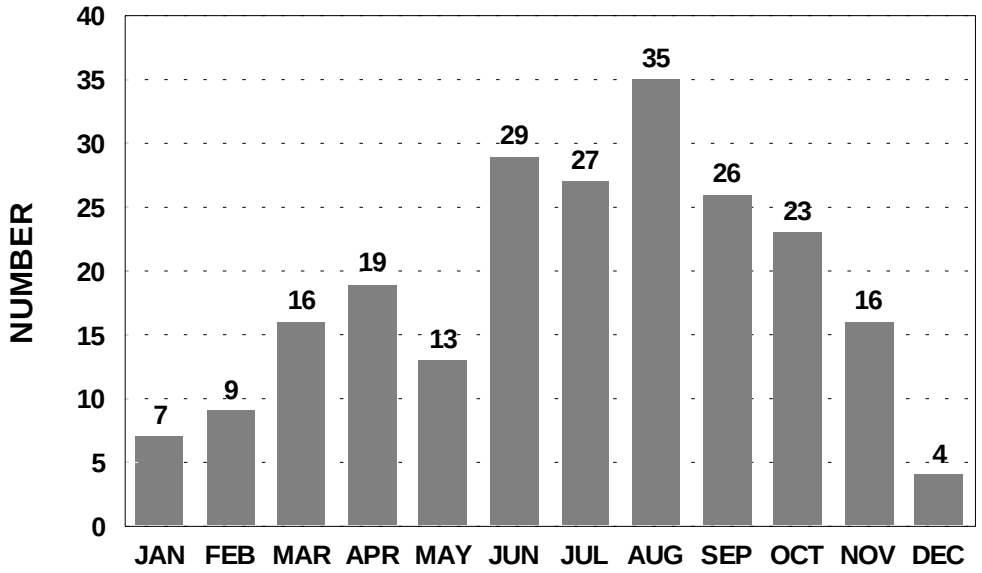

Figure 8. *Frequencies of Electrocution Incidents Identified by FACE by Month, 1982-1994*

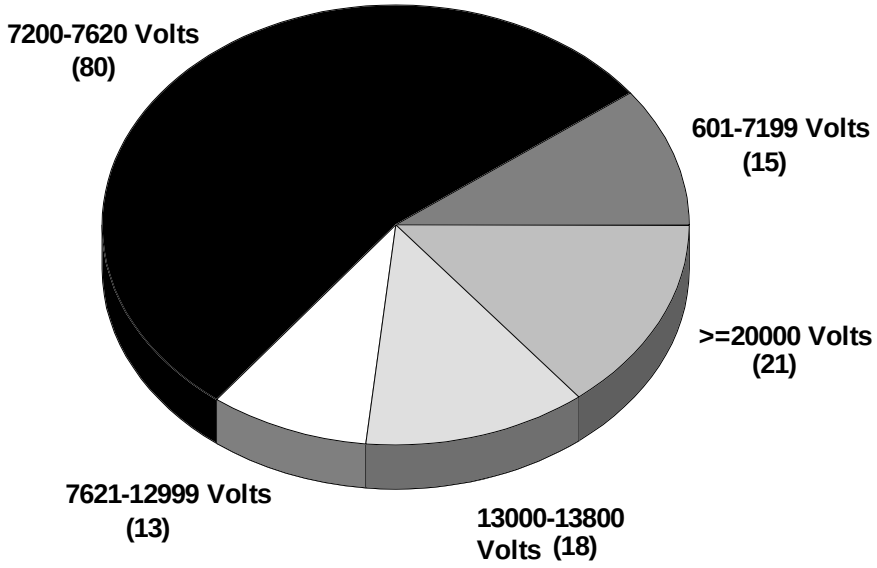

Figure 9. *Frequencies of Electrocution Incidents Identified by FACE by High Voltage Level (>600 Volts), 1982-1994*

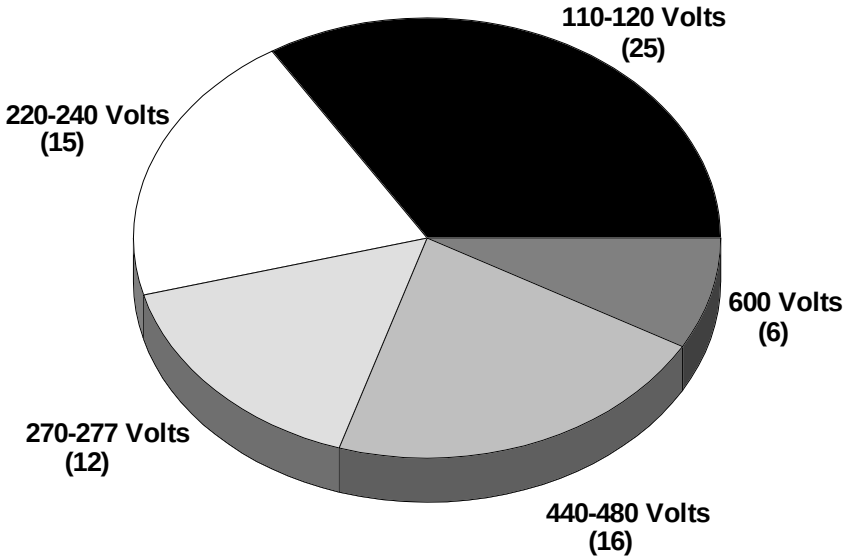

Figure 10. *Frequencies of Electrocution Incidents Identified by FACE by Low Voltage Level (<600 Volts), 1982-1994*

Scenario 1

Workers in various occupations such as sign technicians, tree trimmers, utility line workers, and telecommunication workers are often exposed to overhead powerlines. These exposures can be greatly reduced by isolating or insulating the energy source from the worker. This can be accomplished by erecting a physical barrier, by insulating the powerline, or by following required clearance distances. More than once during FACE investigations, co-workers interviewed did not know the powerlines posed a hazard, i.e., they thought the powerlines were insulated.

Scenario 2

Direct worker contact with energized equipment can occur in a variety of ways. Maintenance technicians might inadvertently contact overhead crane runway conductors. Electricians or technicians troubleshooting or testing electric circuitry might contact an energized circuit. Maintenance workers may fail to replace an isolating plate covering electrical conductors, exposing passing workers. Compliance with the applicable articles of the National Electrical Code and lockout/tagout procedures established by OSHA could eliminate the potential for such contact, thereby reducing the risk of electrocution.

Scenario 3

Workers guiding suspended loads, or standing against or near a crane or other boomed vehicle—such as a concrete pumping truck, or derrick truck—whose boom contacts a powerline are in danger of electrocution. The risk of electrocution could be reduced if OSHA regulations regarding clearance distances [(29 CFR 1926.550 (a)(15)] are observed, or if the required lookout person [29 CFR 1926.550 (a)(15)(iv)] is utilized.

Scenario 4

Improperly installed or damaged equipment can be responsible for occupational electrocutions in a variety of ways. The most frequently cited OSHA electrical regulation is improper grounding of equipment or electrical circuitry. If the frame of a piece of electrical equipment or machinery does not have a grounding conductor attaching the frame to ground, as required to divert dangerous fault current to ground, and an electrical fault occurs, anyone touching that frame and any other object at ground potential would receive an electrical shock. Should a fault occur with a grounding conductor present, the circuit would open or trip as an alert that a problem existed, except in high-resistance grounding applications. Damaged guards can expose workers to energized conductors in proximity to their work areas. Additionally, damaged extension cords or extension cords with their ground prong removed can expose workers to the danger of electrocution.

Failure to maintain a continuous path to ground can expose entire electrical systems to damage and can expose the structures within which they are housed and workers within these structures to electrical and fire hazards.

For example, many electrical systems are installed in a manner that allows a structure's water pipes or other conductive conduit to serve as a continuous path to ground in compliance with the NEC. However, FACE investigations have identified cases of electrocution or fire as a result of an interruption in a continuous path to ground. During renovation or repair activities, conductive components may be replaced by nonconductive components such as PVC pipe, which will interrupt the path to ground. This may result in fire due to the intense overheating of components of the electrical system. Additionally, workers contacting improperly grounded components while being at ground potential would be exposed to electric shock.

Scenario 5

The task of positioning or repositioning conductive equipment may place more than one worker at risk. The weight of mobile scaffolding, grain augers, or aluminum extension ladders equipped with pendant-operated lifts often requires more than one worker for positioning or repositioning, resulting in multiple electrocutions if contact with an overhead powerline occurs. Using a lookout person, observing required clearance distances, or lowering this equipment before transport would greatly reduce worker exposure to any potential electrical hazards present.

DISCUSSION

The fatality data from NTOF help to illustrate the magnitude of the electrocution problem nationally and allow a comparison of the potential risks in various industries. The information from FACE investigations allows for the identification of more detailed information on electrocution hazards, such as contact with overhead powerlines, contact with exposed conductors, inadequate personal protective equipment, and nonexistent lockout/tagout procedures, or other measures necessary for working around energized conductors and equipment.

FACE reports and NTOF death certificates identified many of the same hazards for fatal electrocutions. The largest number of deaths were in Construction, Transportation/Communication/Public Utilities, and Manufacturing, while the highest fatality rates were in the Construction and Mining industries. Linemen were involved in the largest number of electrocutions.

Direct worker contact with an energized powerline caused the largest number of electrocution deaths. Almost all of the incidents investigated by FACE involved alternating current. Over half of these incidents involved voltages over 600 volts. Of the 147 higher-voltage electrocutions, over two-thirds involved distribution voltages (7,200-13,800 volts).

While progress has been made in reducing the number of work-related electrocutions, (50% decrease from 1980-1992), additional efforts are needed if we are to continue progress towards preventing deaths due to electrocution.

PREVENTION: ELEMENTS OF AN ELECTRICAL SAFETY PROGRAM

Virgil Casini, B.S.

At least one of the following five factors was present in all 224 incidents evaluated by the FACE program: (1) established safe work procedures were either not implemented or not followed; (2) adequate or required personal protective equipment was not provided or worn; (3) lockout/tagout procedures were either not implemented or not followed; (4) compliance with existing OSHA, NEC, and NESC regulations were not implemented; and (5) worker and supervisor training in electrical safety was not adequate. These subjects are addressed in various NIOSH Alerts[26-36] and related publications.[37]

Most of the 224 occupational electrocution incidents investigated as part of the FACE program could have been prevented through compliance with existing OSHA, NEC, and NESC regulations; and/or the use of adequate personal protective equipment (PPE). All workers should receive hazard awareness training so that they will be able to identify existing and potential hazards present in their workplaces and relate the potential seriousness of the injuries associated with each hazard. Once these hazards are identified, employers should develop measures that would allow for their immediate control.

Based on an analysis of these data, to reduce occupational electrocutions, employers should:

- Develop and implement a comprehensive safety program and, when necessary, revise existing programs to thoroughly address the area of electrical safety in the workplace.

- Ensure compliance with existing OSHA regulations Subpart S of 29 CFR 1910.302 through 1910.399 of the General Industry Safety and Health Standards[3] and Subpart K of 29 CFR 1926.402 through 1926.408 of the OSHA Construction Safety and Health Standards.[4]

- Provide all workers with adequate training in the identification and control of the hazards associated with electrical energy in their workplace.

- Provide additional specialized electrical safety training to those workers working with or around exposed components of electric circuits. This training should include, but not be limited to, training in basic electrical theory, proper safe work procedures, hazard awareness and identification, proper use of PPE, proper lockout/tagout procedures, first aid including CPR, and proper rescue procedures. Provisions should be made for periodic retraining as necessary.

- Develop and implement procedures to control hazardous electrical energy which include lockout and tagout procedures and ensure that workers follow these procedures.

- Provide those workers who work directly with electrical energy with testing or detection equipment that will ensure their safety during performance of their assigned tasks.

- Ensure Compliance with the National Electrical Code[5] and the National Electrical Safety Code.[6]

- Conduct safety meetings at regular intervals.

- Conduct scheduled and unscheduled safety inspections at worksites.

- Actively encourage all workers to participate in workplace safety.

- In a construction setting, conduct a jobsite survey before starting any work to identify any electrical hazards, implement appropriate control measures, and provide training to employees specific to all identified hazards.

- Ensure that proper personal protective equipment is available and worn by workers where required (including fall protection equipment).

- Conduct job hazard analyses of all tasks that might expose workers to the hazards associated with electrical energy and implement control measures that will adequately insulate and isolate workers from electrical energy.

- Identify potential electrical hazards and appropriate safety interventions during the planning phase of construction or maintenance projects. This planning should address the project from start to finish to ensure workers have the safest possible work environment.

The FACE data indicate that although many companies had comprehensive safety programs, in many cases they were not completely implemented. This underscores the need for increased management and worker understanding, awareness, and ability to identify the hazards associated with working on or in proximity to electrical energy. It is the responsibility of management to provide a safe workplace for their workers and to develop and implement a comprehensive safety program. In some cases, this may entail the development of additional worker training, and/or the evaluation and restructuring of existing safety programs. Management should also provide adequate training in electrical safety to all workers and strictly enforce adherence to established safe work procedures and policies. Additionally, adequate personal protective equipment should be available where appropriate. Information or assistance in accomplishing these measures can be provided by OSHA, electrical safety consultants, or other agencies or associations that deal with electrical safety. A strong commitment to safety by both management and workers is essential in the prevention of severe occupational injuries and death due to contact with electrical energy.

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PART II

FATALITY ASSESSMENT AND CONTROL EVALUATION (FACE)
SUMMARY REPORT ABSTRACTS, 1982-1994
ELECTROCUTIONS

FACE ELECTROCUTION CASES FOR MONOGRAPH

The following pages contain short summaries of the FACE cases summarized in this monograph. The first two numbers preceding the case denote the year in which the case was investigated. The following two numbers identify a sequential file number for a particular year.

Copies of the complete FACE reports may be accessed through the NIOSH homepage at the following address: http://www.cdc.gov/niosh/

82-03 Truck driver standing on the ground directing crane operator electrocuted when crane cable contacted 7200V powerline. Victim on the ground helping to guide a ladder being positioned by the crane.

83-08 Electrician electrocuted at coal-fired power plant while replacing limit switch on coal sampler. Lockout procedures not followed. Contact with 220V line.

83-09 Painter working on electrical transmission tower electrocuted after direct contact with a grounding line that held a static charge.

84-17 Fast food restaurant employee electrocuted while plugging a portable electric toaster into a 110V/20 amp receptacle.

85-01 Worker electrocuted through direct contact with overhead 69000V powerline while dismantling electric substation tower. Co-worker had advised victim that lines not yet deenergized by power company.

85-03 Transportation worker electrocuted when iron rod used to measure asphalt level in storage tank contacted overhead 7200V powerline.

85-04 Electrical line construction foreman electrocuted by electric arc while attempting to cut 7200V powerline and attach it to new pole.

85-06 Warehouse worker electrocuted after coming in contact with bare 440V runway conductor (trolley wire) and grounded metal pallet storage rack. Victim at top of storage rack helping to remove mining auger by attaching a chain to it so it could be lowered by a crane.

85-07 Two steel erection workers electrocuted while using a crane with a telescoping boom to move an assembly of steel framing members. Contact with 23000V overhead powerline.

85-08 Construction worker electrocuted when crane load line contacted 7200V overhead powerline. Victim in process of hooking a load to the crane.

85-11 Mushroom cannery worker electrocuted while attempting to unclog a drain beneath a processing table. Victim contacted motor connection box while kneeling in water.

85-14 Construction worker electrocuted when crane cable contacted 13800V overhead powerline. Victim in contact with crane's outrigger.

85-15 Carpenter electrocuted and another worker severely burned when crane with telescoping boom contacted 34000V overhead powerline while he was setting metal forms for a highway retaining wall. Electricity passed from cable through form through victim to ground.

85-16 Foreman electrocuted after contacting one phase of a 23000V conductor within a switch cabinet. Replacing high-voltage distribution switch at the time of the incident.

85-17 Foreman electrocuted, three crewmen critically injured during erection of 36-foot traffic control device pole which contacted 26000V overhead powerline as derrick truck operator attempted to place it.

85-18 Construction worker electrocuted when 7200V overhead powerline fell on trailer attached to utility truck.

85-19 Driver unloading concrete blocks at building supply mart electrocuted when boom of truck-mounted crane apparently contacted 9000V overhead powerline. Outriggers on truck not set. Truck tipped while boom only 12 to 18 inches from powerline.

85-21 Worker on billboard electrocuted when 24-foot metal hook ladder contacted an overhead powerline.

85-22 Volunteer firefighter electrocuted after contacting 7200V overhead powerline while rappelling down the front of a fire station.

85-24 Video store owner electrocuted when he contacted an energized circuit while repairing an air conditioning thermostat. Victim grounded through aluminum ladder.

85-25 Lineman electrocuted after contacting a distribution system he believed to be deenergized.

85-28 Maintenance worker electrocuted as he attempted to turn off a welder. Exposed cable, broken insulation, water on floor.

85-29 Two construction laborers electrocuted when a crane contacted a 13400V overhead powerline under installation by another firm.

85-30 Sign service worker working from aerial ladder truck electrocuted by direct contact with 7200V overhead powerline.

85-32 Construction worker electrocuted when backhoe broke utility pole, causing 7200V overhead powerline to fall a few feet from where he was standing.

85-34 Billboard worker electrocuted as scaffold contacted 13800V overhead powerline. Working from "stage"-type scaffold positioned between catwalk and billboard.

85-35 Textile worker electrocuted while adding a new supply roll of warp to a weaving loom after contacting a loom and a feeder. Faulty receptacle to feeder.

85-36 Electrical worker electrocuted when he slipped and fell into a 7200V, 240/120V single-phase, step-down transformer he was wiring.

85-37 Brick company worker electrocuted when boom on a truck-mounted crane he was operating with a pendant controller contacted a 7200V overhead powerline.

85-38 Production welder plugged cord of a portable welder into a defective extension cord and was electrocuted.

85-39 Maintenance worker electrocuted when 20-foot piece of angle iron he was carrying struck an uninsulated supply wire on an electrical transformer.

85-41 Mobile home assembly-line worker electrocuted when he contacted the exterior of a mobile home energized by a short circuit in the wiring of an adjacent home.

85-42 While drilling horizontally under a road to install new gas lines, a gas utility worker was electrocuted after a drill contacted a 4160V powerline. Co-worker injured.

85-43 County highway worker electrocuted when the 20-foot steel handle of a modified post-hole digger he was holding contacted a 7200V overhead powerline.

85-46 Soldier electrocuted while installing WD-1 communication wire across road on military firing range. Threw wire across 440V powerlines that crossed the road.

85-47 Iron worker electrocuted after touching ceiling fixture as he was transported from work station in a truck-mounted aerial bucket.

85-48 Service technician electrocuted in crawlspace at private home while performing maintenance on an oil furnace.

86-01 Electronic technician electrocuted as he demonstrated how feeders were to be connected to bus bars. Contact with 380 volts.

86-02 Electrician electrocuted after contacting 277 volts while making a connection in a 4-inch junction box at a construction site.

86-03 Lineman electrocuted while attaching a guy wire to a utility pole during installation of a 7200V powerline between adjoining poles.

86-04 Utility worker electrocuted while trying to open a pole-mounted, ground-level air switch on a three-phase, 69000V powerline.

86-05 School maintenance worker electrocuted after contacting transformer wire.

86-06 Three farm workers electrocuted when grain auger they were moving contacted a 7200V overhead powerline.

86-07 Two farm workers electrocuted when grain auger they were moving contacted a 7200V overhead powerline.

86-08 Apprentice electrician electrocuted after contacting 277V uninsulated wire during installation of overhead junction box.

86-09 Lineman electrocuted while working from an aerial bucket truck to install a transformer. Direct contact with 13200V overhead powerline. Truck not grounded.

86-11 Two electrical workers in aerial bucket electrocuted while attaching transformer to utility pole. Operator on ground inadvertently moved boom upward, causing victims to directly contact high-voltage overhead powerline.

86-14 Operator of plastic extrusion machine electrocuted after contacting metal machine part energized at 10000V (used for treating plastic sheeting). Incident occurred while another worker performing maintenance on machine.

86-16 Bindery machine operator electrocuted when he contacted a 480V circuit inside a panel box while trying to check an electrical relay.

86-17 Truck driver electrocuted when crane boom on his truck contacted a 7200V overhead powerline. Unloading precast concrete manhole assemblies.

86-18 Telephone construction worker electrocuted and two other workers injured when the boom of a truck crane contacted a 7200V overhead powerline. Victim was groundman repairing a guy wire section laying across the truck crane's outrigger.

86-20 Lineman electrocuted after contacting a lightning arrester conductor while working from an aerial bucket. Contact with 7200V overhead powerline.

86-21 Lineman electrocuted when he contacted a 7200V powerline at an electrical substation. Line erroneously assumed to be dead.

86-22 Warehouse worker guiding grain auger by hand electrocuted as auger contacted 12470V distribution system.

86-24 Scale technician electrocuted while helping a crane operator prepare to lift a platform scale frame. Wire winch cable extending from boom tip contacted a 7200V overhead powerline.

86-25 Superintendent electrocuted while inspecting electrical relays in an electrical control panel box.

86-26 Utility worker electrocuted when aerial bucket in which he was working contacted a 7200V overhead powerline.

86-27 Laborer electrocuted when metal pole he was carrying (used to scrape soot from plant smokestacks) contacted a 7200V overhead powerline. Co-worker apparently attempting rescue seriously burned.

86-28 Worker electrocuted while using a 110V auger to install tie-down rods for a manufactured home. Auger had no continuous grounding system. Co-worker received shock, after which auger fell across victim, electrocuting him.

86-29 Mechanic electrocuted when he contacted a grounded horizontal conductor with one hand and an energized three-way connector with the other. Performing maintenance on electrical distribution system.

86-30 Maintenance worker electrocuted when aluminum pruning pole with a saw attached to it contacted a 7200V overhead powerline while he was trimming a tree.

86-31 Groundman electrocuted while transferring electric distribution lines and a transformer to a new utility pole. Co-worker seriously injured.

86-32 Laborer at pickle plant electrocuted when he contacted a faulty splice on a 440V power cord for a portable pump while filling a tank with brine.

86-33 Electrician's helper electrocuted while wiring a fluorescent light fixture in a suspended ceiling. Procedures for deenergizing and testing of circuits not followed.

86-35 Maintenance worker electrocuted while replacing a ballast in a fluorescent light fixture. Conductor not deenergized, polarity reversed because of installation error.

86-36 Carpenter electrocuted when portable electric saw apparently developed a ground fault. Engaged in construction of laundry building for apartment complex.

86-39 Painter and carpenter electrocuted when a tubular metal scaffold they were rolling to another work area contacted a 12000V overhead powerline.

86-40 Lineman on utility pole electrocuted while reaching overhead with a hot-stick to place a jumper line on one phase of a three-phase 7200V primary line.

86-41 Electrical technician electrocuted while testing circuits in a metal cabinet housing power transmission and distribution equipment. Contact with 10000V energized resistor.

86-42 Groundman electrocuted while cleaning connectors that linked overhead powerlines to service lines to a private home. Victim working without rubber gloves from aerial bucket truck.

86-43 Restaurant manager electrocuted after contacting handle of refrigerator that had a ground fault. Slipped on wet, soapy floor he was cleaning.

86-45 Maintenance worker electrocuted when he contacted an energized circuit in the control box of a popsicle-wrapping machine that was not working. Victim performing diagnostic tests while standing on a metal platform one foot above a wet floor.

86-46 Groundman electrocuted when truck's aerial boom contacted a 7200V overhead powerline while he was in contact with the truck.

86-47 Electrician electrocuted while repairing airport runway lights. Co-worker misinterpreted signal, reenergizing circuit before electrician finished.

86-49 National Guard commander electrocuted when he climbed a tower supporting 46000V transmission lines and contacted a jumper line. Engaged in demolition of tower as training exercise.

86-50 Meter technician, working as a lineman, electrocuted while attempting to repair a fallen 120V powerline. Powerline splice caught victim's glove, exposing his arm to direct 120-volt current.

86-51 Truck driver electrocuted while operating remote control of a truck-mounted crane boom that contacted overhead 7200V powerline. Electric current traveled through controller to victim to ground.

86-53 Electrician electrocuted while performing preventive maintenance on a high-voltage circuit breaker at electrical substation.

86-55 Line mechanic electrocuted after contacting energized tap while replacing a fuse holder.

87-02 Laborer electrocuted when he contacted a 7200V overhead powerline. Standing on roof of house as it was being moved to another location, lifting overhead wires so they would clear the house.

87-03 Mechanic electrocuted when 25-foot two-way radio antenna he was helping to load contacted a 7200V overhead powerline.

87-04 Sheet metal apprentice electrocuted while guiding a powered scaffold that was being unloaded from the flatbed of a truck with a truck-mounted crane. Hoist cable contacted 6500V overhead powerline, and was engulfed in flames. Victim standing on wet ground nearby.

87-07 Machine operator electrocuted when he contacted an energized conductor in a motor control box that had had the cover plate removed. Using gang slitter machine to cut bulk rolls of fiberglass at time of incident.

87-08 Laborer electrocuted when 21-foot aluminum flagpole he was installing contacted a 7200V overhead powerline. Victim carrying flagpole upright.

87-09 Laborer electrocuted when he contacted a 13000V underground powerline while digging with a pneumatic clay spade.

87-10 Pump operator electrocuted when the boom on the truck-mounted concrete pump he was operating contacted a 7600V overhead powerline. Incident unwitnessed, but victim probably standing beside truck using a pendant controller.

87-11 Laborer in oil recycling plant electrocuted when he contacted a pump housing that had become energized due to faulty wiring. Engaged in pumping oil from a filtering tank to an analysis kettle.

87-12 Four maintenance workers at a naval installation electrocuted, and a crew chief critically injured, when the tubular welded-frame scaffold they were wheeling into position contacted a 12000V overhead powerline.

87-13 Laborer helping to unload sewer pipe electrocuted when the boom cable of a truck-mounted crane contacted an overhead powerline, causing an electrical arc. Victim grasping pipe and wire choker at time of incident.

87-14 Stagehand electrocuted when he contacted an exposed electrical wire protruding from a junction box. Victim lying on a metal catwalk reaching out to replace a ceiling tile when incident occurred.

87-15 Laborer painting a concrete silo electrocuted when his telescoping paint roller contacted a 7200V overhead powerline.

87-16 Fire chief electrocuted while trying to remove an injured person from a car which had hit a pole carrying a 7200V powerline.

87-18 Laborer electrocuted while steam-cleaning a rubber mill (converts bulk rubber to strips). Contacted machine, which had energized switch, while standing in water with a metal cleaning wand.

87-19 Bricklayer engaged in construction of brick wall electrocuted when tubular welded-frame scaffold contacted 7620V overhead powerline. Electric current flowed from the powerline to a section of wire reinforcement carried by a co-worker to the scaffold to victim to ground.

87-21 Worker setting up injection molding machine in plastics manufacturing plant electrocuted when he contacted an adjacent grinding machine that had a ground fault.

87-22 Mold-maker apprentice electrocuted while trying to repair and install a fluorescent light fixture that had a short circuit.

87-24 Apprentice lineman electrocuted while attaching a wooden cross arm to a new utility pole. Direct contact with 12000V powerline on an existing pole.

87-28 Two painters electrocuted while painting a 20-foot metal light pole from an aluminum ladder. One victim on ladder, the other on ground steadying ladder. Ladder apparently slipped, then slid along crossbar of light pole, placing victim on ladder in contact with 12460V overhead powerline and electrocuting the victim on the ground.

87-29 Lathe operator electrocuted when he contacted the frame of a lathe energized by a ground fault, presumably while walking between two lathes.

87-31 Electronic technician died of burns sustained in explosion in a 20000V switch compartment at a rail car maintenance shop. Victim sprayed cleaning fluid on energized circuits causing ignition.

87-32 Painter electrocuted when 24-foot aluminum ladder he was positioning contacted 7200V overhead powerline. Victim working alone to paint gutters on apartment building .

87-34 Electrician's apprentice electrocuted when he contacted live conductors while disassembling an energized switch box in an office building. Victim apparently believed box to be deenergized.

87-35 Lineman electrocuted while changing jumper wire at electrical substation, contacting energized switch (34500V lines).

87-36 Truck driver electrocuted when his truck-mounted crane contacted a 7600V overhead powerline. Standing at rear of truck operating crane with conductive pendant controller.

87-37 Truck driver electrocuted when the bed of his dump truck contacted a 7200V overhead powerline. Presumably stepped out of truck to inspect exploded tires. He grasped the truck door handle, which provided a path to ground.

87-38 Lineman electrocuted when the boom of a derrick truck contacted a 7200V overhead powerline while he was leaning against the truck. Co-worker raised boom before grounding rods were in place.

87-40 Painter electrocuted when he began wrapping plastic around an insulator in preparation for painting a steel structure at a substation. Contacted 11000V conductor while standing on steel beam.

87-41 Pipe layer electrocuted when the boom of a backhoe contacted a 13200V overhead powerline. Victim was guiding load attached to backhoe bucket.

87-42 Lineman trainee electrocuted when he attempted to remove a ground wire from a 230000V transmission circuit. Grasped tower end of ground still attached to powerline.

87-43 Electrician electrocuted while replacing a socket on an energized fluorescent light fixture. Victim was stripping insulation from an improperly grounded wire on a ballast.

87-44 Construction foreman electrocuted while guiding a boring machine attached to a crane into a ditch. Crane boom contacted 13000V overhead powerline.

87-48 Carpenter and laborer electrocuted when section of tubular welded-frame scaffolding they were helping to move came loose and contacted 13750V overhead powerline.

87-52 Driller electrocuted when boom of hydraulic well drilling machine he was operating contacted a 34500V overhead powerline.

87-53 Groundman electrocuted when energized 13200V powerline broke and fell onto pole trailer onto which he was loading a pole. Trailer was not grounded.

87-54 Truck driver electrocuted when he raised the bed of his dump truck into a 12000V overhead powerline. Victim standing to the side of the truck operating lever that controlled bed.

87-55 Electrician electrocuted when he contacted an energized wire in a fluorescent light fixture at a private residence.

87-56 Utility worker electrocuted while disconnecting power source to a knitting machine motor, inadvertently touching an energized prong on the damaged plug.

87-58 Apprentice electrician electrocuted when he contacted an energized circuit while installing lights on an ocean pier. Victim ignored instructions not to proceed until circuits verified to be deenergized.

87-60 Maintenance manager electrocuted as he attempted to make a connection in an energized air conditioner at an apartment complex.

87-61 Laborer/truck driver electrocuted while holding onto a hook suspended from the hoist cable of a truck-mounted crane. Cable contacted 19900V overhead powerline.

87-62 Handyman electrocuted when he apparently contacted an energized cap on a well while searching for a water leak.

87-63 Electrician electrocuted when he contacted an energized conductor while installing wiring for a refrigeration system.

87-65 Tree trimmer electrocuted when he directly contacted a 7200V overhead powerline while working in a tree.

87-66 Laborer electrocuted when the mast of a well-drilling rig he was operating contacted a 7200V overhead powerline. Victim saw smoke coming from rig's tires, then tried to enter truck cab to shut off truck.

87-68 Electrician electrocuted after contacting a 110V conductor while working in a crawlspace to install a furnace in a cottage.

87-69 Electrician electrocuted when he contacted 480V power supply to a generator that supplied power to a glue machine.

87-70 Electrician electrocuted when he contacted the energized metal frame of a foundry stoker he was trying to repair.

88-02 Painter electrocuted when he contacted the housing of an energized fluorescent light fixture at a textile plant. Ground wire apparently disconnected in the past.

88-03 Apprentice lineman electrocuted while stringing a new length of overhead powerline that contacted an existing 12000V powerline above him. Electricity passed from new line to a trailer through the victim to ground.

88-04 Painter electrocuted when aluminum extension ladder he and a co-worker were raising contacted 7200V overhead powerline.

88-05 Construction worker electrocuted when aluminum extension ladder he was standing on contacted 7200V overhead powerline as it tipped backwards.

88-11 Maintenance supervisor electrocuted when he contacted a 22000V energized conductor in a control box. Victim evaluating malfunction of laser-guided cutting machine. Advised operator to stop the equipment, but not to deenergize it.

88-13 Cement finisher electrocuted when the metal handle of a cement-finishing tool he was using contacted an overhead powerline.

88-19 Deputy sheriff electrocuted while moving a 7200V powerline that fell when a car struck a utility pole.

88-21 Maintenance worker trainee electrocuted when he contacted an energized conductor in a junction box left uncovered the day before when a motor on a textile machine was replaced. Victim engaged in replacement of a plastic vacuum hose on the same machine.

88-22 Two pipefitters electrocuted when the boom of the crane moving a metal welding shed contacted a 12400V overhead powerline. Victims standing on the ground grasping the shed to guide it into place.

88-23 Lineman electrocuted when his hands contacted both sides of a switch on a pole-mounted capacitor bank. Victim inexplicably raised aerial bucket into overhead powerlines after removing gloves.

88-24 Laborer electrocuted when he contacted 115 volts while adjusting the limit switches on an overhead door opener.

88-25 Apprentice lineman engaged in relocation of powerlines electrocuted when he contacted a 13200V overhead powerline. Climbed pole before lines fully deenergized.

88-26 Maintenance worker for structural steel firm electrocuted when the boom of a crane moving a steel I-beam he was guiding contacted a 13000V overhead powerline. Crew engaged in cleanup of storage yard chose to stack I-beams directly below powerlines.

88-31 Welder/pipefitter killed when he contacted an energized 110V conductor while removing a fluorescent light fixture, and fell 29 feet to the floor. Cut into energized wire with uninsulated metal wire cutters.

88-32 Welder electrocuted when he contacted a conductor on an overhead crane. Engaged in adding reinforcing steel to the bridge of an overhead crane at a steel fabrication firm. Victim believed crane to be deenergized.

88-34 Laborer electrocuted when metal basket he was working from apparently damaged insulation on power supply to overhead crane. Steel I-beam with which victim had contact became energized. Victim engaged in repairing security system.

88-35 Assistant manager at municipal swimming pool electrocuted when she contacted a mixing motor that had a ground fault. Engaged in mixing chemical solution to be added to pool.

88-37 Electrician electrocuted when he touched the uninsulated part of a wire stripper that was in contact with a 110-volt circuit that had not been deenergized at the panel box. Installing residential floodlighting.

88-40 Construction laborer electrocuted when he touched the hoist cable of a crane whose boom was in contact with a 2400V overhead powerline. Engaged in removing forms from newly poured concrete wall and placing them on the crane's choker cable.

88-41 Electrician working in crawlspace electrocuted when his shoulder contacted a broken light bulb in an unguarded ceiling-mounted socket, and his head contacted a steel water pipe. Engaged in tracing wiring at a tobacco manufacturing plant.

88-45 Crew leader for electrical contractor electrocuted while installing transformers on concrete pads for an underground transmission system for a housing development. Failure to place grounds.

88-47 Equipment operator/lineman electrocuted when the wooden crossarm on a utility pole gave way, dropping energized wires on him. Engaged in replacing an electrical distribution system.

89-01 Steelworker electrocuted when he contacted a ventilation fan with damaged insulation on the power cord that had allowed the entire frame of the fan to become energized.

89-04 Equipment operator electrocuted when he directly contacted a 7600V overhead powerline while installing a traffic light. Raised aerial bucket from which he was working, apparently misjudging height of powerline.

89-06 Lineman electrocuted when he contacted a 12000V overhead powerline while installing "squirrel guards" on a transformer. Apparently slipped and contacted the energized side of a cut-out switch while working with bare hands.

89-08 Sign technician electrocuted when steel hoist cable attached to the extended ladder on his truck contacted a 12000V overhead powerline as he was driving. Victim apparently realized there was contact, stopped the truck, and stepped outside, still holding the door of the cab.

89-09 Hydroelectric supervisor died as a result of burns he suffered in an electrical fire. While calibrating analog meter, co-worker dropped overheated voltameter onto exposed high-voltage bus bars, creating a short circuit and a fire which ignited clothing. Co-worker seriously burned.

89-10 Machine operator electrocuted when crane boom contacted a 12000V overhead powerline as he was guiding a steel pipe by hand. Victim's firm working at a pit directly under powerline positioning a boring machine that was to drill under a road.

89-11 Lineman supervisor electrocuted when he contacted an energized fuse holder while on a utility pole. Engaged in rebuilding powerlines for rural electric cooperative. No personal protective equipment used.

89-15 Laborer standing on ground electrocuted when the boom of an aerial bucket truck with which he was in contact touched a 7200V overhead powerline. Two workers engaged in clearing tree branches away from powerline, co-worker working in bucket.

89-16 Roofer electrocuted when a 40-foot aluminum ladder he was positioning contacted a 7200V overhead powerline. Engaged in replacing shingles on church roof.

89-17 Electrical foreman and groundman electrocuted when the groundman removed a guy wire from its anchor and began to place it on the ground. Wire apparently contacted a 13200V powerline while both victims were touching it.

89-18 Electrician electrocuted after he contacted an energized 50000V transformer. After deenergizing identical system, mistakenly entered energized area. Performing scheduled maintenance at pulp and paper mill.

89-19 Maintenance mechanic at meat packing plant electrocuted when he contacted a strapping machine power cord with damaged insulation. Current passed through victim to wet floor.

89-26 Apprentice lineman working from aerial bucket electrocuted when he contacted a 13700V overhead powerline while upgrading an electrical distribution system. Holding a clamp in one hand, victim may have pushed a cable off the bucket with the other hand and contacted the powerline.

89-27 Electrical distribution line technician died as a result of injuries suffered when he directly contacted an overhead powerline while repositioning his aerial bucket. Failure to place insulating hose on lines.

89-36 Distribution line technician electrocuted and a co-worker seriously burned when a powerline they were installing contacted an energized 7200V powerline overhead. Both victims on the ground helping to pull slack out of the new line when line snagged in tree, contacting energized line.

89-37 Laborer electrocuted when he contacted a 4160V powerline after inexplicably entering a restricted power service enclosure. Victim engaged in sandblasting air conditioning unit on roof of plant prior to incident.

89-39 Apprentice lineman electrocuted when he touched a 7200V overhead powerline while attempting to transfer lines to a new utility pole. No personal protective equipment or guards used.

89-40 Service operations technician electrocuted after he contacted an energized 7680V switch while working to restore power to a shopping mall. No personal protective equipment used.

89-42 Cable TV installer electrocuted when his head contacted a 7280V overhead powerline that ran 5 feet above the roof of a house. Installing TV cable on existing utility poles at time of incident.

89-43 Foundry laborer electrocuted when a piece of scrap metal he was helping to load into a damaged electric induction furnace became energized. Current passed from scrap metal through victim through furnace frame to ground.

89-48 Truck driver electrocuted when the boom of a truck-mounted crane he was raising by remote control contacted a 14400V overhead powerline. Current passed through power cord of controller through victim to ground.

89-50 Apprentice electrician electrocuted when he apparently contacted an energized conductor in a junction box while in contact with metal gridwork. While installing light fixture at office complex under construction, victim may have inadvertently cross-wired two neutral conductors.

90-01 Three construction workers electrocuted and three others seriously burned when the mobile elevating work platform they were moving contacted a 69000V overhead powerline. Victims moved platform from location where adequate clearance existed but made contact with powerline where ground sloped upward.

90-02 Leader of tree-trimming crew electrocuted during hurricane cleanup when he contacted a downed powerline he believed to be deenergized. Electric current from portable generator operating at gas station nearby reenergized powerline.

90-03 Lineman, working at night, electrocuted during hurricane cleanup when he directly contacted a powerline dangling from a pole. Victim either did not see the line, or believed it to be deenergized.

90-04 Meter reader electrocuted when he grasped a metal clothesline energized by a downed powerline in an effort to regain his balance after tripping over a chain-link fence.

90-05 Lineman electrocuted while attaching a 2400V powerline to a pole-mounted insulator. Victim assured by supervisor that line was deenergized, but it was in fact energized by portable generator.

90-06 Lineman electrocuted when the boom of bucket of the bucket truck from which he was working rotated into an energized 4800V powerline and secondary fuse box. Victim reattaching tool basket to bucket. Basket hook caught on lever controlling boom, swinging boom into powerline.

90-08 Line technician electrocuted after his head directly contacted an energized jumper wire while restoring power after a hurricane. Victim positioned between powerlines trying to locate transmission problem.

90-09 Painter electrocuted when the aluminum extension ladder he was positioning tipped backwards and contacted a 7200V overhead powerline. Engaged in house painting.

90-10 Carpenter working from aluminum ladder jack scaffold electrocuted when a piece of aluminum drip edging he was installing on a roof contacted a 7200V overhead powerline.

90-22 Electrician electrocuted when he inexplicably switched a circuit breaker to the "on" position and contacted an energized bus bar while performing repairs at a hotel following a hurricane. Victim and co-worker assigned to clear ground fault.

90-26 Lineman electrocuted when he contacted a reenergized cutout switch on a utility pole. Had climbed back up pole to remove piece of electrical tape without putting gloves and safety belt back on. Reached for tape, boots slipped, and hand contacted switch.

90-27 Lineman electrocuted when he contacted a 7200V overhead powerline while installing a guy wire. Arm contacted an existing powerline three inches beyond an insulating line hose.

90-29 Driver of cement truck stopped truck below powerline, crane operator (not aware of truck position) swung cement bucket under line, and laborer (victim) pushed down on handle of bucket door, bringing crane cable in contact with 7200V powerline. Crew about to wash out cement bucket with water.

90-31 Laborer died from injuries suffered when the galvanized pipe he was carrying contacted an energized 12500V jumper wire at a electrical substation.

90-34 Tree trimming groundsman electrocuted when the guy wire he was grasping swayed (due to slack in the wire) and contacted an energized pole-mounted jumper wire. Victim had just finished cutting trees and brush from around guy wire, one end of which was secured to utility pole, other end to steel rod in the ground.

90-36 Concrete worker at manufacturing plant electrocuted when he climbed a steel column, stepped onto a steam pipe, and grasped a conductor that powered a wall crane. Attempting to untangle the hoist chain of an overhead crane that was caught on an I-beam.

90-37 Steelworker electrocuted when he contacted the energized casing of a toaster oven in an employee lunchroom while resting his arm on an air conditioner.

90-38 Well driller electrocuted when a metal pipe being hoisted by a truck-mounted crane made direct contact with a 12000V overhead powerline. Victim standing at side of truck using pendant remote controller. Crew engaged in repair of submersible pump for water well at private home.

90-39 Telecommunications company foreman electrocuted when he grasped the door handle of a burning truck mounted with a crane, the boom of which was in contact with a 7200V overhead powerline. Powerline contact occurred when poles supporting billboard were being pulled out of the ground.

90-40 Lineman electrocuted when he simultaneously contacted both sides of a fused powerline jumper. Working from aerial bucket repositioning powerlines after tree trimming operation.

91-01 Distribution line technician electrocuted while clearing branches from a 7200V overhead powerline he believed to be deenergized. Victim positioned in tree, co-worker heard arcing sound, and victim fell to the ground.

91-03 Tree trimming groundsman electrocuted when the boom of an aerial bucket truck with which he was in contact touched a 23000V overhead powerline.

91-05 Construction laborer electrocuted when he apparently contacted a damaged extension cord that became energized. Constructing waterfront bulkhead for residence at edge of lake.

91-08 Truck driver electrocuted when he raised the bed of his dump truck into a 7200V overhead powerline. Standing on the ground operating the lever that raised and lowered the bed.

91-10 Lineman working from aerial bucket electrocuted while restoring power after a storm. Victim grasped supply end of conductor with one hand, chain hoist in other hand contacted neutral jumper. Failure to ground energized line.

91-20 Lineman trainee electrocuted when he grasped the door handle of a pickup truck energized through a powerline on the ground that had contact with a jumper wire. Victim was apparently planning to try to move the truck.

91-21 Construction laborer electrocuted while grasping a wire rope load choker attached to a crane cable with one hand and a vertical steel rod with the other hand. Crane contacted 7200V overhead powerline. Crew engaged in placement of steel roof joist on roof of school under construction.

91-22 Laborer electrocuted while painting a section of support steel for a conveyor system at a plant under construction. Victim and co-worker failed to report receiving minor shocks from conveyor prior to incident.

91-25 Lineman working on ground operating trailer-mounted line tensioner electrocuted when the tensioner became energized. Jerking, then swaying, of new powerline caused it to contact existing 14200V powerline. Possible improper tension on new powerline, or failure of tensioner braking system.

91-28 Textile worker electrocuted when he contacted an energized conductor inside the control box of a carding machine. While inspecting malfunctioning machine, victim directed air from hose with metal nozzle into control box. Nozzle contacted conductor.

91-29 Crew foreman electrocuted when he contacted an energized conductor on a utility pole while attempting to retrieve TV cable wire tangled in overhead powerline.

91-32 Refrigeration technician performing maintenance tasks electrocuted when he contacted the improperly grounded refrigeration unit of a walk-in cooler at a restaurant.

92-01 Line mechanic electrocuted while working from an aerial bucket in hot, humid conditions to attach an energized conductor to a cross-arm-mounted insulator. Co-worker observed current arcing across a cross-arm bolt in contact with victim's chest.

92-02 Lineman electrocuted when he contacted an energized powerline while working from the bucket of an aerial bucket truck. Rubber glove caught in wire and partially pulled off, causing wrist to directly contact powerline.

92-06 Roofing mechanic trainee electrocuted when he inadvertently contacted an energized service entrance conductor on the roof of a warehouse. Incident occurred as victim stood up after kneeling on corner of roof to take measurements.

92-07 Electrical technician electrocuted when he inadvertently contacted an energized conductor inside a voltage regulating control cabinet at a new rolling mill. Victim attempting to identify voltage regulation problem, tracing wiring that was not color-coded.

92-12 Powerline worker electrocuted when he grasped an energized jumper wire he apparently believed to be deenergized. Victim impaired by marijuana, using no personal protective equipment. Assigned to repair section of lines plagued by intermittent outages.

92-16 Textile machine operator electrocuted while directing compressed air from hose with metal nozzle in an attempt to cool the electrical components inside the control panel of a sueder machine at a textile plant. Control panel left uncovered.

92-20 Electrical supervisor electrocuted at a plastic-bottle packaging plant when he contacted an energized conductor inside a control panel. Tracing wiring in control panel for a compressor motor starter without deenergizing unit.

92-24 Roofer's helper electrocuted and a co-worker injured when the metal ladder platform hoist they were positioning contacted a powerline. Moving hoist in preparation for placement of new shingles on roof of residence.

92-25 Electrician electrocuted when he contacted an energized powerline while working from an aerial bucket truck to replace cutout switches on a utility pole. No personal protective equipment used, nor were lines covered with insulating blankets or line sleeves.

92-27 Painter electrocuted when the metal ladder he was moving contacted an overhead powerline. Engaged in job site cleanup after painting exterior of private home.

92-30 Apprentice lineman electrocuted when he slipped on wet ground, allowing his unprotected upper body to fall against the utility pole he was helping to set, as the top of the pole was in contact with an overhead powerline.

93-14 Truck driver and company president electrocuted when the boom of a truck-mounted crane contacted a 7200V overhead powerline. Driver using remote control for unloading of concrete blocks at residential construction site. President attempted to assist him upon observing contact, inadvertently contacting energized truck himself.

93-18 Apprentice electrician electrocuted when he apparently lost his balance while standing on a metal ladder attached to operator's cab of an overhead crane and contacted a conductor on another overhead crane. Climbing ladder to reach second crane to perform maintenance on hoisting motor.

94-08 Department of Transportation foreman is electrocuted and a highway maintenance worker severely burned when truck bed contacts overhead 7,200-volt powerline. The dump truck containing asphalt was backed against a paving machine the men were leaning on.

94-10 Journeyman wireman electrocuted after contacting energized switch gear components at a power plant. The journeyman simultaneously contacted two 6.9 kV buss terminals.

94-17 A HVAC contractor and his employee were electrocuted while installing aluminum straps to anchor ductwork to floor joists in a crawlspace. The victim contacted an energized strap, then was grabbed by the contractor. Electrical energy flowed through both men to ground.