Analysis of Fatalities and Injuries Due to Powerline Contacts

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ABSTRACT: Since many construction worker fatalities and injuries are the result of contacts with overhead powerlines, a detailed investigation was conducted on approximately 500 powerline accidents. The objective was to learn more about the conditions and circumstances surrounding these accidents. Because nearly 60% of the accidents involve equipment, these types of accidents were examined in greater depth. Cranes and boom trucks are most frequently involved in equipment powerline contacts. Most equipment contacts are with the boom or the load line. Carrying or handling metallic items, especially aluminum ladders, are the cause of many nonequipment-related fatalities. Human contacts most frequently occur with the hands. The ages of workers killed in powerline contacts are generally in the range of 20–29 years. These contacts when considered by the hour of their occurrence in the day are similar to the pattern observed in other construction accidents. The occurrence of these contacts by the month of the year show an unusual peak in October, a phenomenon that is not explained by the data.

INTRODUCTION

The construction industry continues to be a leader in the frequency of fatalities and disabling injuries. Many of these fatalities and injuries are the result of contacts with overhead powerlines. Unfortunately, most of these contacts result in fatalities. The most unfortunate aspect of these types of injuries is that these are recognized hazards. In addition, these are generally known to exist prior to any construction work ever taking place. Clearly, research and prudent safety practices are required to halt this pervasive killer.

Since overhead powerlines are the source of a significant number of fatalities, it is deemed appropriate to develop a greater understanding of the reasons why electrical contacts occur with such a high frequency. This is especially true of this type of hazard as it is generally known and understood that such contacts are very likely to be fatal.

Previous powerline safety research has tended to focus on what can be done to improve current safety practices and to increase equipment safety technology. Advances in safety technology include insulating links, adding devices to heavy equipment that can sense powerline proximity, erecting barrier cables, etc. This technology will take some time before it will impact safety in the construction industry, as there are no regulatory mandates to impose these advances. The annual toll of fatalities and injuries has decreased due to advances in general safety practices; however, further significant improvements are not likely to occur without additional knowledge about accident occurrences. To make the next iteration in construction powerline safety, new research efforts need to be conducted on what the current causes of fatalities and injuries in the construction industry are. The attitude often expressed is that some fatalities and injuries are inevitable. This is not so. Fatalities and injuries should always be viewed as being avoidable.

LITERATURE REVIEW

The latest statistics prepared by the National Safety Council show that approximately 900 construction worker fatalities occur each year (*Safety* 1995). Analysis of construction fatality data from 1985 to 1989 showed that 11% of the fatalities were caused by contacts with overhead powerlines (*Analysis* 1990). Another study of construction fatality data for 1980, 1985, and 1990 revealed that the ranking of causes of powerline contacts were direct human contacts, crane boom contacts, materials contacting with the lines, and ladder contacts (Hinze and Russell 1995). Similar causes were noted in a publication produced by the National Institute for Occupational Safety and Health (NIOSH) (''Request'' 1985).

In a special publication by the Occupational Safety and Health Administration (OSHA) (*Controlling* 1991), several safety procedures were outlined when working near powerlines. These procedures included deenergizing the powerlines, using insulated protective equipment, and keeping a safe distance from energized lines.

Of the fatalities caused by contact with overhead powerlines, those of most general interest appear to be involving equipment, especially cranes. Electrocutions caused by cranes coming in contact with powerlines have been the focus of recent research efforts. One Canadian study (Dickie 1991) showed that of the fatalities resulting from crane operations, 44% were caused by powerline contact. Another study examined different data sets obtained from Canada, France, and the United States. The U.S. data included only 23 accidents; thus, the conclusions from that effort were biased considerably by the larger database obtained from Canada and France (Paques 1993).

The Paques study was perhaps the most detailed study of crane accidents involving powerlines. It examined powerline contacts by different pieces of equipment, including mobile cranes, boom trucks, dump trucks, backhoes, aerial buckets, crawler shovels and excavators, concrete pumps, and miscellaneous equipment. Most of the analysis focused on the Canadian data because of the similarity in the data-collection methodology (similar time period and the broader coverage of equipment accidents). The results showed that mobile cranes (26.6%), boom trucks (39.6%), or dump trucks (10.0%) were involved in 76% of the equipment contacts with powerlines. Furthermore, ground helpers (as opposed to operators) were involved in 90% of the mobile crane contacts and 70% of the backhoe contacts. Operators were involved in 70% of the boom truck accidents, 77% of the dump truck accidents, and 61% of the aerial bucket accidents. This is perhaps the most definitive work on equipment contacts with powerlines.

RESEARCH METHODOLOGY

The goal of this research was to compile and analyze behavioral or situational factors that lead to powerline fatalities

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and injuries. The raw data for analysis was obtained directly from the Region 10 OSHA office in Seattle, Washington. The data was made available through OSHA's Integrated Management Information System (IMIS). The injury data for those incidents involving work activities in the Standard Industrial Classification (SIC) of 15, 16, and 17 were of particular interest. These SIC codes include general building, highway/heavy, and specialty construction codes.

The data analyzed included 509 separate and complete OSHA incident abstracts, which are construction related and "nonutility." The analysis provides a good national overview of the conditions surrounding powerline contacts. This paper presents the primary findings of interest.

The research was conducted in three stages: data collection, data compilation, and data analysis. The data was collected by requesting a data run of OSHA investigations involving overhead powerlines from the Region 10 OSHA office. The run was limited to 1985 through the present in order to isolate the more recent powerline safety problems. The OSHA data utilized a word search focused on electrocutions and electrical shocks. This provided a 1,200-page document listing all electrocutions that were reported since 1985 in the United States. More electrocutions may have actually occurred, but not all states participated in the data development in each of the years. Data compilation consisted of processing the powerline contact variables into a computer database. Finally, an analysis was conducted listing and comparing the powerline contact variables. Primary analysis was conducted with the Statistical Package for the Social Sciences (SPSS).

The data received from OSHA came in hard-copy form and, for each case, contained a situational abstract, individual citations, and victim data. Some of the abstracts were difficult to decipher or they provided limited pertinent information. In addition, some of the victim data was not well thought out and contradicted the abstract description. These lapses in the data resulted in missing information or data of limited value, but, to the extent possible, all cases were analyzed.

The IMIS information was examined with a particular focus on retrieving information that would be particularly helpful in establishing information related to the following issues:

- Type of contact with powerlines
- Job activity of victim when contact was made
- Voltage rating
- Activity being performed
- Citation frequency
- General information including: age, month, sex, union affiliation, company size, jobsite size, and SIC code
- Injury data
- Equipment motion preceding contact
- Equipment and human contact points

RESULTS

Contacts with powerlines cause many electrocutions. From the IMIS data, a total of 509 electrical contact cases were evaluated. Of these, 447 involved at least one fatality. Some involved two or three fatalities and one or more injuries in the same fatality incident (see Table 1). Powerlines that electrocute construction workers tend to be overhead powerlines. Of all the cases examined, only 10 consisted of fatalities due to contact with underground or buried powerlines. This may bear some testimony to the success of the 1-800-dig system in which utilities (including electrical power companies) mark their lines in areas where underground work is to take place. The high frequency of contacts with overhead powerlines suggests that the targeting efforts should focus on this potential hazard.

The type of powerline was identified in 367 cases. The records show that 92% of the fatalities are the result of workers coming in contact with distribution lines, with the remaining fatalities being equally distributed between drop-down service lines (120–480 V) and transmission lines (66 kV+). The voltages of the powerlines involved in these cases varied from 120 V for drop-down services to as much as 614,000 V for transmission lines. The voltage was provided in 365 cases. The voltage in 219 cases (60%) was in the range of 7,000–20,000 V.

The information concerning the nature of the contact with the powerlines was provided in 498 cases. These were primarily fatality cases, with a small number of injury cases. The most common type of contact with powerlines is equipment, followed by contact with an item being carried, and then by direct human contact (Fig. 1). There were also a notable number of contacts with powerlines by ladders. Equipment was involved in more than 50% of the incidents. Categorized as "equipment" were incidents where the equipment itself made direct contact with the powerlines. The information in Fig. 1 includes equipment in some cases categorized as "item carried" or "human"—when the worker was on a piece of equipment when powerline contact was made; e.g., a worker in an aerial bucket made direct contact with a powerline or materials being held came in contact with the powerline. The

TABLE 1. Number of Fatalities per Electrocution Case

Number of fatalities in one case (1)	Frequency (2)	Percent of fatality cases (%) (3)
1	417	93.29
2	28	6.26
3	2	0.45
Total fatality/electrocution cases	447	100

Note: The sum of the fatalities equals 479.

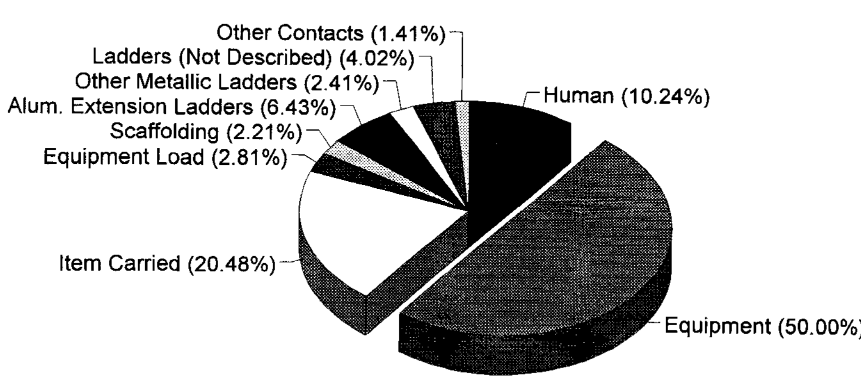

FIG. 1. Contacts with Powerlines

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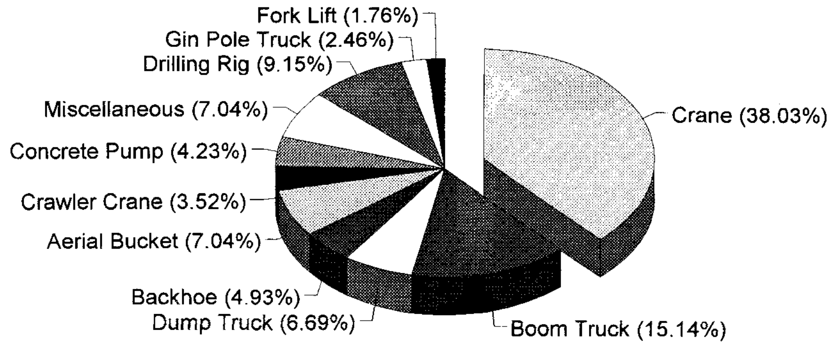

FIG. 2. Equipment Involved

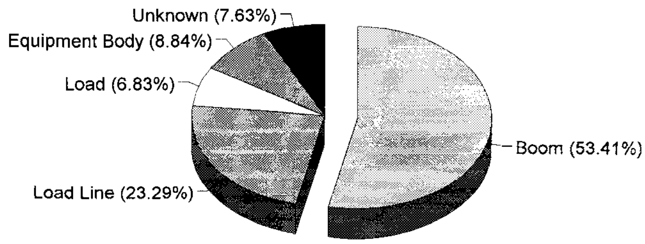

FIG. 3. Equipment Contact Point

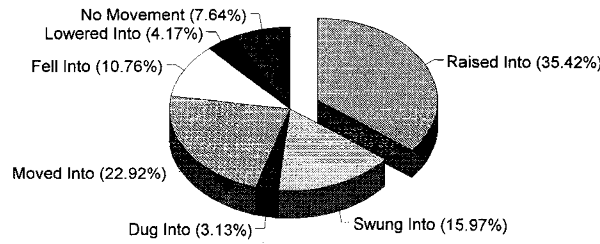

FIG. 4. Motion Prior to Contact

TABLE 2. Component of Heavy Equipment Making Initial Electrical Contact

Equipment (1)	Boom (2)	Load line (3)	Load (4)	No contact (5)	Body (6)
Crane	31	42	6	1	—
Boom truck	30	8	1	—	—
Dump truck	—	—	—	—	19
Backhoe	12	—	2	—	—
Aerial bucket	5	—	—	13	—
Shovels	5	4	—	—	—
Cement pumps	11	—	—	1	—
Miscellaneous	38	4	8	2	3
Totals	132	58	17	17	22

high number of equipment contacts was considered significant and worthy of closer analysis.

Heavy equipment was involved in contacts with powerlines in 284 cases (see Fig. 2). Cranes are associated with the greatest number of such incidents. This is followed by boom trucks. The boom truck case numbers might actually be higher, as boom trucks may have been classified as cranes when some of the report abstracts were written, i.e., many reports were not written with sufficient detail to discern the type of crane. Roofing trucks with material delivery escalators were included among the boom truck counts. The drilling-rig category includes equipment used to drill blast holes, water wells, dewatering wells, for soil-core testing, etc. Miscellaneous equipment included auger feed trucks, skidders, conveyor trucks, semitrucks, front-end loaders, pickup trucks, etc.

Information on equipment contact points was investigated in the 249 cases involving the direct contact of equipment with powerlines. The case numbers show that equipment booms are the most common contact point with powerlines, followed by the load line (see Fig. 3). Further examination of the data shows that the nature of the powerline contact is largely dependent on the type of equipment involved. Obviously, boom contacts would generally include some type of crane or hydraulic excavators, often referred to as backhoes. The largest number of boom truck powerline contacts (31%) occur in material delivery. Load-line accidents would typically relate to cranes. On the other hand, equipment body contacts are most commonly associated with dump trucks. The ''unknown'' category includes incidents in which insufficient information was

TABLE 3. Activity of Heavy Equipment at Time of Electrical Contact

Equipment (1)	Loading (2)	Moving the boom (3)	Moving equipment (4)	Unloading (5)	Unknown (6)
Crane	18	52	5	8	20
Boom truck or conveyor truck	—	35	4	2	4
Dump truck	—	NA	3	14	2
Drill rig	—	13	5	—	4
Backhoe or excavator	—	10	3	1	2
Aerial bucket	—	6	—	—	—
Cement pump truck	—	6	—	2	4
Gin pole truck	1	1	6	—	—
Miscellaneous	1	13	3	—	1
Totals	20	136	29	27	37

Note: NA stands for not available.
[a]Denotes cases in which the abstract did not describe the type of equipment contact.

provided in the abstract descriptions or where no witnesses survived to describe the details of the accidents.

Table 2 shows the varying equipment components making contacts and the type of equipment involved in these powerline contacts. The most significant information about equipment component contacts can be summarized as follows:

- Most crane contacts occur with the load line.
- Most boom truck contacts occur with the boom.
- Dump truck contacts occur primarily with the dump-bed body.
- Most backhoe contacts occur with the boom.
- Most aerial bucket contacts do not occur with the equipment itself, but with direct human contact.
- Most cement pump truck contacts occur with the boom.
- Most miscellaneous equipment contacts occur with the boom.

The information on powerline contacts was examined in greater detail. For example, the movement of the equipment and of materials being handled were studied. The most common type of action associated with the various cases is when equipment or material (ladder, conduit, etc.) is raised into the powerline. Next in frequency was moving the equipment or material into the powerline, followed by swinging the equip-

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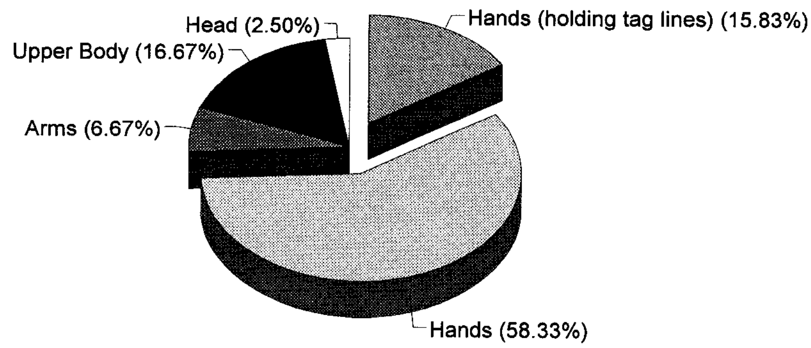

FIG. 5. Human Contact Point

ment material into the powerline (see Fig. 4). Not included in this figure are cases in which the movement prior to contact was not evident (lack of witnesses or lack of details in the accident reports).

In addition to the type of action that initiated contact, the activity being performed was also examined. The basic types of activities consisted of loading, moving the equipment, moving the boom (equipment body being stationary), unloading, and unknown movement (see Table 3). The most common type of activity prior to crane contact with powerlines is that of "moving the boom." This includes moving the boom of the crane with and without a load. This is also a common activity of boom trucks and aerial buckets that come in contact with powerlines. Dump trucks were also typically involved in powerline contacts during stationary unloading, an activity that results in the bed of the truck being raised to heights that place the bed in the proximity of powerlines. A summary of the most common activities associated with each piece of equipment is as follows:

- Most crane contacts occur when the cranes are moving the boom.
- Most boom truck contacts occur when they are moving the boom.
- Most dump truck contacts occur when they are unloading.
- Most drill rig contacts occur when they are moving the boom.
- Most backhoe contacts occur when they are moving the boom.
- Most aerial bucket contacts occur when they are moving the boom.
- Most cement pump truck contacts occur when they are moving the boom.
- Most contacts of miscellaneous equipment occur when they are moving the boom.

An investigation of the functions of workers electrocuted in equipment-related powerline contacts revealed that nearly half (47.5%) of the workers were riggers or spotters. The operators were the victims in many (37.9%) incidents. Side labor or workers who were only peripherally involved with the actual equipment operation constituted the remaining fatalities (see Table 4).

TABLE 4. Function of Workers Electrocuted in Equipment Incidents

Function of electrocuted worker (1)	Frequency (2)
Operator	37.9% (99)
Rigger or spotter	47.5% (124)
Unrelated labor[a]	14.6% (38)

[a]Workers not directly involved in the task being performed by the equipment.

The analysis considered powerline contact cases in which equipment was not involved. These were specifically cases in which the workers made direct contact with the powerline. Human contact points were provided in 120 cases (see Fig. 5). The case numbers show that hand contacts (direct contact including cases in which a sling or guy was held) account for most (74%) of the points of contact. This lends credence to the usefulness of personal protective equipment (PPE) for the hands. Although there may be reluctance among operators and riggers to use PPE, results show the necessity for their use in powerline utility work.

A significant number of electrical shock cases involved metal ladders. These 59 ladder contacts can be summarized as follows:

Moving the ladder—56% (33)
Putting up the ladder—24% (14)
Taking the ladder down—20% (12)

The various cases seemed to be associated with similar types of work. This was examined in greater detail. The IMIS did provide information on the SIC associated with the work being performed at the time of the electrical shock. The SIC codes for each of the electrical shock cases are summarized in Table 5. The construction classifications with the largest number of electrical shock incidents are indicated by a superscript

TABLE 5. Incidence of Electrical Shock Cases by SIC Codes

SIC code (1)	SIC titles (2)	Frequency (3)	Percent (4)
1521	General contractors–single-family houses	8	1.6
1522	General contractors–residential buildings	4	0.8
1541	General contractors–industrial buildings	8	1.6
1542	General contractors–nonresidential buildings	11	2.2
1611	Highway and street construction contractors	25	4.9
1622	Bridge, tunnel, and elevated highway	15	3.0
1623[a]	Water, sewer, pipeline, and communications	40	7.9
1629	Heavy construction, not elsewhere classified	9	1.8
1711	Plumbing, heating, and air-conditioning	4	0.8
1721[a]	Painting and paper hanging special trade	37	7.3
1731	Electrical work special trade contractors	6	1.2
1741	Masonry, stone setting, and other stone work	5	1.0
1742	Plastering, drywall, acoustical, and insulation	1	0.2
1751	Carpentry work special trade contractors	8	1.6
1761[a]	Roofing, siding, and sheet metal work	47	9.3
1771	Concrete work special trade contractors	19	3.8
1781	Water well drilling special trade contractors	12	2.4
1791	Structural steel erection special trade	15	3.0
1793	Glass and glazing work special trade	1	0.2
1794	Excavation work special trade contractors	8	1.6
1795	Wrecking and demolition work special trade	2	0.4
1796	Installation or erection of building equipment	2	0.4
1799	Special trade contractors, not elsewhere	26	5.1
0783[a]	Tree trimming	43	8.5
Various	Materials delivery	16	3.2
Various	Sign erection	5	1.0
Various	Not SIC 15, 16, or 17, but construction related	129	25.5

Note: The SIC codes are based on the work performed on the site. The total for column 3 is 506, and that for column 4 is 100%.
[a]These types of work stand out due to their higher frequency.

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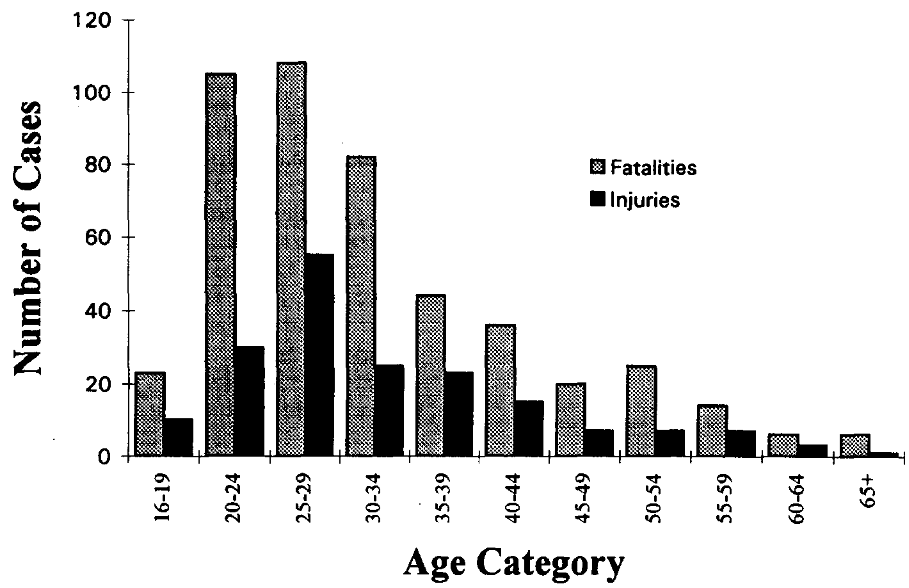

FIG. 6. Age of Workers Involved in Electrical Contact Cases

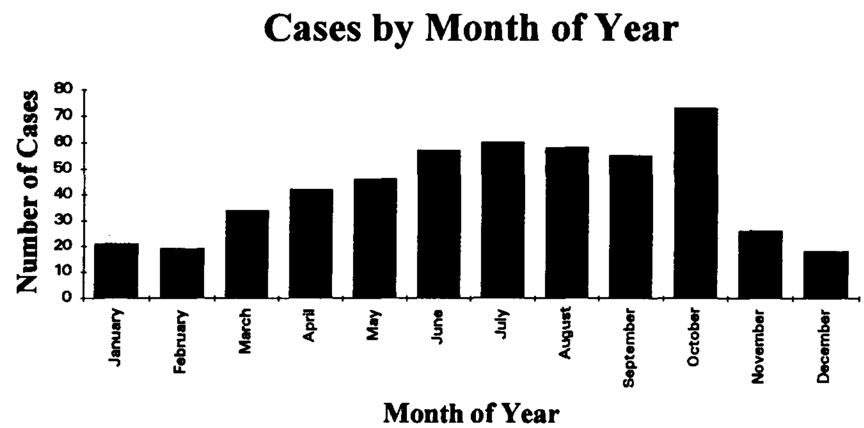

FIG. 7. Frequency of Electrical Shock Cases by Time of Day

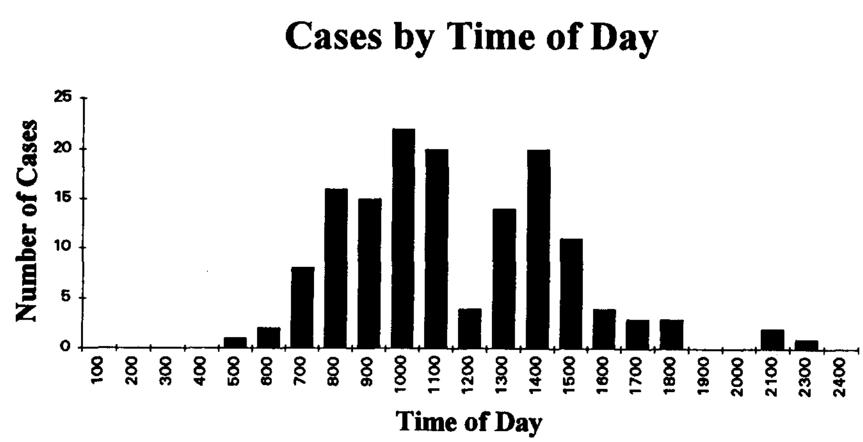

FIG. 8. Frequency of Electrical Shock Cases by Month of Year

"aye" in column 1. Results show that sewer construction, painting, roofing, and tree-trimming have the highest frequencies of powerline contacts.

The fatality and injury victim ages were provided in all 509 cases. The age frequencies show that the younger construction workers (ages 20 to 30) are the ones being killed and injured in the greatest numbers (see Fig. 6). This may be explained by the large numbers of young workers doing construction work, coupled with their lower level of field experience. While this is somewhat in agreement with the age distribution of construction workers, the peak is higher than the national fatality peak for this age group.

Information on the time of injury or fatality occurrence was provided in 146 cases. This is summarized in Fig. 8. The time of day is given in international hours. The times of accident occurrence follow daily construction activity closely. Morning cases increase with respect to greater construction activity until the dropping off period during lunch time. After lunch, the

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number of cases goes back up then drops off in the evening. This pattern is consistent with the time-of-day patterns observed in other studies on construction fatality and injury data.

The month in which the accident occurred was provided in all 509 cases. The case frequency follows monthly construction activity closely, with the exception of a spike in October (see Fig. 7). Case frequencies are low during the winter months and then increase for the high construction activity during the summer months. The spike in October is an oddity and defies simple interpretation. Further analysis showed that the spike was smaller if nonconstruction and tree-trimming activities were excluded from the data. Nonetheless, the spike in October still existed after this data restriction was imposed.

CONCLUSIONS

There are indeed a disproportionately large number of fatalities and injuries attributable to contacts with overhead powerlines. When such electrical contacts are made, a large majority of the incidents result in fatalities. Examination of the circumstances surrounding these electrical contacts reveals that the causes of a large number can be categorized into a few situations. The most common condition is where the boom of large equipment, namely cranes and backhoes, comes in direct contact with overhead powerlines. In addition, results show that different pieces of equipment have differing modes of coming into contact with powerlines. Of those instances in which large equipment is not involved, a large number of electric shocks and electrocutions are the result of metal ladders, especially aluminum ladders, coming into contact with powerlines.

Results show that the trades or crafts most often involved in electrical shock cases are roofers, tree-trimmers, sewer and pipeline workers, and painters. These are the tradespeople who commonly work out of doors, in close proximity to electrical powerlines. When heavy equipment is used near electrical powerlines, it appears as if the spotters are also used to perform rigging services. When spotters are involved in other activities, they cannot effectively direct the operations of equipment.

RECOMMENDATIONS

The high number of electrical contacts resulting from the use of large equipment provide some obvious areas of concern. These pieces of equipment include various types of cranes, hydraulic excavators, dump trucks, concrete pump trucks, etc. Greater attention might be given to training, which would specifically address work in close proximity to powerlines. Work assignments for spotters should be clear and they should not be asked to perform other tasks. Consideration should also be given to improving the communication between the spotters and equipment operators.

Further exploration of the feasibility of using proximity devices on equipment may be warranted. There may even be a need to reevaluate site layouts so that the chance of contacts with powerlines is minimized. Using barrier cables, installing insulating loops on load lines, marking overhead wire locations on the ground, and using spotters may all prove helpful in reducing contacts with overhead powerlines. Ideally, an effort should be made to relocate or deenergize powerlines that are known to exist in the construction work area, especially when in close proximity to where large equipment are to be operated.

Since it is known that roofers, tree-trimmers, sewer and pipeline workers, and painters have especially high incidences of powerline contacts, these trades should be targeted for additional training that will focus on minimizing contacts with overhead powerlines.

The incidence of electrocutions resulting from the use of metal ladders deserves some further consideration. Consideration might be given to insulating the ladders in some way or in coating them with a clear nonconductive material. Of course, the use of ladders around energized powerlines is never a prudent practice. Attempts should be made to do the work so that the powerlines are at a safe distance. Deenergizing the lines when in close proximity to work where metal ladders are used would be most prudent. Of course, work practices consistent with the OSHA regulations would preclude the use of metal ladders in the vicinity of powerlines. By wearing insulated rubber boots and gloves, workers may also be able to avoid electrical shocks, especially where lower voltage lines are involved.

Finally, although the IMIS data was used exclusively to develop the conclusions concerning contacts with overhead powerlines, this source of information could be considerably enriched. The abstracts used to extract most of the information were quite varied between different states and regions. The reports of some states are quite detailed while others appear to be hastily drafted. More uniform training in the development of meaningful abstracts would be very helpful for further study of the data. Part of the training should educate the compliance officers on construction terminology. For example, when a crane is involved in an accident, the abstract should clearly state whether it is a tower crane, lattice-boom crane, or a hydraulic boom crane and if it is a rubber-tired crane, a crawler crane, or a stationary crane. If the terminology were better understood by the compliance officers, they would be able to draft more complete abstracts.

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