AN ANALYSIS OF ELECTRICAL FATAL EVENTS IN THE CONSTRUCTION INDUSTRY 2005 — 2007

Prepared for: **Office of Statistical Analysis**
Occupational Safety and Health Administration
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This report is based upon OSHA-inspected fatal events in construction during calendar years 2005 to 2007. The data analyzed were provided by David Schmidt, Director, Office of Statistical Analysis, Occupational Safety and Health Administration. William R. Schriver, Ph.D., Director Emeritus; Thomas E. Cressler II, M. S., Associate Director Emeritus; John Moore, Ph.D., Acting Director and John Wagner, M. S., Research Associate II conducted the study and prepared this report. This research was supported by contract No J089F26523 with the United States Department of Labor, Occupational Safety and Health Administration. The authors are solely responsible for all interpretations, conclusions and any errors found in the report.

Executive Summary

In 2007 electrical fatalities accounted for just over twelve percent of all construction fatalities. The good news, however, is that in terms of number and percent of construction fatalities, there has been a notable reduction in the time period 1991 through 2007.

This study is based on an analysis of 215 electrical fatalities for the period 2005 through 2007. The underlying data was extracted from the fatality-reports prepared by OSHA Compliance Safety and Health Officers (CSHO). Files were reviewed to determine for each fatal event: primary cause and contributing factors, worksite by end-use, operation involved, evaluation of the safety program of the employer, union status, victim activity and role, and the number and type of OSHA citation issued by proximal cause. CIRPC's observations were confirmed by verification with the CSHO's.

Contact with overhead power line was found to be the leading primary cause of the fatality with the major secondary causes in such events "insufficient planning" and "inattention". For the proximal cause "using/working on electrical components" the prime secondary causes were "proper procedure not followed" and "inadequate training".

A few other findings are perhaps of interest. Nearly forty percent of the events occurred in one or another type of residential construction. We also analyzed the CSHO's evaluations of the quality of employer safety programs. Unfortunately these data were not reported for all 215 events, and in some cases where a report was available it was not always complete. The finding however, was that in about half the cases the programs were evaluated as nonexistent or inadequate.

Unlike some other construction operations (such as roofing), those working with electricity tend to have higher skills and longer tenure, factors which may make further progress in fatality reduction more likely than in some other construction activities. Keys to such progress are found in better planning, better training and a change in workplace culture.

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I. Introduction

Fatal work injuries continue to be a problem in the United States. There has, however, been a downward trend in these fatalities over the period 1992 to 2007. The number of fatalities peaked at 6,632 in 1994 and stood at 5,657 for 2007. In the five year period (2002-2007) the number varied within a rather narrow range from 5,534 in 2002 to 5,840 in 2006. Variation in the number of fatalities during this five year period may be largely a function of the level of economic activity each year and despite the fact that the numbers continue to be too high the good news is that the fatality rate has fallen significantly over the fifteen year period from a high of 5.3 per 100,000 workers to a low in 2007 of 3.8 per 100,000. (BLS 2009)

The overall fatality statistics cited above hide some significant variation by industry. For example the construction industry in 2007 accounted for 1204 of the, 5657 fatalities—the highest number for all of the fifteen major economic sectors. The fatality rate for construction was 10.5 per 100,000 compared with the overall rate of 3.8, and while there were three other sectors with higher rates (Agriculture, Forestry and Fishing; Mining; Transportation and Warehousing), these sectors employed relative fewer workers. (BLS 2009)

Within the Construction sector there is also considerable variation in fatality rates. For example, structural iron and steel workers experienced a rate of 45.5 while that for roofers was 29.4 and for electric power line installers and repairers 29.1. (BLS 2009)

The Construction Industry Research and Policy Center (CIRPC) at the University of Tennessee has, under contract, explored in some detail the nature and causes of fatalities in crane utilization and steel erection and is currently undertaking a companion study to this of falls from roofs in residential family housing. (Journal of Construction Engineering and Management 2006, 2009)

The current study focuses on a fourth area of danger, electrocutions. In a recent analysis of fatal events in construction for 2007 based on information collected by OSHA in the process of investigating 737 events, 89 deaths were related to electrical exposure. (CIRPC 2009) Figure 1 shows the breakdown of these events by primary causes.

II. Overview of Trends in Fatal Electrical Events

The last three decades have witnessed a substantial decrease in electrocution fatalities. A National Institute for Occupational Safety and Health (NIOSH) report covering the period from 1980 to 1992 reported a decline in electrocution fatalities from nearly 600 year in 1980 to about 250 in 1992 - - a decrease of more than 50%. (NIOSH 1998)

Fortunately, the trend noted by NIOSH in the 1998 study has continued. For the period 1991-2 to 2007 the CIRPC has produced an analysis of fatal events in the construction industry. (CIRPC Various) These allow for an extension of the NIOSH finding to the year 2007. These reports concerned the direct causes of fatal events broken down into thirty one causes. While limited to construction as distinct from the NIOSH study coverage of electrocutions in all industries, the 1980 to 1992 trend continued from an average of 112 in 1991-92 to a low of 83 per annum in 2005 (89 deaths in 2007). While the construction related decline was less than the overall total for the earlier period, a reduction in the neighborhood of twenty percent is still notable. This decrease takes on increased signification in light of the fact that construction employment (non-farm) increased for a similar period of time (1990 to 2006) by almost 41 percent (from 5.2 million in 1990 to 7.7 million in 2006. (Commerce 2008) Adjusting the 1990 figure to the estimated 1991-92 value based on employment gains, the "predicted" fatality total for 2006 would be 166/year compared with the "actual" figure of 87 deaths.

Figure 1

Electrical Fatal Event Causes, 2007

Description	Number of Victims/Events	Percent of all Construction Fatal Events
Electric Shock by Touching exposed wire	10	1.4
Electric shock by equipment contacting power source	36	5.0
a. ladder	4	0.6
b. scaffold	3	0.4
c. crane/lifting equipment/boom/ dump truck	16	2.2
d. contact while handling materials such as gutters, iron rods, etc.	13	1.8
Electric shock from equipment installation/tool use	33	4.6
Electric shock, other	7	1.0
Shock/burn from lightning	3	0.4
TOTAL	**89**	**12.4**

The CIRPC annual report data allows us to look further at some trends involving electric-related deaths in construction. Figure 2 shows the fatal event and fatality breakdown for major classification of direct cause:

(a) Electric shock by touching exposed wire (9)

(b) Electric shock by equipment contacting power source (10)

(c) Electric shock from equipment installation/tool use (11)

(d) Electric shock, other (12)

(e) Shock/burn from lightning (29)

For the seventeen year period as a whole there is very little variance between the number of "events" and "fatalities". There were 1779 events resulting in 1801 fatalities. For practical purposes, then, the data for "events" can be seen as a proxy for an analysis of individual fatalities.

For the period 1991- 2007 as a whole, fatal events in construction totaled 11,242 of which 1779 involved electrocutions, or 15.8 percent. The trends in fatal electrocution events can be seen in Figure 3, and Figure 4 showing prime causes during the period in terms of number of events compared with total construction events and the events as a percent of total electrical events. These data are reproduced in graphic form in Figures 5 and 6.

As shown in Figure 3 and Figure 5, the total number of events has trended downward with occasional "blips". For the period as a whole the largest number of deaths are in category 10 causes (electric shock by equipment contacting power source) totaling 732. The second most common cause was in category 11 (electric shock from equipment installation/tool use) at 575 events. These two categories together accounted for nearly three-quarters of the total events.

Figure 2

Construction and Total Electrocution Events and Fatalities, 1991 – 2007

EVENT	Events #	Fatalities
9	374	375
10	732	751
11	575	576
12	65	65
29	33	34
ELEC TOTAL	1779	1801
TOTAL	11242	11425

Category's
9 = Electric shock by touching exposed wire 10 = Electric shock by equipment touching power source 11 = Electric shock from installation/tool use 12 = Electric shock, other 29 = Shock/burn from lightning – included in total, but not in breakdown

Figure 3.

Fatal Electrical Events in Construction by Major Classification of Direct Cause
Related to all Construction for 1991 - 2007

	9		10		11		12		Total	
Year	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1991	29	4.84%	59	9.85%	10	1.67%	14	2.34%	112	18.70%
1992	28	4.67%	59	9.85%	10	1.67%	15	2.50%	112	18.70%
1993	30	5.27%	46	8.08%	21	3.69%	5	0.88%	102	17.93%
1994	30	5.27%	45	7.91%	21	3.69%	6	1.05%	102	17.93%
1995	36	6.13%	49	8.35%	36	6.13%	5	0.85%	127	21.64%
1996	24	4.21%	35	6.14%	23	4.04%	4	0.70%	87	15.26%
1997	20	3.31%	46	7.62%	26	4.30%	3	0.50%	101	16.72%
1998	20	3.21%	58	9.29%	45	7.21%	0	0.00%	126	20.19%
1999	14	1.99%	37	5.25%	33	4.68%	1	0.14%	87	12.34%
2000	20	3.14%	39	6.12%	35	5.49%	0	0.00%	94	14.76%
2001	28	3.89%	36	5.01%	48	6.68%	0	0.00%	116	16.13%
2002	22	3.06%	41	5.70%	47	6.54%	0	0.00%	114	15.86%
2003	16	2.26%	47	6.65%	43	6.08%	2	0.28%	111	15.70%
2004	15	1.91%	34	4.33%	48	6.11%	3	0.38%	103	13.12%
2005	17	2.26%	30	3.98%	35	4.65%	0	0.00%	83	11.02%
2006	15	1.92%	35	4.49%	61	7.82%	0	0.00%	113	14.49%
2007	10	1.40%	36	5.03%	33	4.61%	7	0.98%	89	12.43%
Total	**374**	**3.33%**	**732**	**6.51%**	**575**	**5.11%**	**65**	**0.58%**	**1779**	**15.82%**

Category's
9 = Electric shock by touching exposed wire 10 = Electric shock by equipment touching power source 11 = Electric shock from installation/tool use 12 = Electric shock, other 29 = Shock/burn from lightning – included in total, but not in breakdown

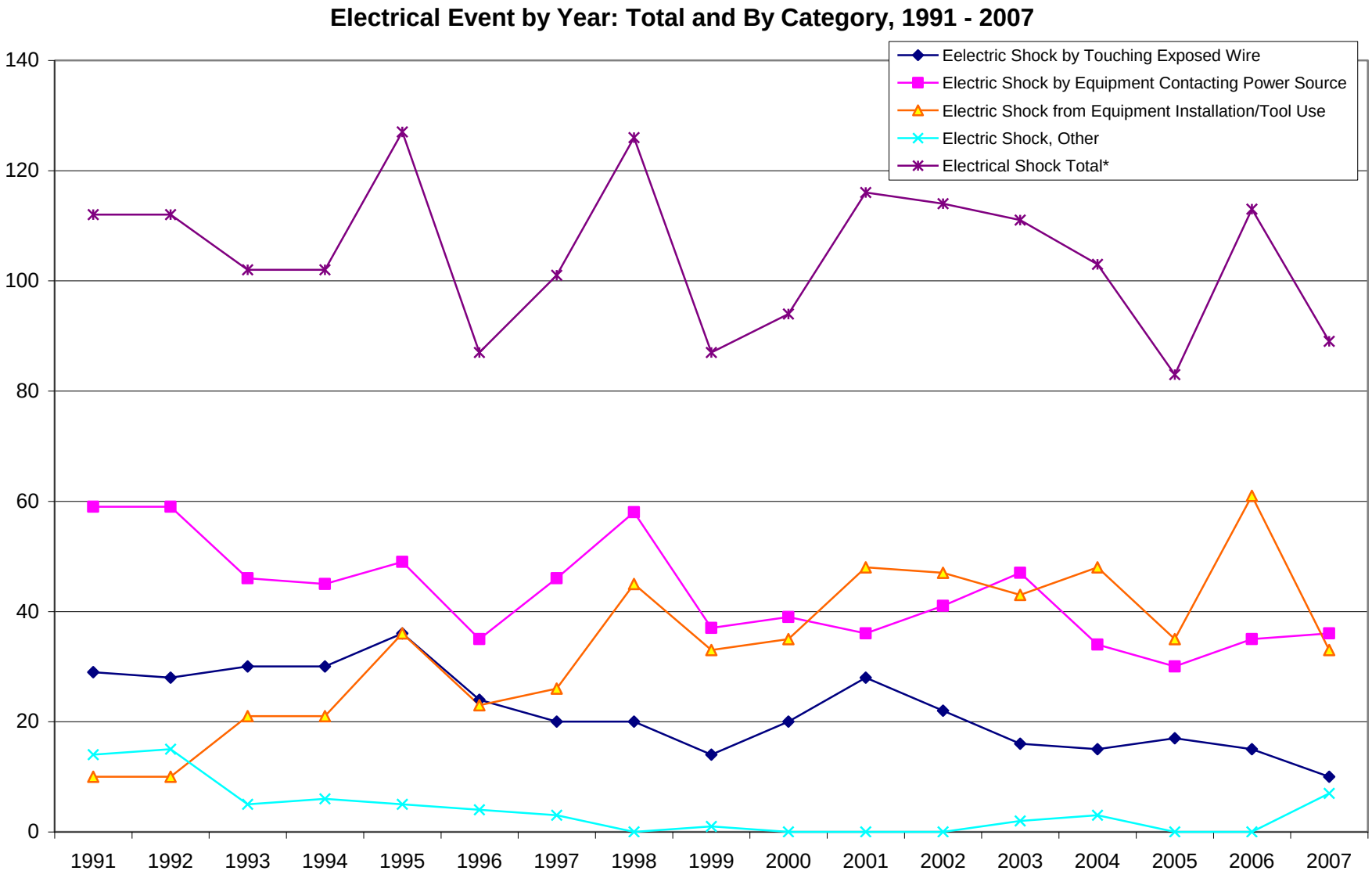
Figure 4.

Electrical Events by Type and Percentage for Years 1991 - 2007

	9		10		11		12	
Year	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1991	29	25.89%	59	52.68%	10	8.93%	14	12.50%
1992	28	25.00%	59	52.68%	10	8.93%	15	13.39%
1993	30	29.41%	46	45.10%	21	20.59%	5	4.90%
1994	30	29.41%	45	44.12%	21	20.59%	6	5.88%
1995	36	28.35%	49	38.58%	36	28.35%	5	3.94%
1996	24	27.59%	35	40.23%	23	26.44%	4	4.60%
1997	20	19.80%	46	45.54%	26	25.74%	3	2.97%
1998	20	15.87%	58	46.03%	45	35.71%	0	0.00%
1999	14	16.09%	37	42.53%	33	37.93%	1	1.15%
2000	20	21.28%	39	41.49%	35	37.23%	0	0.00%
2001	28	24.14%	36	31.03%	48	41.38%	0	0.00%
2002	22	19.30%	41	35.96%	47	41.23%	0	0.00%
2003	16	14.41%	47	42.34%	43	38.74%	2	1.80%
2004	15	14.56%	34	33.01%	48	46.60%	3	2.91%
2005	17	20.48%	30	36.14%	35	42.17%	0	0.00%
2006	15	13.27%	35	30.97%	61	53.98%	0	0.00%
2007	10	11.24%	36	40.45%	33	37.08%	7	7.87%
TOTAL	**374**	**21.02%**	**732**	**41.15%**	**575**	**32.32%**	**65**	**3.65%**

Category's
9 = Electric shock by touching exposed wire 10 = Electric shock by equipment touching power source 11 = Electric shock from installation/tool use 12 = Electric shock, other 29 = Shock/burn from lightning – included in total, but not in breakdown

Figure 5


Electrical Event by Year: Total and By Category, 1991 - 2007
Eelectric Shock by Touching Exposed Wire
Electric Shock by Equipment Contacting Power Source
Electric Shock from Equipment Installation/Tool Use
Electric Shock, Other
Electrical Shock Total*
140
120
100
80
60
40
20
0
1991
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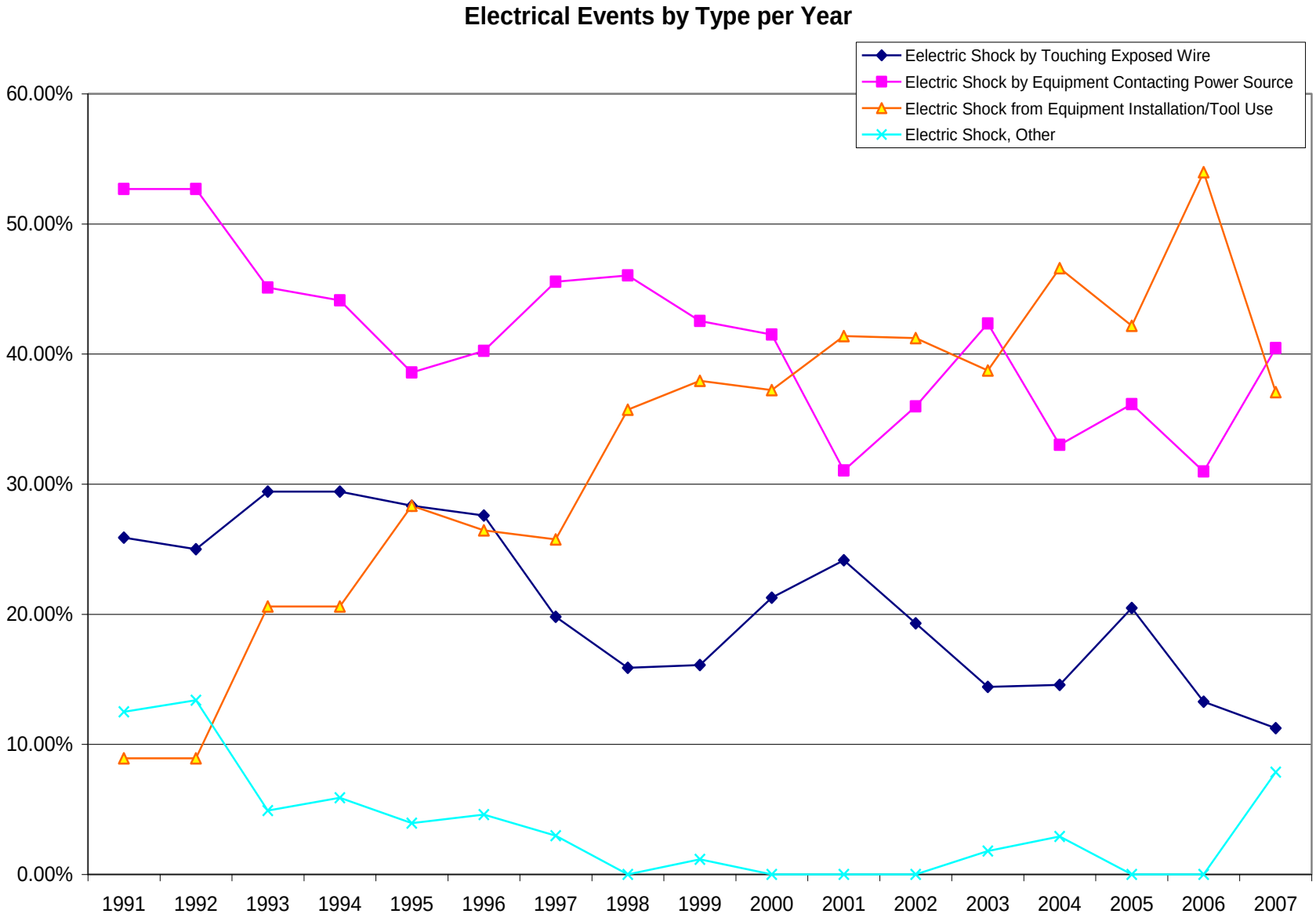
2007

Figure 6


Electrical Events by Type per Year
Eelectric Shock by Touching Exposed Wire
Electric Shock by Equipment Contacting Power Source
Electric Shock from Equipment Installation/Tool Use
Electric Shock, Other
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
1991
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1993
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1996
1997
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2000
2001
2002
2003
2004
2005
2006
2007

Within the overall picture of events, some changes can be noted. As seen in Figure 4 and Figure 6, the category 10 events which started at almost 50 percent of the total has recently settled in the forty percent range, while category 11 events have risen form a low (excluding 1991-92) in the twenty percent range to events in the high thirty to forty percent range. The most consistent trend has, perhaps, been in category 9 (electric shock from touching exposed wire) which declined from about 30 percent of events to something in the 10 to 20 percent range. Category 12 events (electric shock/other) tend to vary considerably, but are relatively unimportant.

The foregoing provides an overview of fatal electrical events, but little detail. In order to better understand the factors associated with these events, CIRPC undertook a detailed analysis of the case files prepared following each event. The methodology and findings follow.

III. Data and Methods

Potential electrical fatal events were identified by first performing a fatality cause search for the OSHA fatality codes 08 (Electrocution by Touching Exposed Wire/Source), 09 (Electrocution by Equipment Contacting Wire), 10 (Electrocution from Equipment Installation/Tool Use), 11 (Electric Shock, Other and Unknown Cause), and 23 (Fire/Explosion). Secondly, a text search of the narrative information available in the IMIS database for the years 2005 to 2007 using the key words “electric,” “shock,” “burn,” “volt,” “arc,” and “current.” OSHA then provided CIRPC with copies of the case files for the Federal and State Program States compiled by the Compliance Safety and Health Officers (CSHOs) in the field who inspected the identified fatalities.

Of the 287 case files preliminarily identified as involving an electrical fatality, CIRPC received 245 from OSHA (85.4 percent of the total requested) and each was reviewed. This

resulted in the selection of 215 case files that were identified as containing an electrical fatality. The selected case files were then reviewed again to determine for each fatal event:

(1) Primary cause and contributing factor(s)

(2) Work site by end-use function

(3) Operation involved in the fatality

(4) CSHO's evaluation of the safety program of the victim's employer

(5) Union representation

(6) Victim's activity at time of fatality

(7) Role of victim in the fatality

(8) Number and type of OSHA citations by proximal cause

Also, information was extracted from the case files to determine: (1) if power lines were contacted, what contacted them; (2) the voltage amounts involved in the event; and (3) for the experience of the electrician or lineman (journeyman, master, etc.).

Analysis showed that all 215 fatal events occurred with three categories of primary causes:

1. Contacting Overhead Power Line
2. Using/Working on Electrical Components / Tools
3. Contact with Energy Source (Other than overhead power lines and electrical tools and components)

Contributing factors to each primary cause were also developed, but they were not necessarily mutually exclusive. Contributing factors by definition precede in occurrence to the direct cause.

IV. Study Findings

Primary Causes and Contributing Factor(s)

Primary causes involved in each fatal event are shown in Figure 7 in order of frequency. "Contacting Overhead Power Line" was the leading cause with 110 (51.2%) of the 215 fatal events. The contributing factors for this cause in rank order were "Insufficiently Planned Operation," "Inattention," "Unaware of Hazard," "No Competent Person Present," "Language Barrier," "Not a Routine Task," "Drugs/Alcohol," and "Employee Misconduct" (shown in Figure 8).

Figure 7.
Primary Causes of Electrical Fatal Events for 2005-07

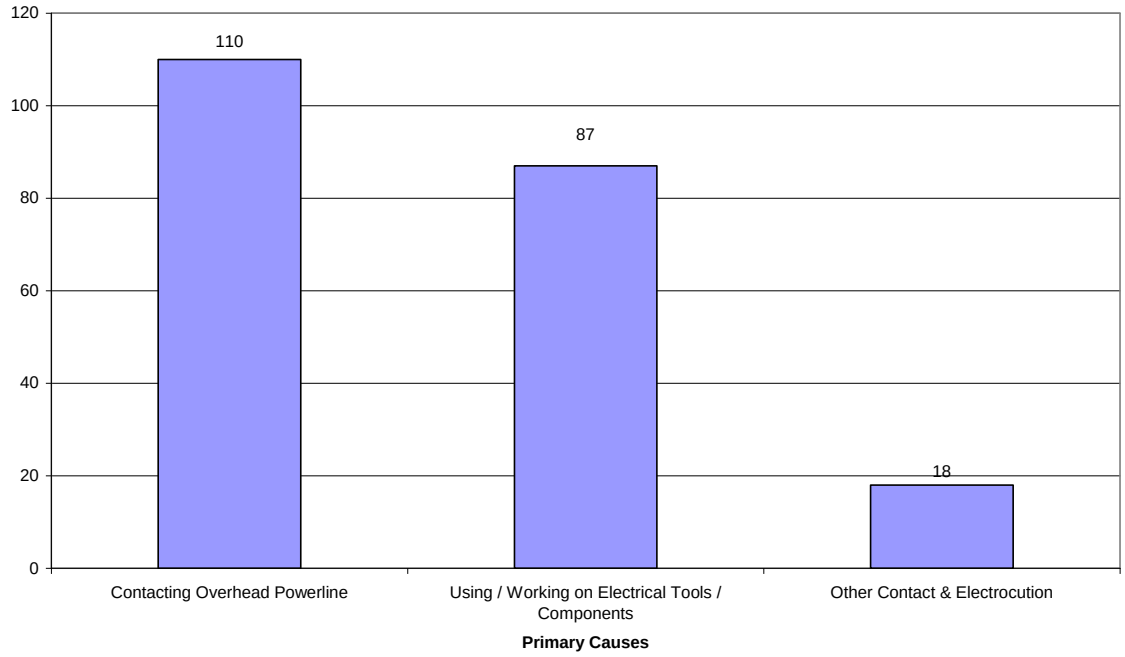
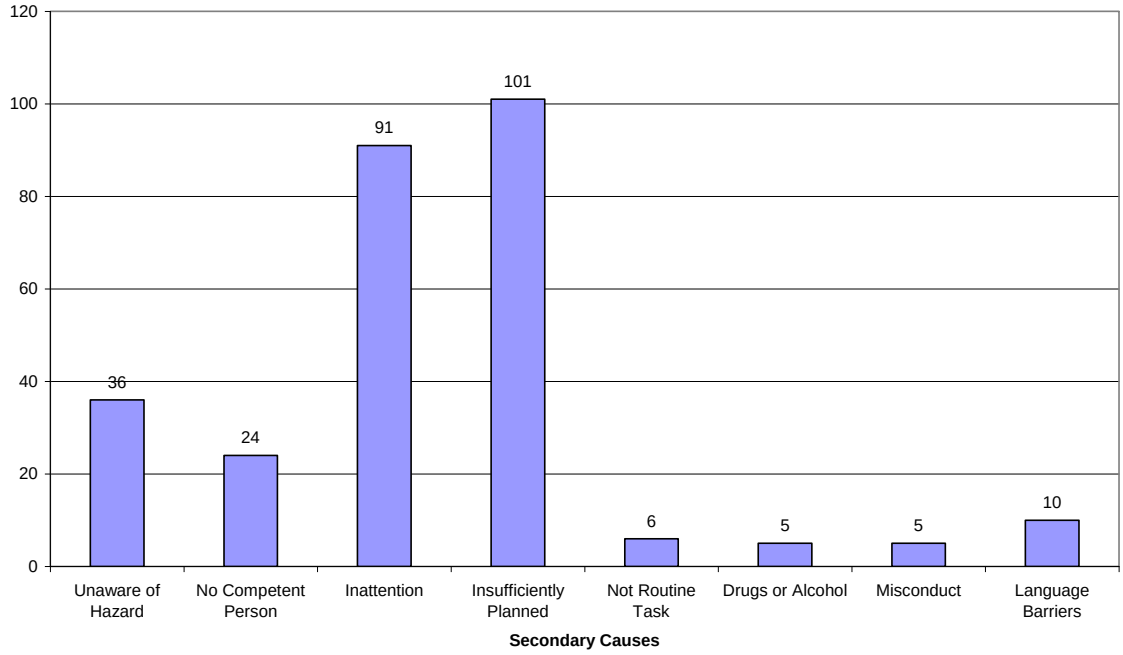
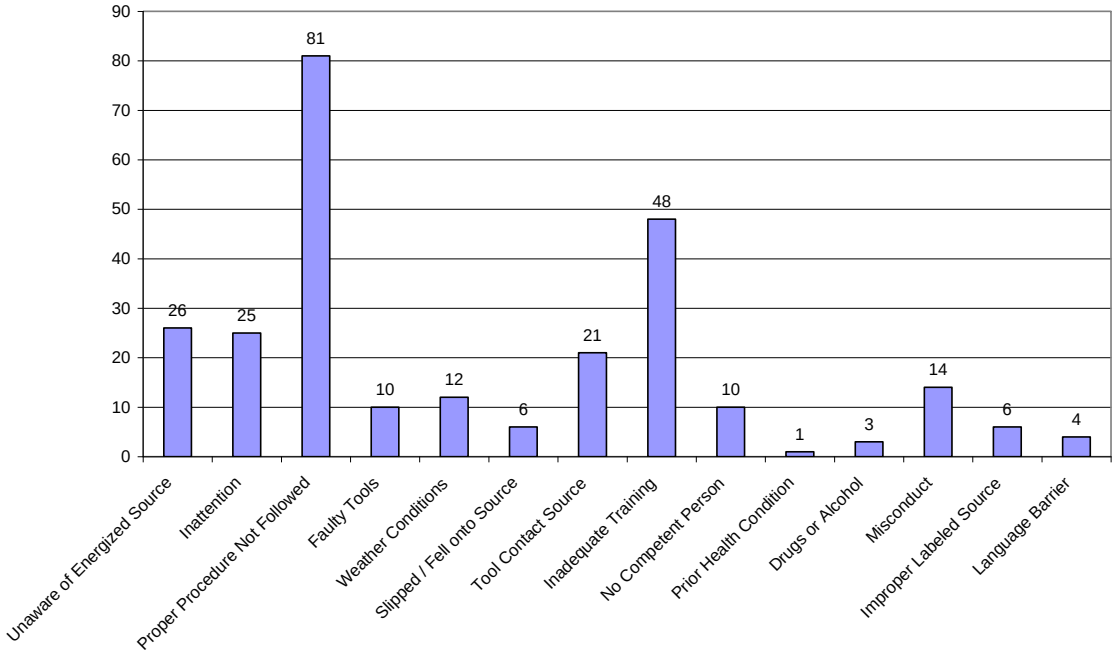


Figure 8.
Secondary Causes of Power Line Contact Fatal Events



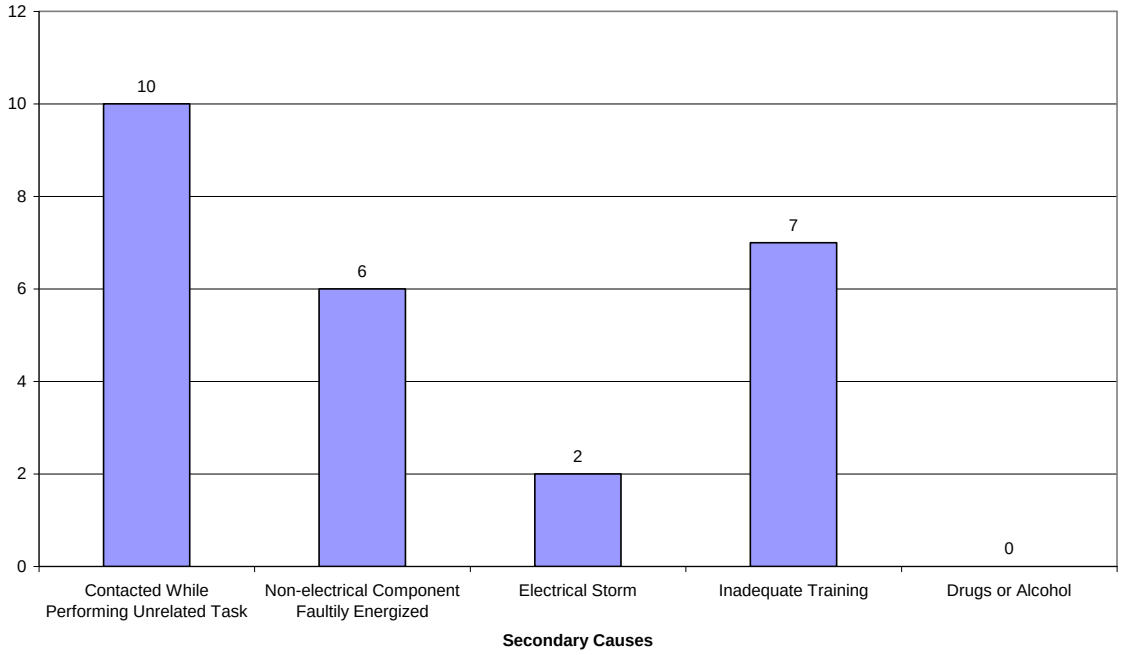
"Using/Working on Electrical Components / Tools" ranked second as a primary cause, resulting in 87 (40.5%) of the fatal events. The factors that were identified as contributing to this cause and in rank order were: "Proper Procedure Not Followed," "Inadequate Training," "Unaware of Energized Source," "Inattention," "Tool Contacted Source," "Employee Misconduct," "Weather Conditions," "Faulty Tools/Equipment," "No Competent Person Present," "Slipped/Tripped/Fell into Source," "Improperly Labeled Source," "Language Barrier," "Drugs/Alcohol," and "Prior Health Conditions" (shown in Figure 9).

Figure 9.
Secondary Causes of Electrocution by Tool/Equipment Usage



"Contact with Energy Source" (Other than overhead power lines and electrical tools and components) ranked third of the primary causes, representing 18 (8.4%) of the fatal events. The contributing factors for this cause in rank order were "Contacted while Performing Unrelated Task," "Inadequate Training," "Non-electrical Component Faultily Energized," and "Electrical Storm" (shown in Figure 10).

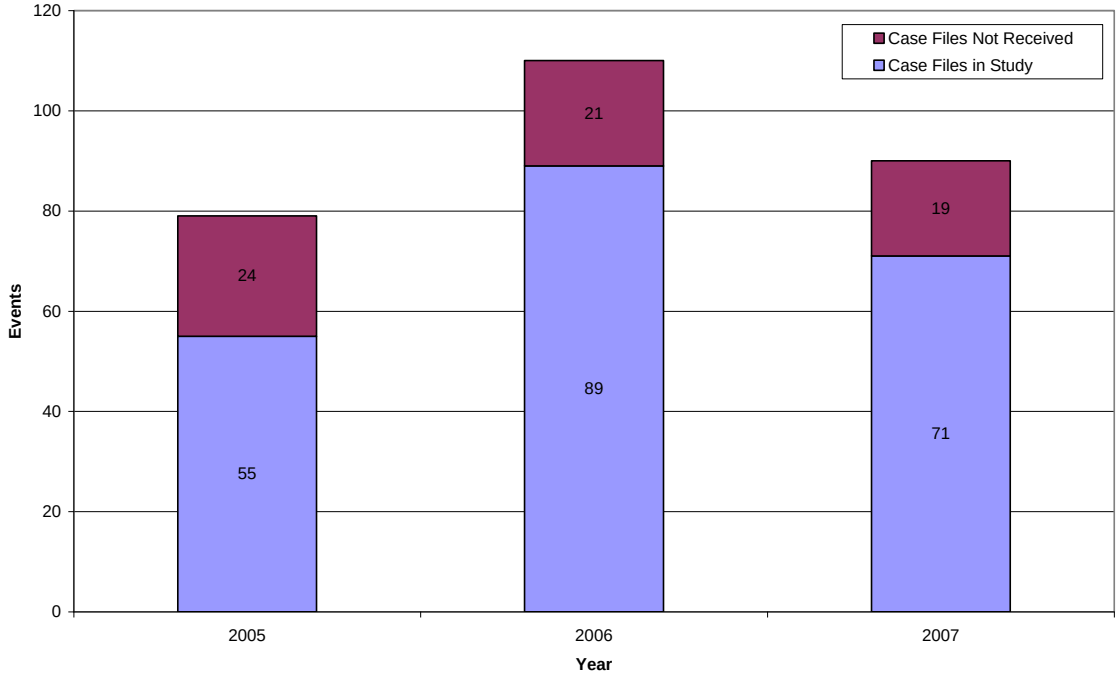
Figure 10.
Secondary Causes for Other Electrical Fatal Events



Fatal Events by Year

For the years 2005 through 2007 there was a one year spike in fatal electrical events, 55 in 2005, 89 in 2006, and 71 in 2007 (Figure 11). This pattern has occurred during previous periods, for example 1995 and 1998 (CIRPC 1995, 1998).

Figure 11.
Electrical Fatal Events by Year

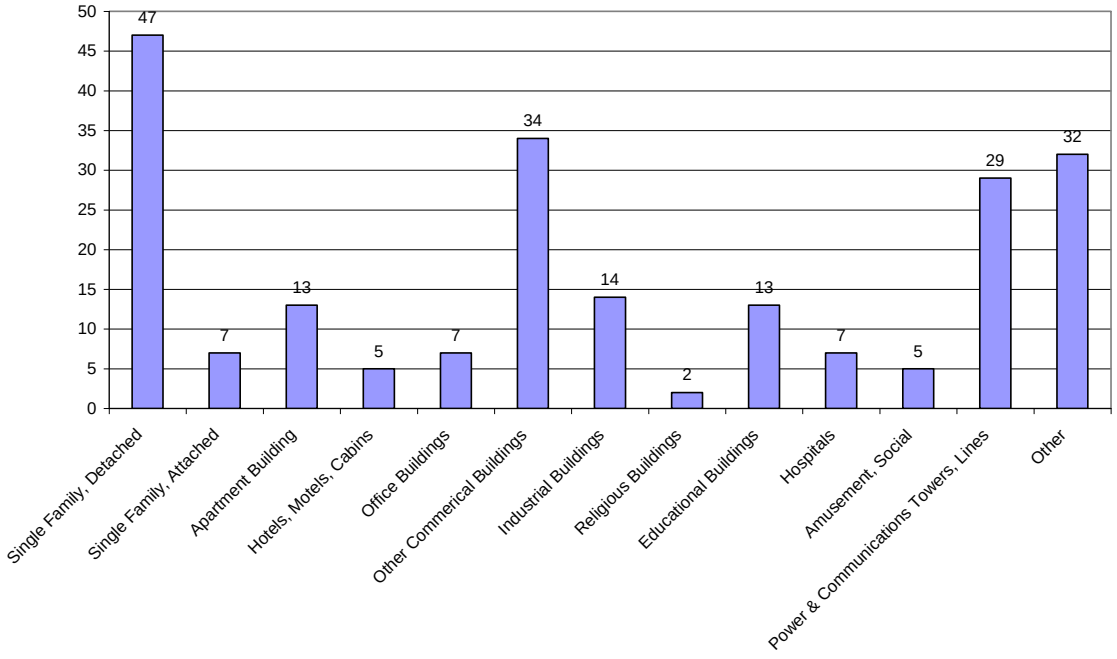


Work Site by End-Use

The United States Census Bureau classifies construction worksites by functional end-use and value of construction work (Census 2002). In fatal electrical events, the most frequent end-use group was "Single Family Houses, Detached" with 47 events (21.9%). End-use group "Other Commercial Buildings" had the next highest total at 34 (15.8%) followed by "Other" with 32 (14.9%) and Power & Communications Tower, Lines with 29 (13.5%). Figure 12 shows the frequency of fatal events by end-use codes.

In contrast to some other construction activities, electrical events were significantly less important in residential construction. For example, in 2006 new single family construction put in place amounted to approximately 55% of total construction compared to the 21.9% of fatal electrical events as reported above (SA 2008).

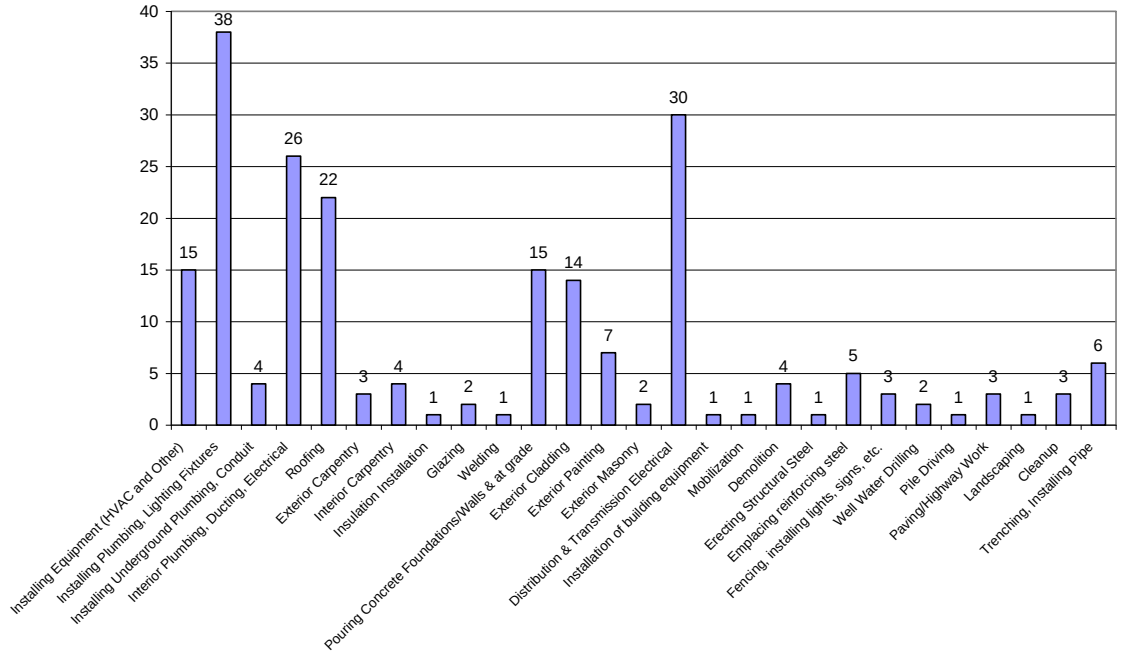
Figure 12.
End Use Type for Electrical Fatal Events



Operations Involved in Fatal Electrical Events

A significant number of fatal events involved an operation associated with installing electrical components. This research revealed that 38 (17.7%) of the 215 fatal events occurred during "Installing Plumbing, Lighting Fixtures" process as shown in Figure 13. Events involving "Distribution & Transmission of Electrical" represented 30 (14.0%) events, followed by "Interior Plumbing, Ducting, Electrical" with 26 (12.1%), Roofing with 22 (10.2%), and lastly "Pouring Concrete/Concrete Processes at 15 (7.0%) and "Installing Equipment (HVAC and other) at 15 (7.0%).

Figure 13.
Construction Operations of Electrical Fatal Events



Occupations

The case files contained the occupation of each victim involved in a fatal event. The top ranking occupations were "Electricians" with 57 (26.5%), "Laborers" with 55 (25.6%), "Lineman" with 26 (12.1%), and lastly "Roofers" with 17 (7.9%). Figure 14 lists all the occupations from each electrocution.

Figure 15 compares the occupational classification distribution for construction as a whole and for electrical fatal events. The top three trades involved in electrical fatalities are "over represented" compared to the total construction population. While the numbers should not be considered precise, they do show marked occupational difference with over 70 percent of the electrical cases involving only three occupational groups while these same occupational groups accounted for little more than 20 percent of all construction occupations.

While it is not surprising that electricians and lineman account for a large portion of the electrocutions it is interesting that laborers and roofers taken together are electrocuted almost as often as electricians and linemen.

Figure 14.
Victim Occupation of Electrical Fatal Events

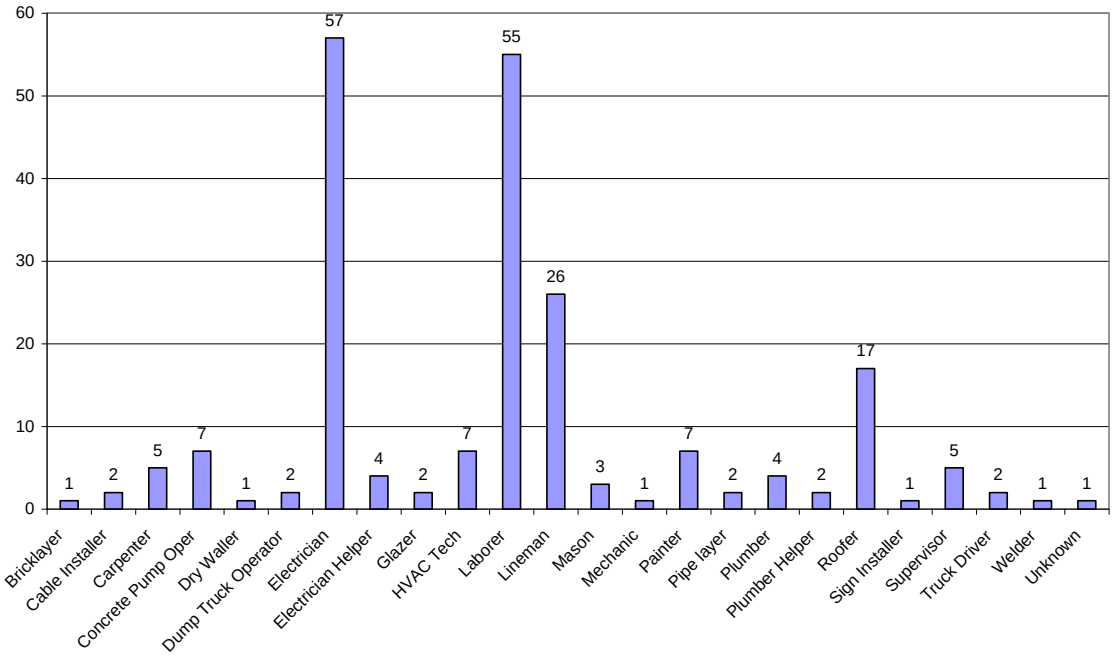


Figure 15

Distributions of Occupations:
Total Construction and Fatal Electrical Events

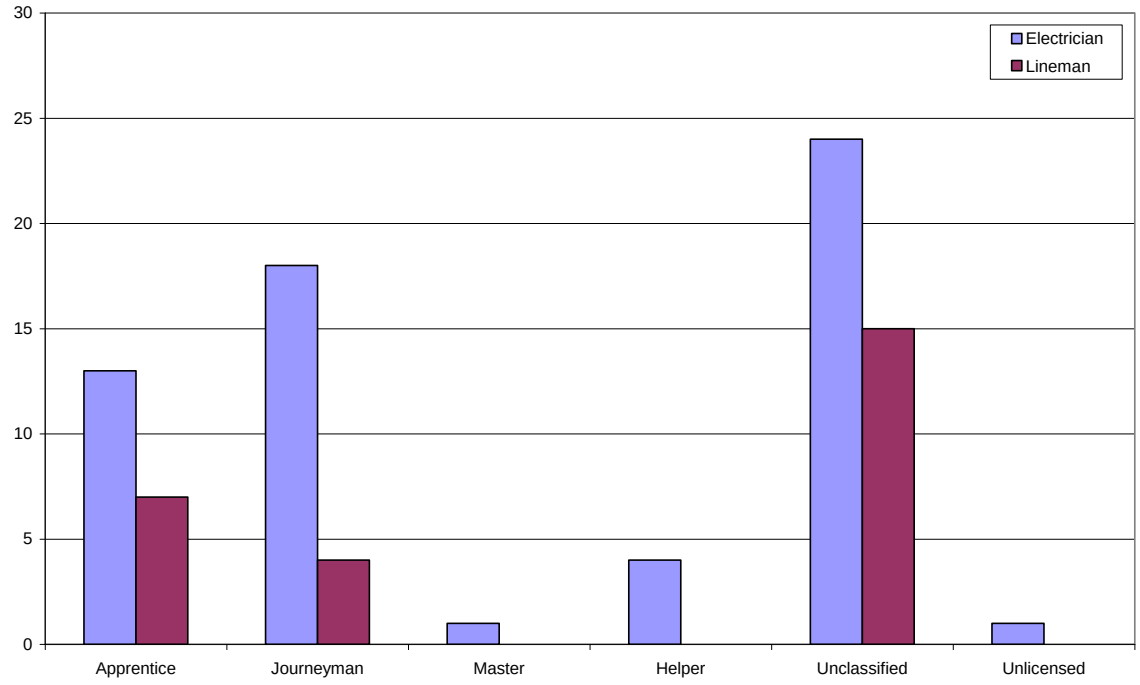
Occupation	All Construction	Fatal Electrical Events
Electrician/Lineman	5.6%	38.0%
Laborer	12.8%	25.6%
Roofer	2.8%	7.9%
Subtotal	21.2%	72.1%
Other	78.8%	27.9%
Total	100.0%	100.0%

Source: CPWR 2007, Table 10b

The “Electrician” occupation was further separated into classifications using data found in the narrative section of the OSHA case files. The classifications were “Master,” “Journeyman,” “Apprentice,” “Unclassified,” and “Unlicensed.” The classifications in rank order were as following “Unclassified Electrician” with 24 (42.1%), “Journeyman Electrician” with 18 (31.6%), “Apprentice Electrician” with 13 (22.8%), “Master Electrician” with 1 (1.8%), and “Unlicensed Electrician” with 1 (1.8%) (Figure 16). Since the “Master Electrician” category amounts to only 1.8%, it may suggest the important role of experience and training in preventing fatal events.

The “Linemen” occupation was also separated similarly and the rank order were “Unclassified Lineman” with 15 (57.7%), “Apprentice Lineman” with 7 (26.9%), and “Journeyman Lineman” with 4 (15.4%) (Figure 16).

Figure 16.
Classification of Electricians and Linemen for Electrical Fatal Events

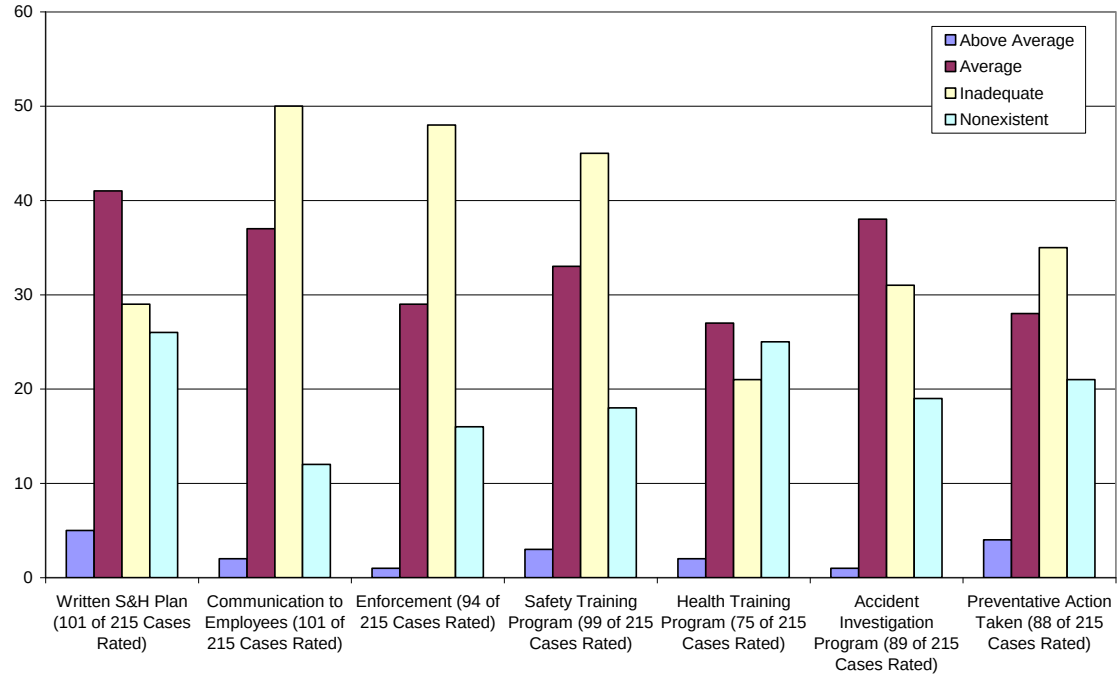


Employer's Safety and Health Program

CSHOs are required to rate employers' safety and health (SH) programs during fatality investigations using the following scale: (a) nonexistent, (b) inadequate, (c) average, and (d) above average. Seven components of an employer's SH program are rated: (1) is there a written SH program and, if so, how does it compare to the OSHA guidelines; (2) how well has the employer communicated its SH program to the employees; (3) how well has the employer enforced its SH program; (4) what type of safety training program does the employer have; (5) what type of health training program does the employer have, (6) when the fatality occurred did the employer perform its own investigation and how well was it performed; and (7) what type of preventive action had the employer taken to prevent the fatal event (OSHA 1998).

Of the 215 electrical fatal events only 152 (70.7%) of the case files examined contained copies of the form used to rate SH programs (OSHA Form 1A). However, not every form available for review included ratings for all seven categories. Figure 17 shows the total number of CSHO employer ratings for each of the seven components and the specific component rating. For the data available for review 46 percent of the employers were rated as having "average" or "above average," while 54 percent were rated as having "nonexistent" or "inadequate" programs. These evaluation results are very similar to the ratings found in a study of crane fatalities (Beavers et al. 2006).

Figure 17.
Safety Program Rating for Companies with Electrical Fatal Events



Union and Non-union Representation

The OSHA case files contained information on whether the victim was or was not represented by a union. Union representation of the victim was indicated in 25 (11.6%) of the cases (Figure 18). This figure is consistent with the percentage of all construction that is unionized (14%) in 2005 as reported by the Center for Construction Research and Training (CPWR 2007). There was little difference in the size of the projects of the victims' employer as measured by contract value between those with union contracts and those without. Sixty percent of union projects and 67% of non-union projects were under $250,000 (Figure 19).

Figure 18.
Collective Bargaining Agreement in Electrical Fatal Events

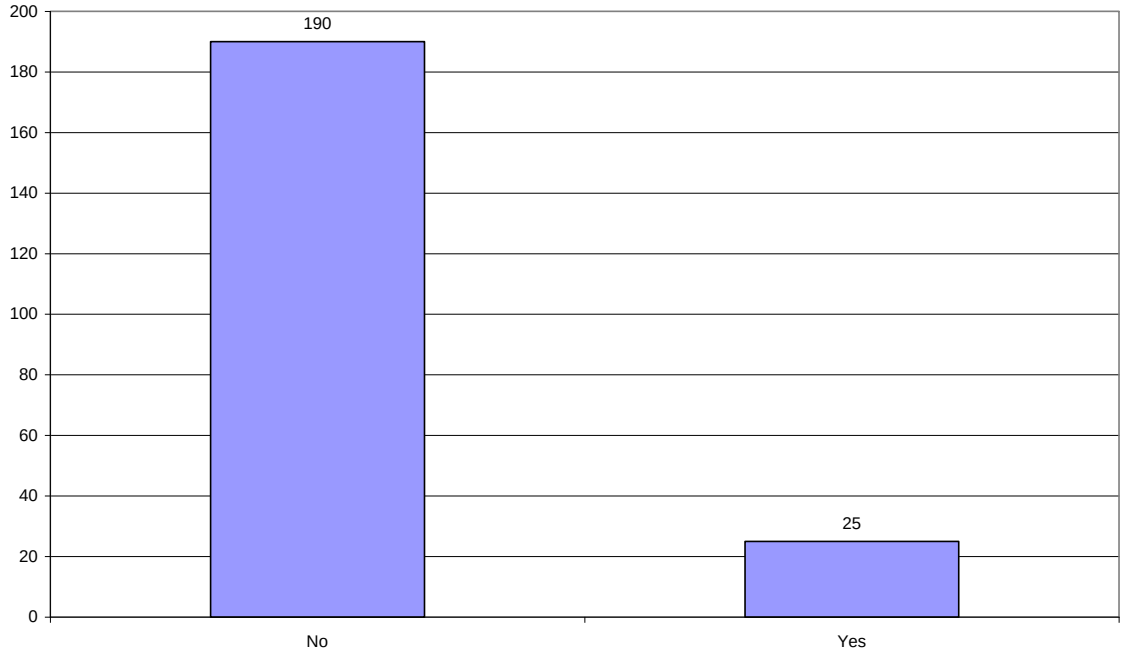
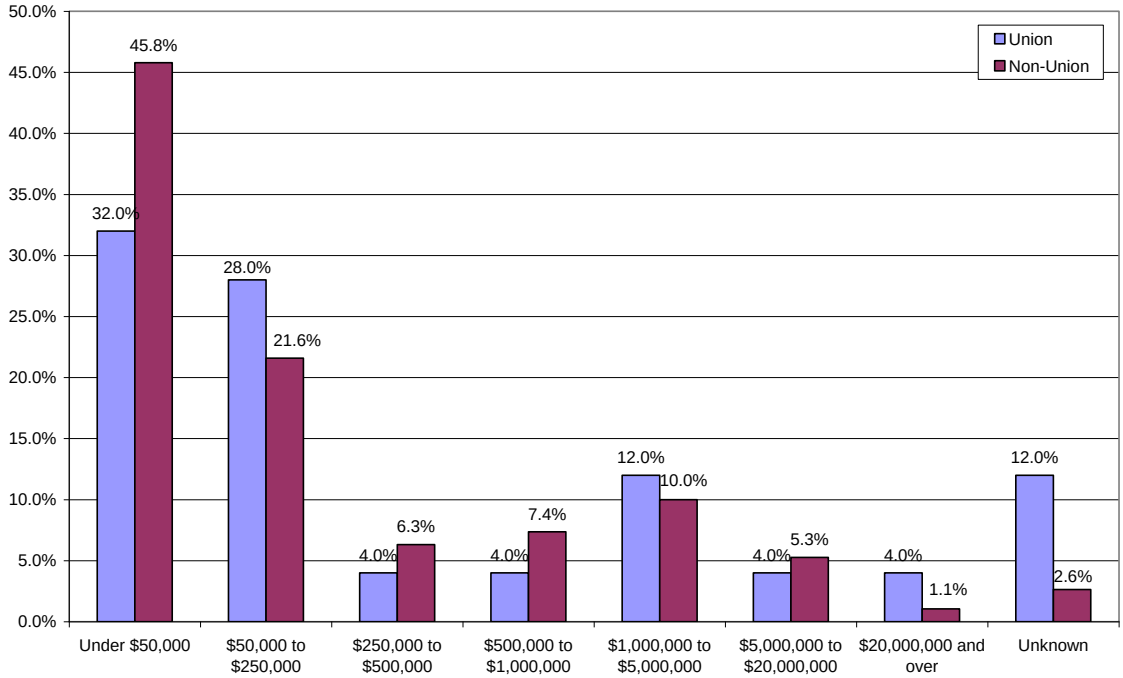


Figure 19.
Project Costs by Union Status for Electrical Fatal Events

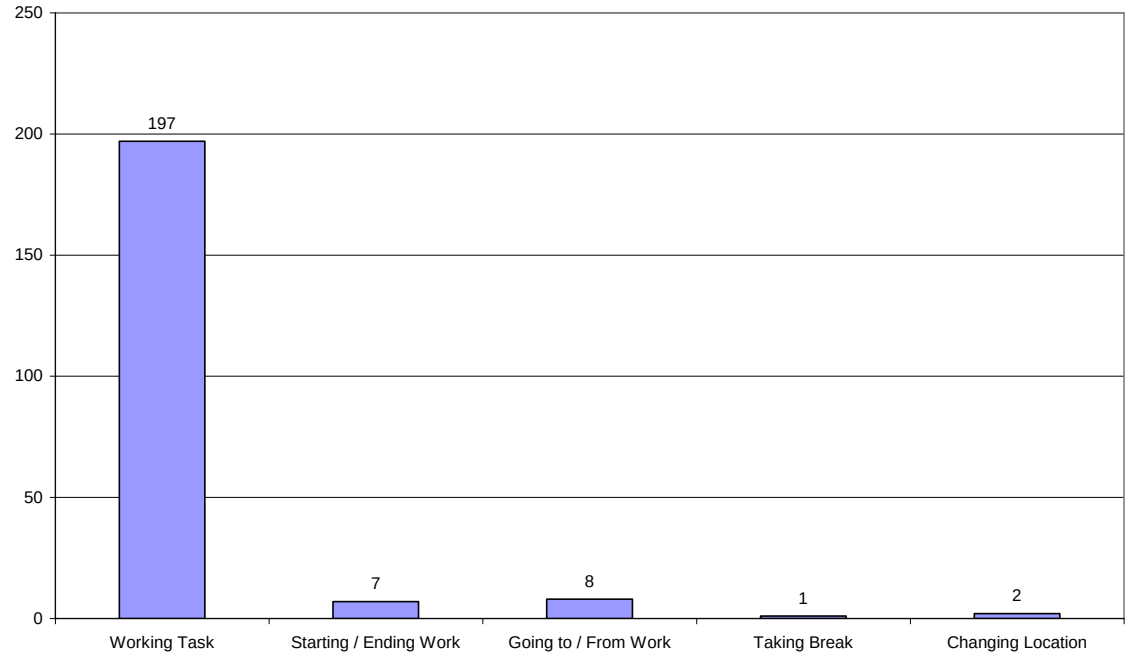


Victim Activity

The authors attempted to determine the victim's activity at the time of the fatality. To do this five activity categories were developed: was the victim; (1) working his/her task, (2) changing location (3) taking a break, (4) starting or ending work, and (5) unknown. Figure 20 shows this data by electrical events. Of the 215 fatal electrical events 197 (91.6%) of the victims were working their task, 10 (4.7%) were going to/from work or changing location, 7 (3.3%) were starting/ending work, and 1 (0.5%) was taking a break.

Often, when conducting a work change event, i.e., changing location, taking a break, or starting/ending work, apparently the victim may remove their personal protective equipment completely (gloves, mask, etc).

Figure 20.
Victim Activity during Electrical Fatal Events

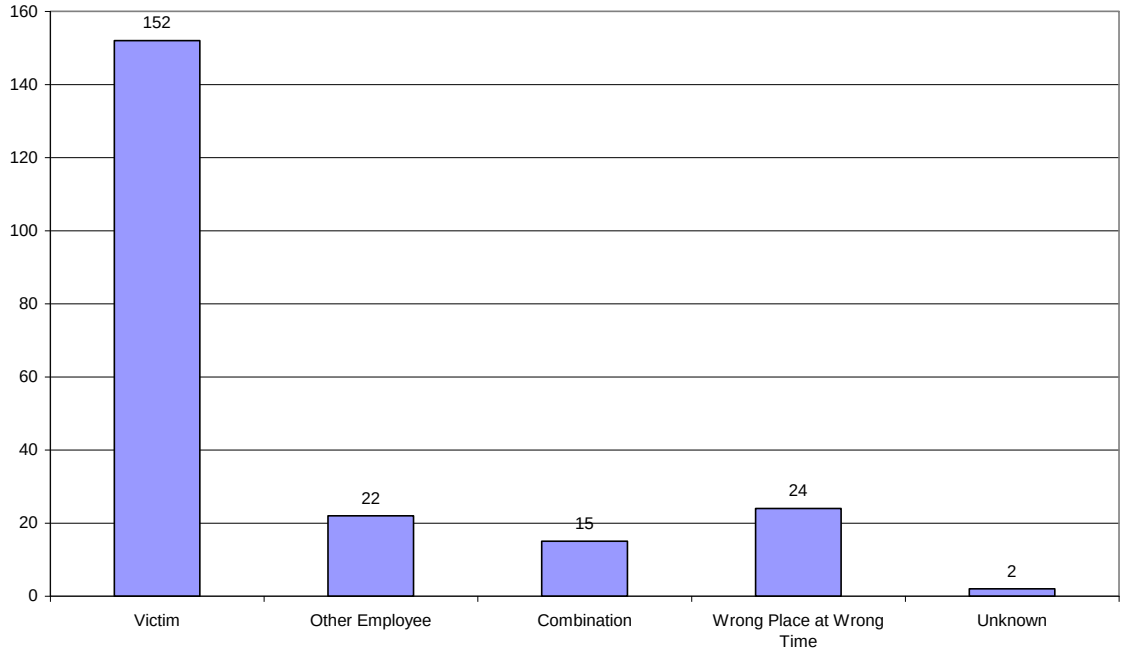


Role of Victim in Fatal Event

From the case files the authors evaluated, where possible, who initiated the fatal event. This excludes all indirect conditions and obligations of employers to provide jobsites free of known hazards. The direct action determination was made, often only inferentially, as to whether the victim's actions substantially contributed to the event. As a result, five categories were developed. The first category, "victim," was defined as: immediate actions by the victim alone initiated the fatality. The second category, "other worker," was defined as: "actions by another worker initiated the fatality." The third category, "combined," was defined as: "immediate actions by both the victim and other worker initiated the fatality." The fourth category "wrong time/wrong place," was defined as: "no assignment of direct cause to a specific individual. A final and fifth category "unknown" was a designation to include those events where classification into one of the first four categories was not possible.

Figure 21 shows "victim" alone accounted for 152 (70.7%) of the events; "wrong time/wrong place" accounted for 24 (11.2%) event; "other employee" accounted for 22 (10.2%) events; "combination" accounted for 15 (7.0%) events; and "unknown" accounted for 2 (0.9%).

Figure 21.
Electrical Fatal Events - Fatality Initiated by



As noted above the analysis of victim involvement shown in Figure 21 excludes indirect conditions and employer obligations to provide a safe working environment. If we expand our consideration to the secondary factors associated with the three primary causes identified in this study an interesting picture emerges. In Figure 22 below we have classified the major secondary causes into three categories: (1) primarily victim related, (2) primarily employer related, and (3) a possible combination of causes. For example, "lack of training" would seem to fall in the category of employer responsibility, while "inattention" would seem to be related to the victim and his or her behavior. Rather than look at all factors, we have confined our analysis to the top factors (amounting to over 80 percent of the secondary factors identified).

Included in the "victim related" category were "inattention" (106), "proper procedure not followed" (81), "unaware of hazard" (56) and "tool contact with source" (21) for a total of 259 observations.

"Employer related" secondary causes included "insufficiently planned" (101), "lack of training" (55), and "no competent person present" (24) for a total of 180 secondary causes.

"Contact while performing unrelated work" (10) was the only major factor in the "possible combinations" category.

Figure 22

Secondary Factors in Distribution of Fatal Events

	Number	Percentage
Victim Related	264	58
Employer Related	180	40
Combination	10	2
Total	454	100

While subjective elements entered into the initial categorization of secondary cause and into the three-fold assignment of "responsibility", it seems clear that in the final analysis the aphorism "safety is everyone's business" is very appropriate.

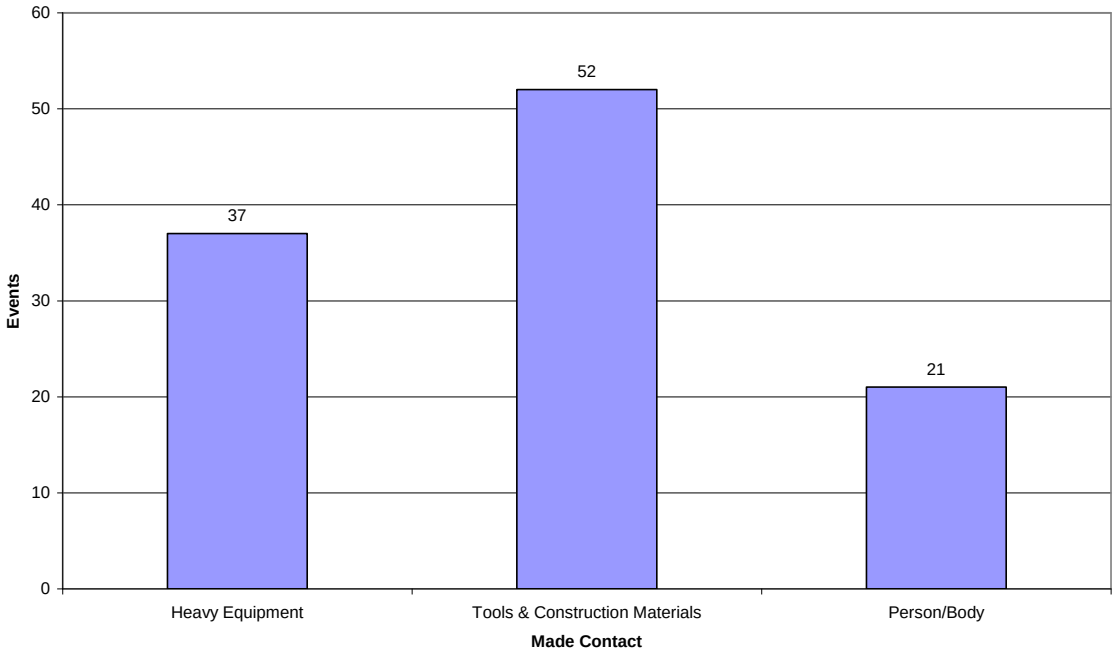
It should be noted that while the "victim-employer" dichotomy is of interest it is probably also over-simplistic. There is little doubt that interrelationships exist. For example, better training might well lead to less inattention, and lack of awareness of a hazard may be obviated with the presence of a competent person.

Power Line Contacted Items

For electrocutions involving "Contacting Overhead Power Line" as the primary fatality cause the data "What contacted the power line" was collected. The contacting items were

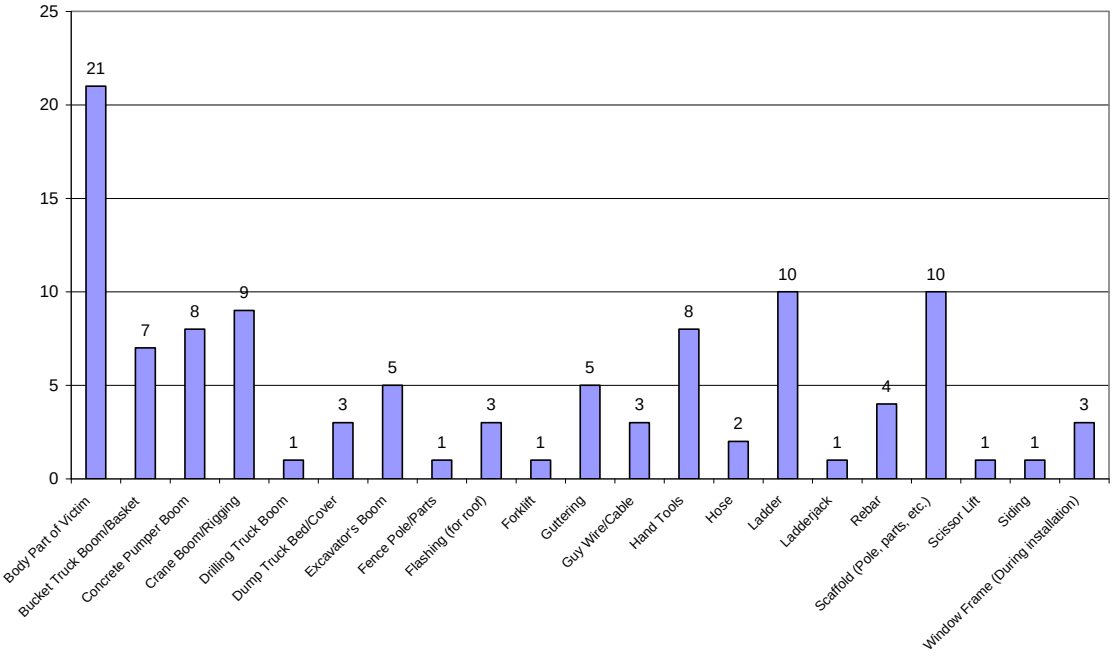
grouped together into the following categories for each event. They were "Heavy Equipment," "Tools & Construction Materials," and "Person/Body." The categories in rank order are "Tools & Construction Materials" with 52 (47.3%), "Heavy Equipment" with 37 (33.6%), and "Person/Body" with 21 (19.1%) (Figure 23).

Figure 23.
Grouped Contacting Power Line during Electrical Fatal Events



The ungrouped categories for "Contacting Overhead Power Line" in rank order were "Body Part of the Victim" with 21 (19.1%), "Ladder" with 10 (9.1%), "Scaffold & Scaffold Parts" with 10 (9.1%), "Crane Boom & Rigging" with 9 (8.2%), "Concrete Pumper Truck Boom" with 8 (7.3%), and "Hand Tools" with 8 (7.3%) (Figure 24).

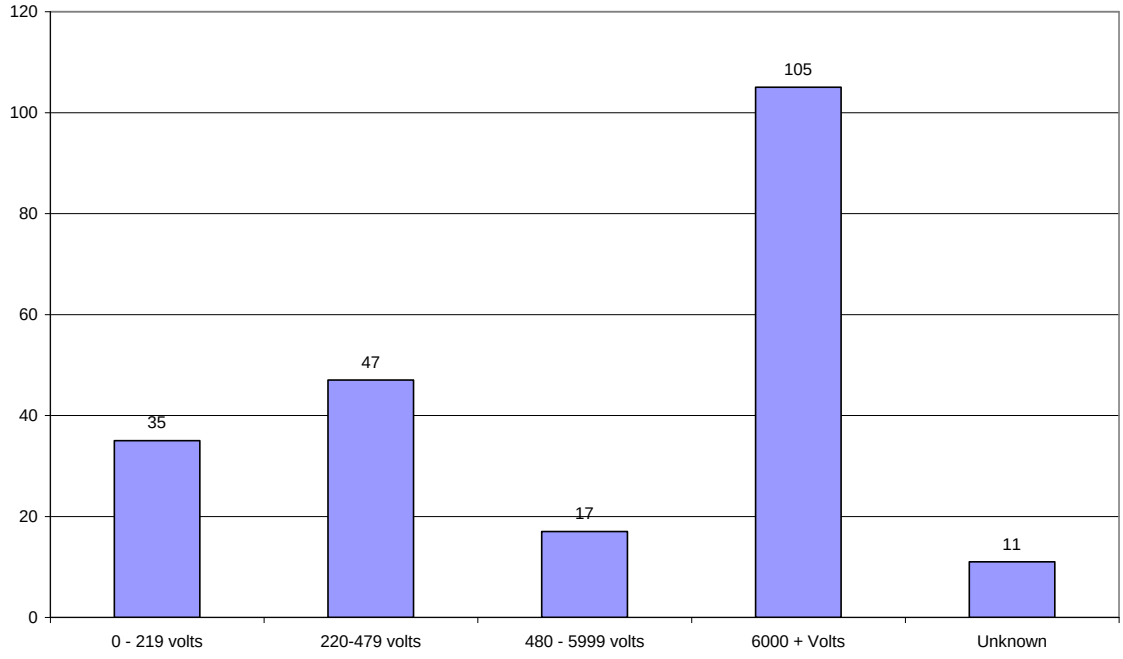
Figure 24.
Contacted Power Line during Electrical Fatal Events



Voltage

The voltage of the electrocution was gathered for each of the fatal events. The voltage was separated into the following categories "0 – 219 volts," "220 – 479 volts," "480 – 5999 volts," "6000 or more volts," and "Unknown." The rank order of the voltage amounts were as following "6000 or more volts" with 105 (48.8%), "220 – 479 volts" with 47 (21.9%), "0 – 219 volts" with 35 (16.3%), "480 – 5999 volts" with 17 (7.9%), and "Unknown" with 11 (5.1%) (Figure 25).

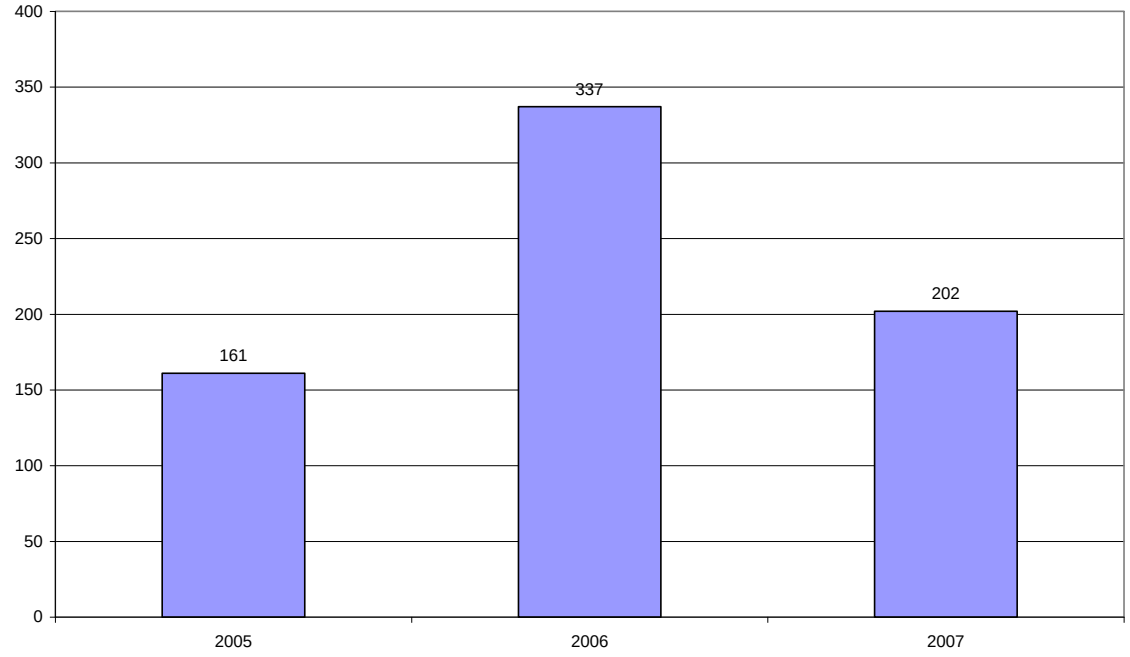
Figure 25.
Voltage Levels for Electrical Fatal Events



OSHA Citations

Two hundred and fifteen case files investigated revealed 700 citations for OSHA standard safety violations averaging 3.38 citations per cited employer. Eight employers did not receive a citation. For 2005 OSHA issued 161 (23.0%) citations for standard violations. In 2006 there were 337 (48.1%) citations and 2007 had 202 (28.9%) citations (Figure 26).

Figure 26.
Standard Violations per Year for Electrical Fatal Events



The standard most violated was 1926.416(A)(1) ("No employer shall permit an employee to work in such proximity to any part of an electric power circuit, unless the employee is protected against electric shock by de-energizing the circuit and grounding it or by guarding") with 73 (10.4%) citations. The second ranked standard was 1926.21(B) (2) ("The employer shall instruct each employee in the recognition and avoidance of unsafe conditions") with 46 (6.6%) citations. The third ranked standard was 1926.416(A) (3) ("The employer shall ascertain by inquiry or direct observation, or by instruments, whether any part of an energized electric power circuit, exposed or concealed, is so located that the performance of the work may bring any person, tool, or machine into physical or electrical contact with the electric power circuit") with 39 (5.6%) citations.

V. Summary

Overall Findings

- Electrocutions have continued to decline over the time span 1991 to 2007
- As a percentage of overall construction fatalities, electrocutions have also experienced a significant decline
- It is disturbing to note that among the four major proximate causes, "electric shock from equipment installation/tool use has increased dramatically in terms of numbers and percent of direct causes. The reason for this could be a fruitful area of inquiry

Case Report Findings

This "case report" study critically reviewed data from 215 electrocution fatal events in the construction industry from 2005 to 2007 investigated by OSHA in the Federal and State Program States. The primary purpose of the study was to determine what safety practices need to be improved to reduce fatal events involving electricity. The following are the key findings:

- The primary cause "Contacting Overhead Power Lines" led all categories for electrical fatal events. Some 110 of 215 events fell into this category.
- Dominating the secondary cause of power line contact fatalities were "Insufficiently Planned" and "Inattention". Together these two factors accounted of 192 of the 278 identified secondary causes in this category.
- Similarly, the two secondary causes of electrocution by Tool/Equipment usage were "Proper procedure not followed" and "Inadequate training" amounting to nearly fifty percent of the causes. These factors are suggestive of those found relative to power line contact.
- Body part of victim was the top ranking item contacting overhead power lines.
- The construction operations "Installing Plumbing, Lighting Fixtures," "Distribution & Transmission," and "Interior Plumbing, Ducting, and Electrical Work" were the most frequent operations where fatalities occurred. Each of these operations involved more than 25 fatalities.
- It is not surprising that electricians and linemen constitute the largest occupational groups associated with fatal electrical events, but it may be surprising to some that nearly as many fatalities involved laborers and roofers.

- The end-use categories of residential "Single Family, Detached" had the greatest number of events. When grouped with other residential facilities, these events amounted to nearly 40% of the identified end uses.

- The victim's own actions dominated the initiation of the fatal event accounting for 197 of the 215 fatal events.

- When secondary factors are considered, a majority of fatalities may relate to individual behavior on the part of the victim, but it is also true that a significant percentage of events are related to lack of training or other failures on the part of management.

- The rated/evaluated employer safety and health programs overall were almost even split between being rated average and above or nonexistent/inadequate. However, in many cases the files did not contain the investigators evaluation of these programs.

- Over 90% of the victims (91.6%) were working at their task when the fatality occurred.

- The immediate action of the victim was responsible for almost three-fourths (70.7%) of the fatalities rather than the actions of fellow workers or other factors.

- The dominant violations of OSHA standards were the lack of protection from electric power circuit by de-energizing or guarding the employee.

- More than half of the fatalities involved voltages of 6000 or above.

Recommendations

In the final analysis, the prevention of fatalities lies with individuals and the culture in which they operate. It is clear that employee carelessness is the cause of many fatalities, but it is also clear that lack of training and job planning by supervisors are factors behind a major segment of these regrettable accidents. As a part of the training of electrical workers, we found the NIOSH (NIOSH 2009) publication Electrical Safety and Health for the Electrical Trades (Student Manuel) to be of great potential value if generally used in the industry. Unfortunately, this manual focuses on what to do after an accident and does not address the pre-accident environment and responsibilities. Perhaps this could be addressed in a further revision.

With regard to the data, a more comprehensive study could be completed if the case file data available for analysis was more complete and better organized. In most cases the narrative,

police reports, and witness statement, pertaining to the file must be reviewed to fill in the details of the incident. While perhaps of minimal value to OSHA overall, consistency between the federal and state programs in the use of the "standard" forms would be helpful to those interested in determining causation rather than simply the assessment of responsibility.

In this project for the first time in our years of experience with other causes (falls from roof, steel erection, cranes) we had direct contact with a number of CSHO's and found them to be extremely helpful in pointing out any errors or omissions in our analysis. The response rate from our follow-up e-mails and telephone calls was approximately fifty percent. Several of those contacted expressed their appreciation for the fact that someone was looking at the reports relative to the causes of the fatalities rather than with a sole focus on enforcement. In this regard we feel it would be helpful if all CSHO's were alerted to the possible multipurpose use of the case file.

Finally, we note that during the period under investigation CFR 29 1901 Subpart S was revised with an effective date of August 15, 2007 – five months prior to the end of our period of investigation. It should be most interesting in a year or two to compare the results of the current study with those of an updated report based, say, on 2008-2010 case files.

Appendix Charts and Tables

Table A-1.

Top 25 Violation of Standards from Electrical Fatal Events

Rank	Standard		Description	#
1	19260416 A01		No employer shall permit an employee to work in such proximity to any part of an electric power circuit, unless the employee is protected against electric shock by deenergizing the circuit and grounding it or by guarding	73
2	19260021 B02		The employer shall instruct each employee in the recognition and avoidance of unsafe conditions	46
3	19260416 A03		The employer shall ascertain by inquiry or direct observation, or by instruments, whether any part of an energized electric power circuit, exposed or concealed, is so located that the performance of the work may bring any person, tool, or machine into physical or electrical contact with the electric power circuit.	39
4	19260020 B01		Accident prevention - It shall be the responsibility of the employer to initiate and maintain such programs	24
4	19040039 A / CAL/OSHA 1509 A		Within eight (8) hours after the death of any employee, you must orally report the fatality/multiple hospitalization by telephone or in person to the Area Office of OSHA	24
6	19260020 B02		Shall provide for frequent and regular inspections of the job sites, materials, and equipment to be made by competent persons designated by the employers	17
7	19260950 C01/ CAL/OSHA 2946 B02		No employee shall be permitted to approach or take any conductive object without an approved insulating handle closer to exposed energized parts than shown in Table V-1	13
8	19260451 F06		Scaffolds shall not be erected, used, dismantled, altered, or moved such that they or any conductive material handled on them might come closer to exposed and energized power lines than 10 feet	12
9	19260550 A15	I	For lines rated 50 kV. or below, minimum clearance between the lines and any part of the crane or load shall be 10 feet;	11
10	19261060 A		The employer shall provide a training program for each employee using ladders	10
11	19101200 E01		Employers shall develop, implement, and maintain at each workplace, a written hazard communication program	9
12	19260600 A06		All equipment covered by this subpart shall comply with the requirements of 1926.550(a)(15) when working or being moved in the vicinity of power lines or energized transmitters.	8
12	19260454 A		The employer shall have each employee who performs work while on a scaffold trained by a person qualified in the subject matter to recognize the hazards	8
12	19260417 B		Equipment or circuits that are deenergized shall be rendered inoperative and shall have tags attached at all points where such equipment or circuits can be energized.	8
15	19260095 A		Protective equipment shall be provided, used, and maintained	7
16	19261053 B12		Ladders shall have nonconductive siderails if they are used where the employee or the ladder could contact exposed energized electrical equipment	6
16	19260503 A01		The employer shall provide a training program for each employee who might be exposed to fall hazards.	6
16	19260454 B		The employer shall have each employee who is involved in erecting, disassembling, moving, operating, repairing, maintaining, or inspecting a scaffold trained by a competent person	6
16	19260453 B02	V	A body belt shall be worn and a lanyard attached to the boom or basket when working from an aerial lift.	6
16	19260451 G01		Each employee on a scaffold more than 10 feet (3.1 m) above a lower level shall be protected from falling to that lower level.	6
16	19260405 G02	IV	Flexible cords shall be connected to devices and fittings so that strain relief is provided	6
16	19260403 B02		Listed, labeled, or certified equipment shall be installed and used in accordance with instructions included in the listing, labeling, or certification.	6
16	19100335 A01	I	Employees working in areas where there are potential electrical hazards shall be provided with, and shall use, electrical protective equipment	6
16	19100333 A01		Live parts to which an employee may be exposed shall be deenergized before the employee works on or near them	6
16	19100332 B01		Practices addressed in this standard. Employees shall be trained in and familiar with the safety-related work practices for electrical	6

Of the top 25 most frequently cited violations in the cases reviewed for this report, the most frequently cited standard is “Lack of protection from electrical power circuit by de-energizing or guarding”.

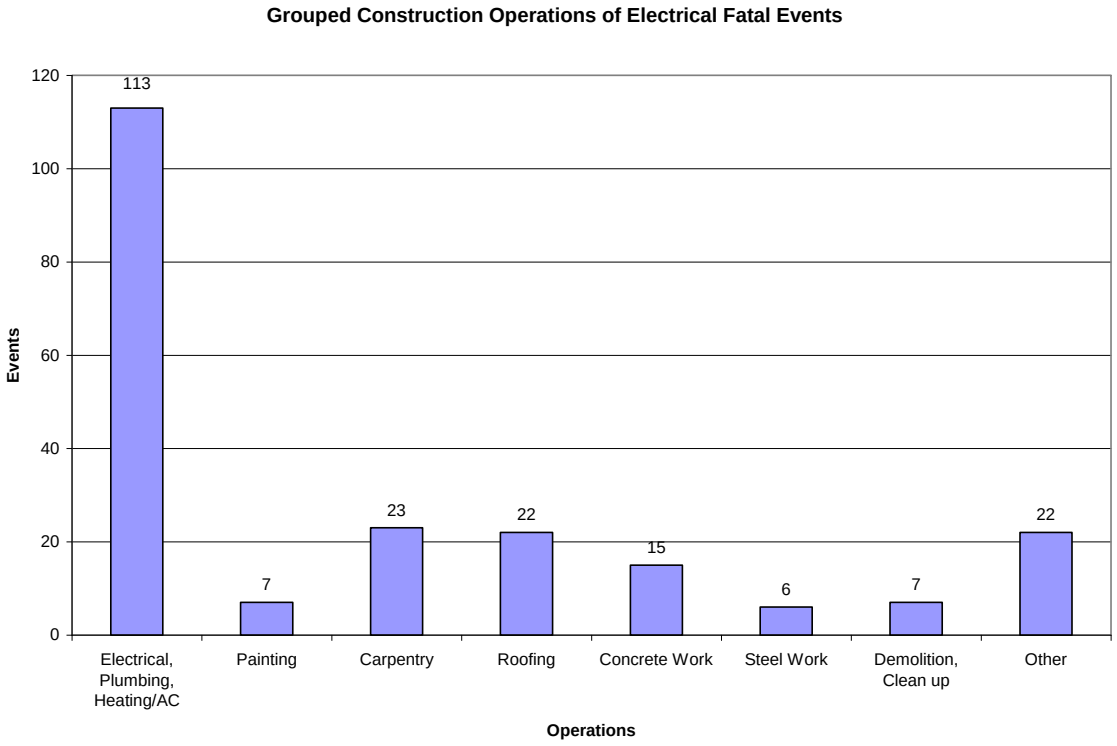
Table A-2.

Top 20 Violation of Electrical Standards from Electrical Fatal Events

Rank	Standard		Description	#
1	19260416 A01		No employer shall permit an employee to work in such proximity to any part of an electric power circuit, unless the employee is protected against electric shock by deenergizing the circuit and grounding it or by guarding	73
2	19260416 A03		The employer shall ascertain by inquiry or direct observation, or by instruments, whether any part of an energized electric power circuit, exposed or concealed, is so located that the performance of the work may bring any person, tool, or machine into physical or electrical contact with the electric power circuit.	39
3	19260950 C01/ CAL/OSHA 2946 B02		No employee shall be permitted to approach or take any conductive object without an approved insulating handle closer to exposed energized parts than shown in Table V-1	13
4	19260451 F06		Scaffolds shall not be erected, used, dismantled, altered, or moved such that they or any conductive material handled on them might come closer to exposed and energized power lines than 10 feet	12
5	19260550 A15	I	For lines rated 50 kV. or below, minimum clearance between the lines and any part of the crane or load shall be 10 feet;	11
6	19260600 A06		All equipment covered by this subpart shall comply with the requirements of 1926.550(a)(15) when working or being moved in the vicinity of power lines or energized transmitters.	8
6	19260417 B		Equipment or circuits that are deenergized shall be rendered inoperative and shall have tags attached at all points where such equipment or circuits can be energized.	8
8	19260095 A		Protective equipment shall be provided, used, and maintained	7
9	19261053 B12		Ladders shall have nonconductive siderails if they are used where the employee or the ladder could contact exposed energized electrical equipment	6
9	19260503 A01		The employer shall provide a training program for each employee who might be exposed to fall hazards.	6
9	19260405 G02	IV	Flexible cords shall be connected to devices and fittings so that strain relief is provided	6
9	19260403 B02		Listed, labeled, or certified equipment shall be installed and used in accordance with instructions included in the listing, labeling, or certification.	6
9	19100335 A01	I	Employees working in areas where there are potential electrical hazards shall be provided with, and shall use, electrical protective equipment	6
9	19100333 A01		Live parts to which an employee may be exposed shall be deenergized before the employee works on or near them	6
9	19100332 B01		Practices addressed in this standard. Employees shall be trained in and familiar with the safety-related work practices for electrical	6
16	19260417 A		Controls that are to be deactivated during the course of work on energized or deenergized equipment or circuits shall be tagged.	5
16	19260404 F06		The path to ground from circuits, equipment, and enclosures shall be permanent and continuous.	5
18	19260404 B01	II	All 120-volt, single-phase 15- and 20-ampere receptacle outlets on construction sites, shall have approved ground-fault circuit interrupters for personnel protection.	4
18	19260100 A		Employees working in areas where there is a possible danger of head injury from impact, or from falling or flying objects, or from electrical shock and burns, shall be protected by protective helmets.	4
18	19100147 C07	I	The employer shall provide training to ensure that the purpose and function of the energy control program	4

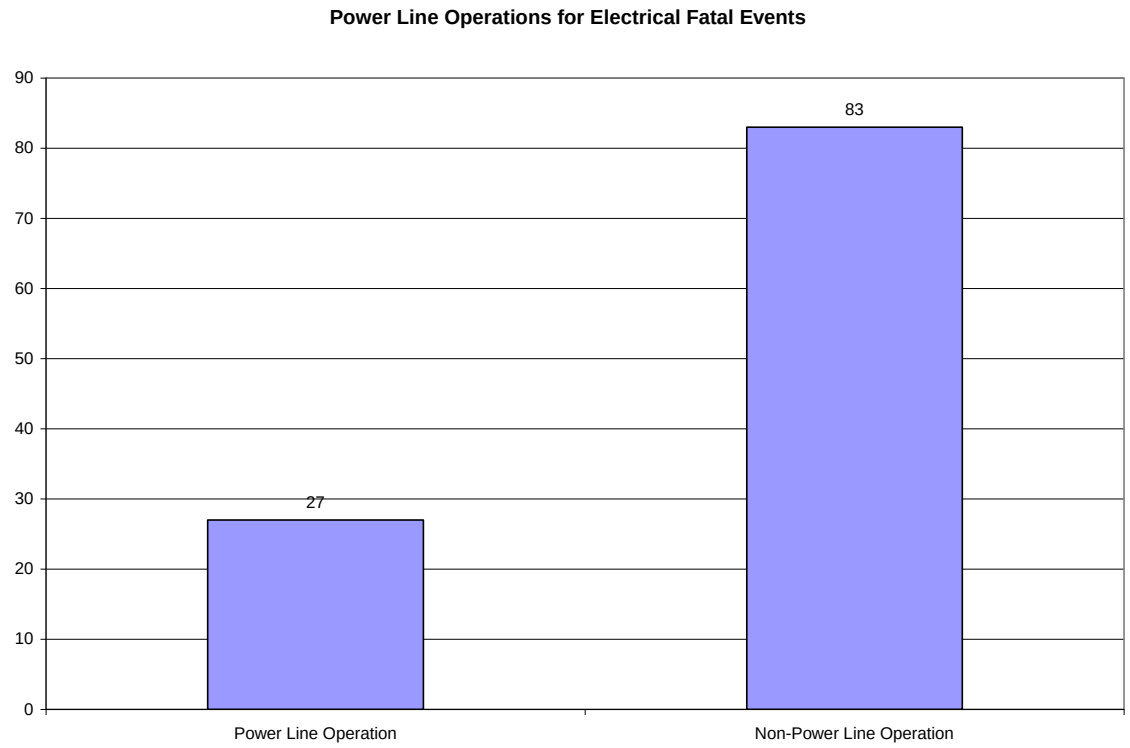
The Top 20 OSHA electrical standards. The most cited is “Lack of protection from electrical power circuit by de-energizing or guarding.”

Figure A-3



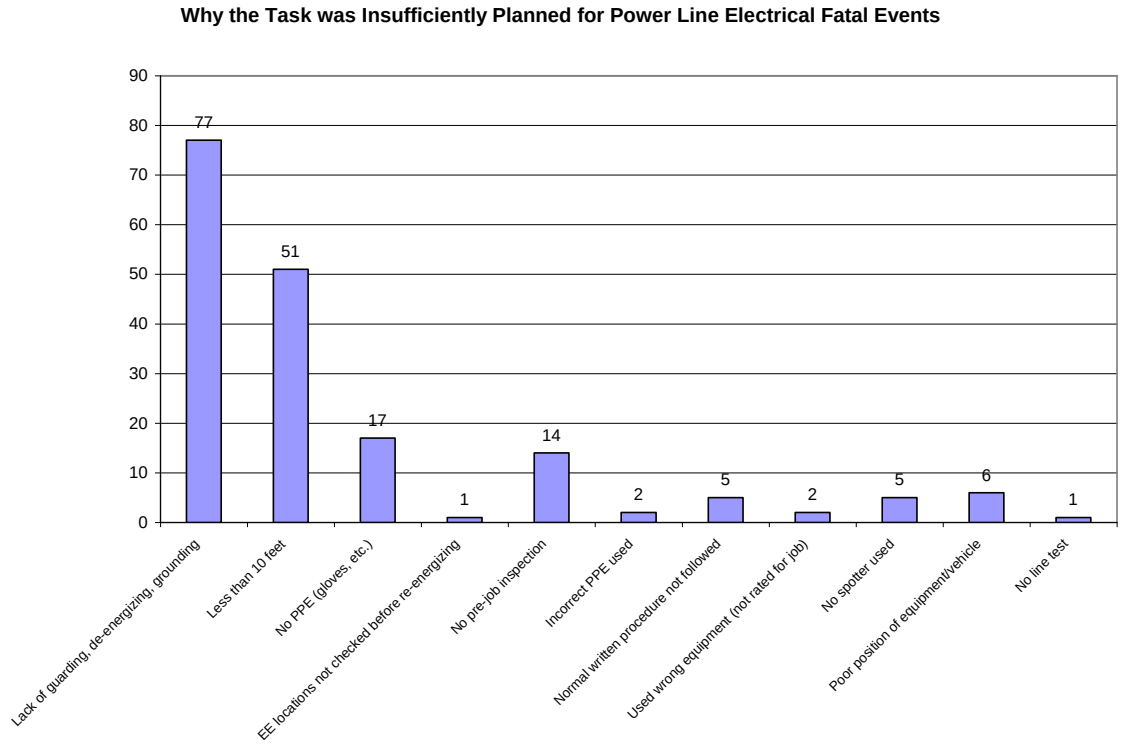
The Construction Operations grouped by categories showed "Electrical, Plumbing, Heating/AC" as having 113 (52.6%) of the total fatalities.

Figure A-4



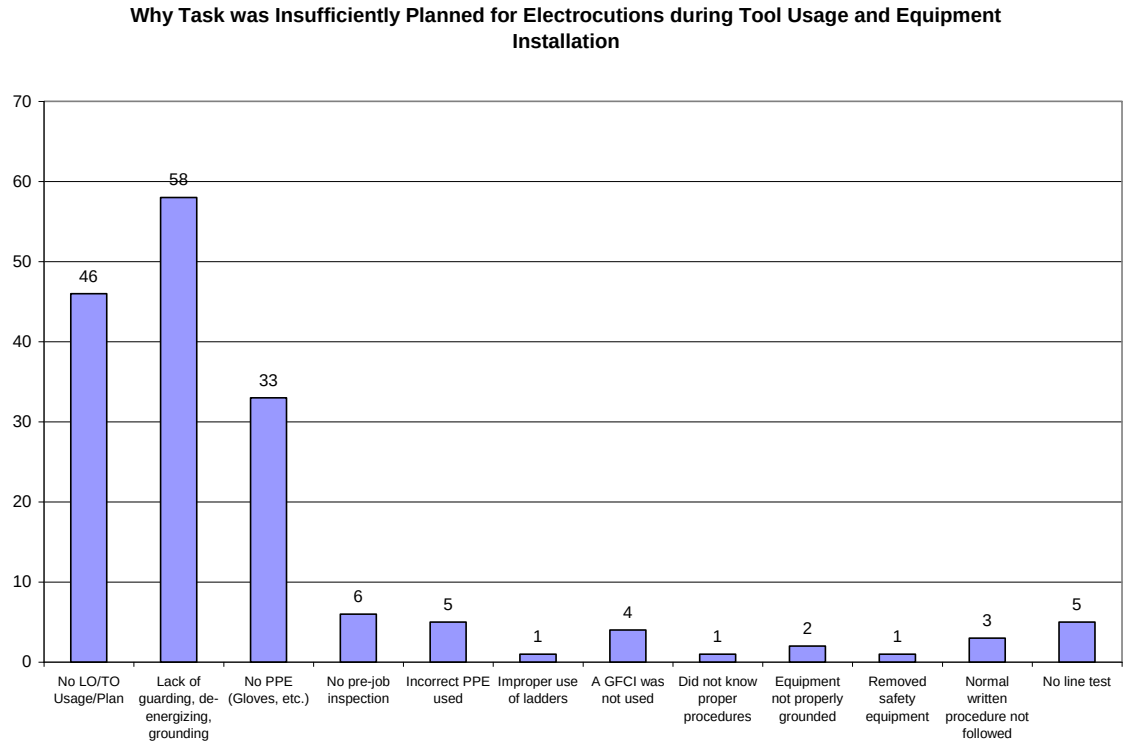
Non-Power Line Operations (accidental contact of power lines) had 83 (75.5%) of the total power line fatalities. Power Line Operations (contact while working on lines) occurred in 27 (24.5%) of the total power line fatalities.

Figure A-5.



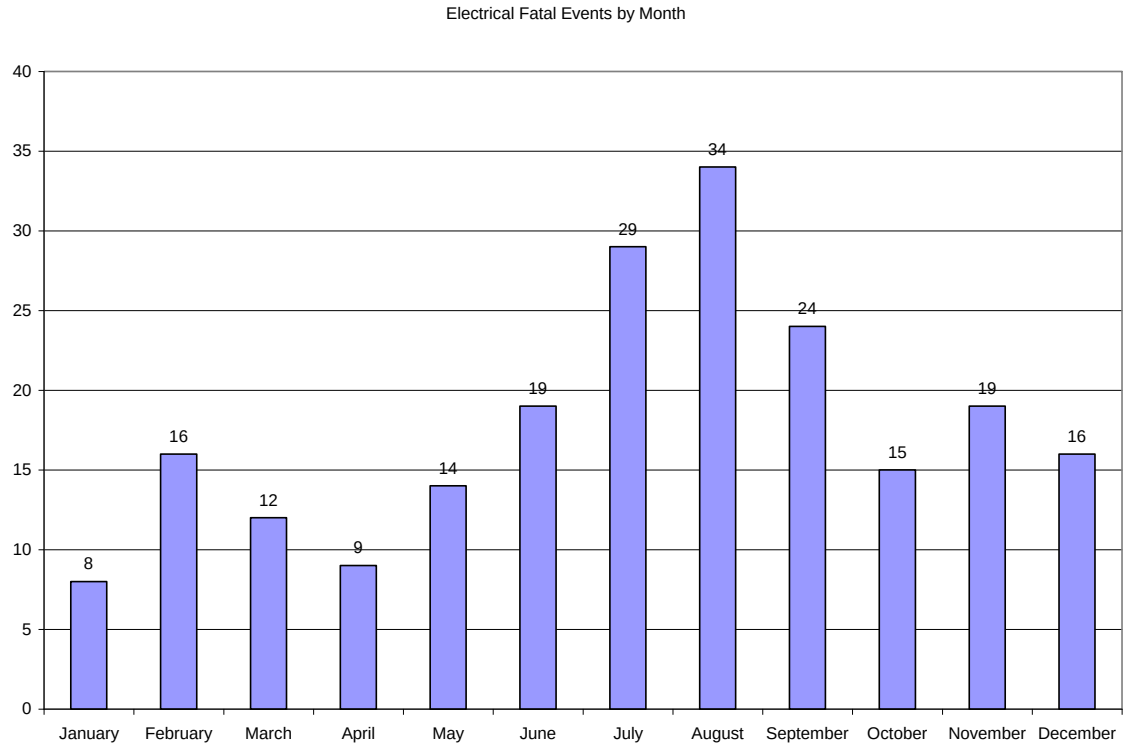
"Lack of guarding, de-energizing, and grounding" (77) and the task operating "Less than 10 feet" (51) were the majority of the factors why the task was insufficiently planned in power line electrocutions.

Figure A-6.



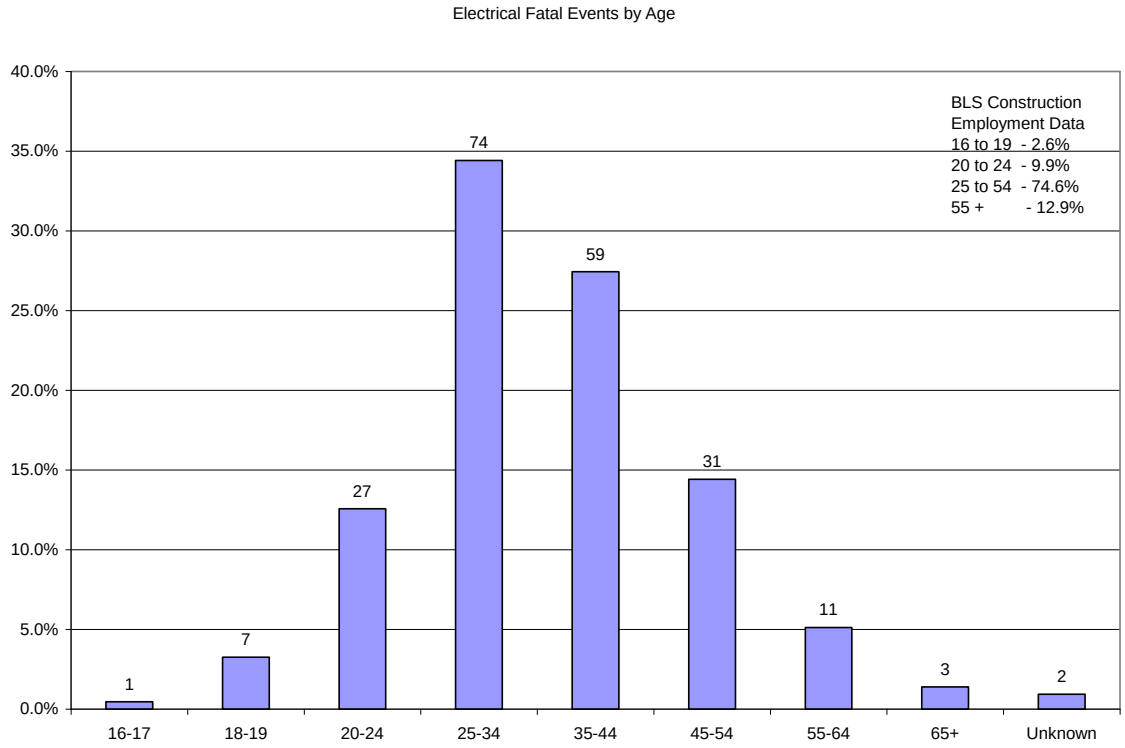
"Lack of Guarding" (58), "No Lock out/Tag out usage" (46), and "No PPE" (33) were the top factors explaining why the task was insufficiently planned in tool usage and equipment installation electrocutions.

Figure A-7.



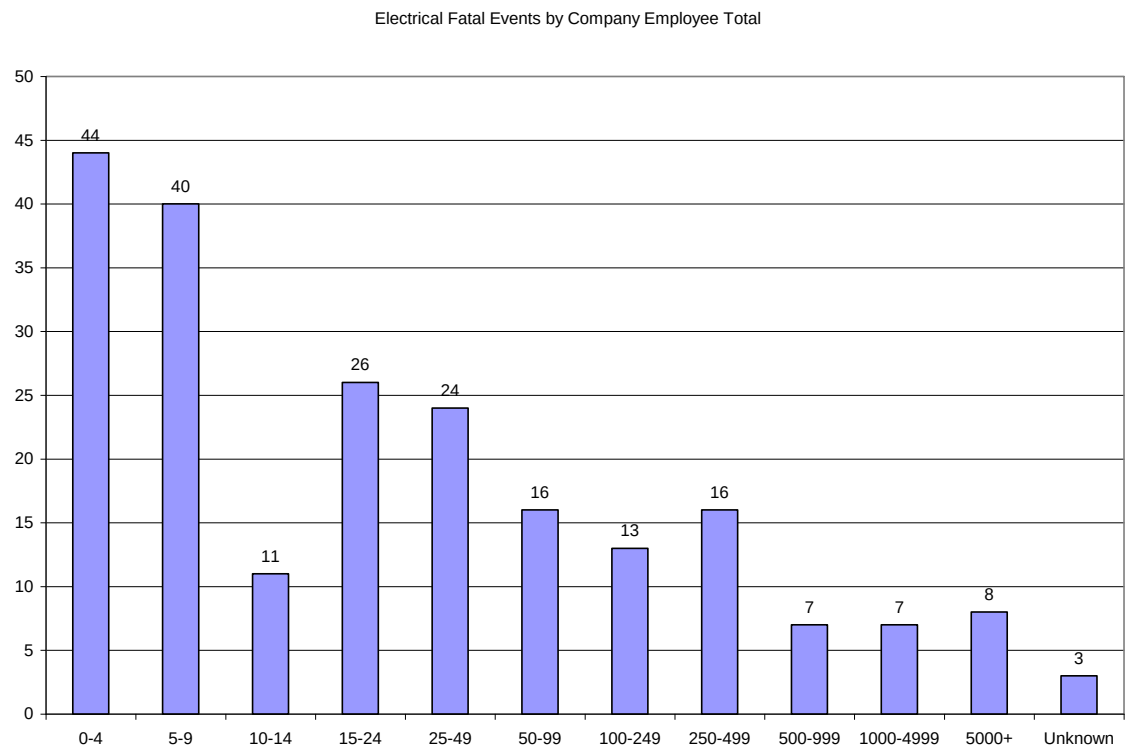
The months of August (34) and July (29) were the top ranking months for electrical fatalities. The months of July, August, and September accounted for 40.5% of all the electrical fatalities for the year.

Figure A-8.



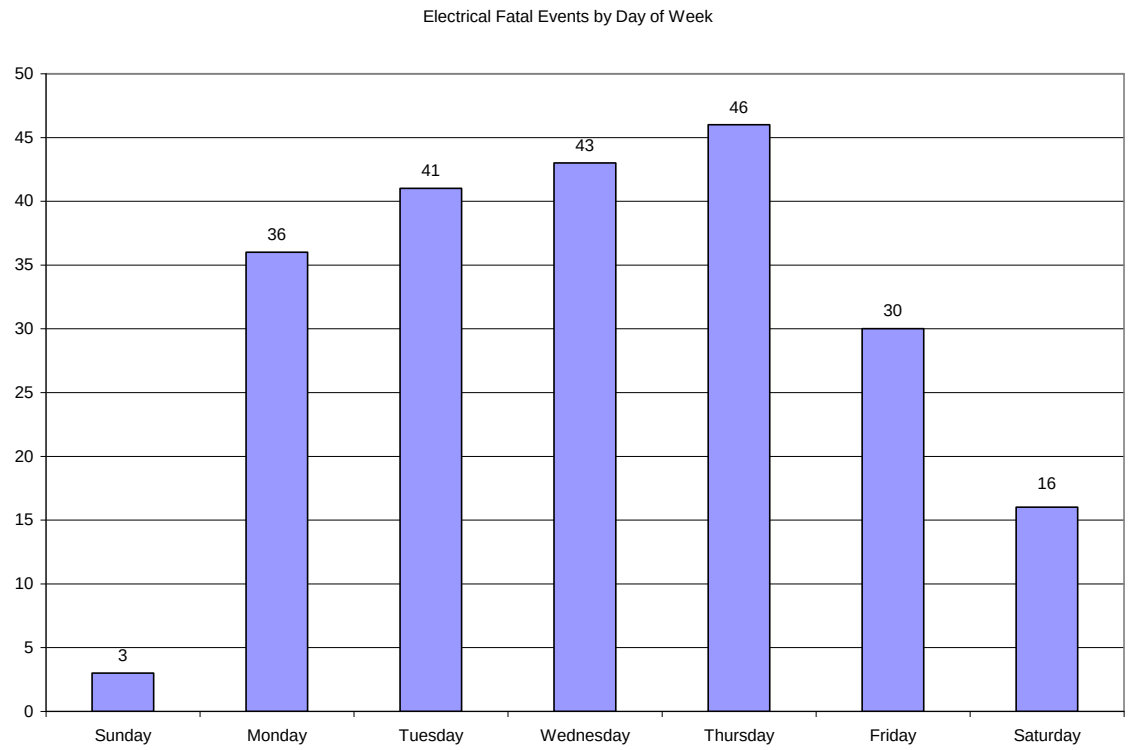
The electrical fatalities by age had the 20-34 (34.7%) age group as the highest ranking category with 35-44 (27.7%) and 45-54 (14.9%) following it respectively. When compared with the BLS construction employment data the electrocution age percentages were very similar.

Figure A-9.



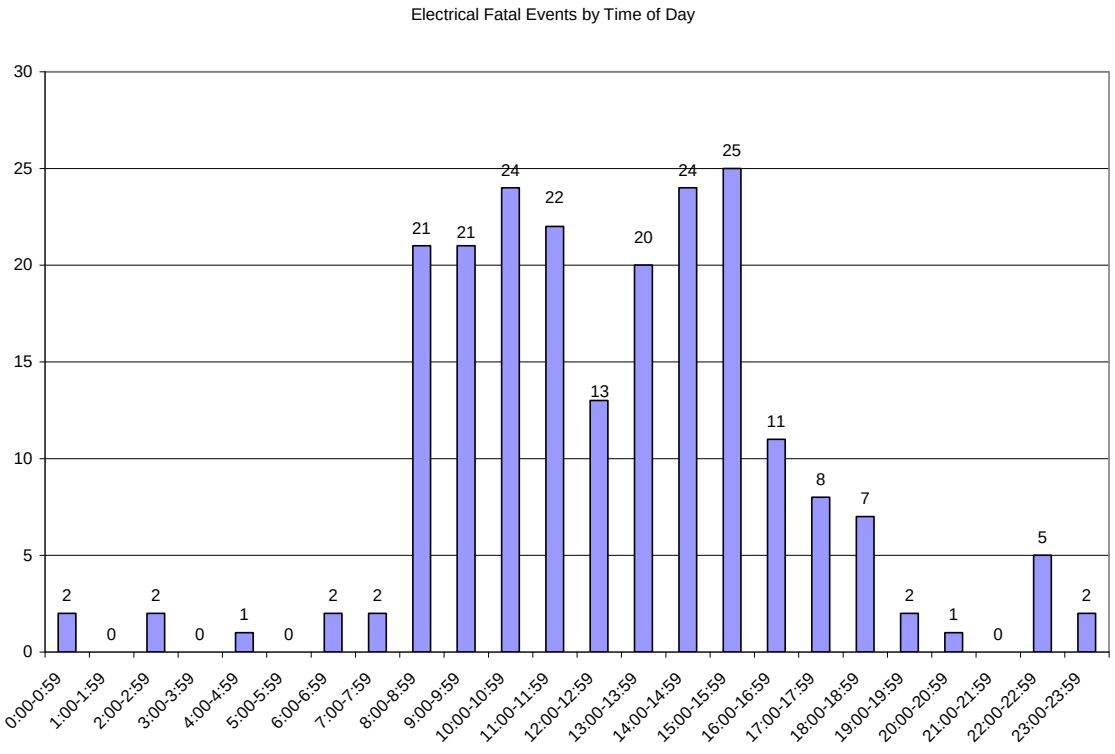
Nearly 40 percent of the fatalities occurred in firms with fewer than ten employees.

Figure A-10.



The rank order of electrical fatalities by the day of the week was: Thursday (21.7%); Wednesday (20%); and Tuesday (19.1%).

Figure A-11.



The rank order of electrical fatalities by time of the day was 15:00-15:59 (11.6%), followed by 14:00-14:59 (11.2%), and 10:00-10:59 (11.2%). During the working hours of 8:00 to 16:00 (typical construction working hours) there was very little variation except for the 12:00-12:59 period which may be explained by a meal break time.

Table A-12.

Electrical Fatal Events by SIC

SIC	Description	# of Occurrences
1521	General Residential Single Family Homes	8
1522	General Residential Other than Single Family Homes	3
1541	General Industrial Buildings and Warehouses	1
1542	General Non-Residential and Non-Industrial	5
1611	Highway Street Construction	3
1623	Water, Sewer, Power, and Communication Lines	17
1629	Other Heavy Construction	4
1711	Plumbing, Heating, and Air Conditioning	13
1721	Painting and Paper Hanging	5
1731	Electrical Work	75
1741	Masonry, Stone Setting, and Other Stone Work	3
1742	Plastering and Dry walling	4
1751	Carpentry Work	3
1761	Roofing, Siding, and Sheet Metal Work	35
1771	Concrete Work	13
1781	Water Well Drilling	1
1793	Glass and Glazing Work	2
1794	Excavation Work	3
1795	Demolition Work	2
1799	Other Special Trades	14
8711	Engineering Services (was oiling heavy equipment)	1

In rank order for the SIC codes of employers involved in electrical fatalities, Electrical Work at 75 (34.9%) was followed by Roofing, Siding, and Sheet Metal Work with 35 (16.3%) and Water, Sewer, Power, and Communication Lines with 17 (7.9%).

CITATIONS

Bureau of Labor Statistics (2009). Current Population Survey, Census of Fatal Occupational Injuries, U. S. Bureau of the Census and U. S. Department of Defense, 2009.

Construction Industry Research and Policy Center (CIRPC) (2009) An Analysis of Fatal Events in the Construction Industry, 2007. February 2009.

Construction Industry Research and Policy Center (CIRPC) (Various). An Analysis of Fatal Events in the Construction Industry. See reports for 1991-2 and 1993-4 and annually thereafter to 2007. These reports available at http://bus.utk.edu/cirpc/research/ConstructionFatalityReports.htm

Irizarry, J., Simonsen, K. L., and Abraham, D. M. (2005) "Effect of safety and environmental variables on task durations in steel erection." Journal of Construction Engineering and Management, Vol. 131 (12) 1310–1319.

Journal of Construction Engineering and Management (2006). J. E. Beavers, etal "Crane Related Fatalities in the Construction Industry", Journal of Construction Engineering and Management, Vol. 132, No. 9, September 1, 2006.

Journal of Construction Engineering and Management (2009). J. E. Beavers, etal "Steel Erection Fatalities in the Construction Industry, Journal of Construction Engineering and Management, Vol. 135, No. 3, March 1, 2009.

National Institute for Occupational Safety and Health (NIOSH) (1998). Worker Death by Electrocution: A Summary of NIOSH Surveillance and Investigation Findings, May 1998. OHHS (NIOSH) Publication No. 98–131.

National Institute for Occupational Safety and Health (NIOSH) (1998) Electrical Safety (Student Manual) Revised Edition, March 2009

U. S. Department of Commerce (2008). Statistical Abstract of the United States, 2008. Table 612.