

Causes of Electrical Deaths and Injuries Among Construction Workers

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Background Contact with electrical current is the fourth leading cause of deaths of construction workers. This study evaluates electrical deaths and injuries to construction workers.

Methods Two sources of data were analyzed in detail: (1) 1,019 electrical deaths identified by the Bureau of Labor Statistics, Census of Fatal Occupational Injuries (CFOI) for the years 1992–1998; and (2) 61 electrical injuries identified between November 1, 1990 and December 31, 1998 from a George Washington University Emergency Department injury surveillance database.

Results Contact with “live” electrical wiring, equipment, and light fixtures was the main cause of electrical deaths and injuries among electrical workers, followed by contact with overhead power lines. Among non-electrical workers, contact with overhead power lines was the major cause of death. Other causes included contact with energized metal objects, machinery, power tools, and portable lights. Arc flash or blast caused 31% of electrical injuries among construction workers, but less than 2% of electrical deaths.

Conclusion Adoption of a lockout/tagout standard for construction, and training for non-electrical workers in basic electrical safety would reduce the risk of electrical deaths and injuries in construction. Further research is needed on ways to prevent electrical deaths and injuries while working “live”. *Am. J. Ind. Med.* 43:398–406, 2003. © 2003 Wiley-Liss, Inc.

KEY WORDS: construction; electrocution; electrical injury; arc flash; surveillance; lockout/tagout; training

INTRODUCTION

Contact with electric current is a major cause of injury and death among construction workers [Jenkins et al., 1993;

Kisner and Fosbroke, 1994; Rossignol and Pineault, 1994; McVittie, 1995; Ore and Casini, 1996; Bureau of Labor Statistics, 1997; Construction Resources Analysis, 1997; Janicak, 1997; Kisner and Casini, 1998; Loomis et al., 1999; Robinson et al., 1999]. According to a study based on NIOSH's National Traumatic Occupational Fatality (NTOF) database, construction industry workers suffered more than 2,100 fatal electrocutions between 1980–1992 (40% of the total number of electrocutions for all workers), about 160 annually, and had the highest death rate from electrocutions among all industries (2.4 deaths per 100,000 workers) [Kisner and Casini, 1998]. For the period 1994–2000, the Census of Fatal Occupational Injuries (CFOI) data produced by the Bureau of Labor Statistics (BLS) indicate that contact with electric current was the fourth leading cause of work-related deaths—after falls, transportation incidents, and contact with objects and equipment. An average of 145 construction workers (13% of all construction worker deaths)

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were electrocuted each year. Almost half (44%) of these electrocutions occurred due to contact with overhead power lines [Bureau of Labor Statistics, 2002]. Electrocutions involving overhead power lines have been extensively described in the literature [Janicak, 1997].

In 1998, NIOSH investigated occupational deaths from electrocution as part of its Fatality Assessment and Control Evaluation (FACE) program [Kisner and Casini, 1998]. Five scenarios characterized the majority of the incidents resulting in death: (1) direct worker contact with an energized power line (28%); (2) direct worker contact with energized equipment (21%); (3) boomed vehicle contact with an energized power line (18%); (4) improperly installed or damaged equipment (17%); and (5) conductive equipment contact with an energized power line (16%).

In addition to electrical shock, other types of electrical injuries include burns from electrical shock, arc-flash and flame burns, arc-blast impact from expanding air and vaporized materials, and falls resulting from electrical shock [Casini, 1998a].

This article examines the causes of fatal and non-fatal electrical exposure injuries among construction workers using two sources of data: (1) construction deaths for the years 1992–1998 identified by the CFOI database; and (2) an injury surveillance database of construction workers treated at the George Washington University (GWU) Emergency Department (ED) between November 1, 1990 and December 31, 1998. The purpose of this article is to generate ideas for interventions that could decrease the number of electrical deaths and injuries among construction workers. Both fatal and non-fatal injury data were included in the study since there can often be different patterns of causation for deaths compared to injuries.

METHODS

Fatal Injuries

We obtained construction industry fatality data in the United States for the 2-digit Standardized Industrial Classification (SIC) Codes 15, 16, and 17 for the years 1992 through 1998 from the Census of Fatal Occupational Injuries (CFOI), a Bureau of Labor Statistics (BLS) database. CFOI was chosen since it has the most complete listing of deaths in United States since its inception in 1992.

Deaths where the electrical exposures occurred prior to 1992 were eliminated so that the results of this analysis would be most applicable to current working conditions. The resulting data were entered into a Microsoft Access 97 database.

Electrical deaths were identified by selecting all records involving the BLS event codes 310–319 (contact with electrical current) and through a search of the narratives of the remaining construction CFOI records using the keywords “arc,” “flash,” “blast,” and “electr”. This search identified a

total of 1,019 electrical deaths, including 17 deaths due to arc flashes and blasts (these deaths were primarily classified under event codes for fires and/or explosions). These 1,019 deaths are the denominator when we refer to “total electrical deaths.”

The event codes and narratives for each case were used to classify the deaths into categories involving contact with: electrical equipment (e.g., electrical control panels, circuit breakers, junction boxes, switch boxes, and transformers); electrical wiring; light fixtures; energized objects (indirect contact through an object such as an aluminum ladder becoming energized by contact with electric current); appliances and machinery; power tools; portable lights; and unknown sources of electricity. In this way, many deaths classified under event codes 310 (contact with electric current, unspecified) and 319 (contact with electric current, n.e.c.) could be classified into one of the above categories.

Non-Fatal Injuries

Hospital registration forms were reviewed to identify all construction workers treated at the GWU ED between November 1, 1990 and December 31, 1998 for work-related injuries and illnesses. We included any worker whose job title was coded by 1980 Standard Occupational Code (U.S. Department of Commerce, 1980) in the following categories: construction trades; construction laborers; construction helpers; construction managers; construction supervisors; construction inspectors; sheet metal workers; or elevator installers and repairers. We included construction tradespeople with non-construction industry employers—such as maintenance painters or electricians employed by a government agency or university. Other job titles such as welders and material moving equipment operators were included if they appeared (from the employer name) to be engaged in construction work. We abstracted demographic, diagnosis, cause-of-injury, and hospital discharge information onto a standardized data collection form. The diagnoses and external causes-of-injury were coded according to the ICD-9 CM [U.S. Department of Health and Human Services, 1991]. All information was entered into an Epi Info Version 6.04b database [Dean et al., 1994].

During the 8 years of data collection, 3,395 injured construction workers were identified. Of these, three were fatally injured. Work-related illness and injury data from this surveillance database have been previously described [Hunting et al., 1994, 1999]. We also conducted several targeted follow-up studies to examine causes and consequences of injury in greater detail than provided by medical records. Between 1993 and 1998, 643 workers completed a telephone interview. Since electrical injuries were not specifically targeted (as were eye injuries and falls, e.g.), only eight interviews were completed from this group. Interview information, when present, was used to enhance data obtained from the medical record.

Classification of Electrical Versus Non-Electrical Workers

We classified workers into two groups: electrical workers and non-electrical workers. The electrical workers category included electricians, electrician apprentices, helpers involved in electrical work, electrical power installers and repairers, and supervisors of electricians and electrical power installers and repairers. All other workers were included in the non-electrical workers category (e.g., construction laborers, carpenters, construction and maintenance painters and roofers). We used this classification for both fatal and non-fatal injuries. As previously discussed, however, the ED case series includes workers from outside of SIC categories 15–17.

Classification of Voltages

Voltages involved in the electrical injuries and deaths were usually omitted. However, since homes use 120/220 V, we assigned that voltage to all cases involving homes where the voltage was not specified. Similarly, since power tools use 120/240 V, cases involving power tools were classified as 120/240 V. Cases involving light fixtures inside non-residential buildings were classified as low voltage (under 600 V) unless the voltage was specified in the record.

Analytical Methods

Analyses are primarily descriptive. For the CFOI analysis, comparative analyses (e.g., between trades) are based on proportions not rates because denominator information is not known for construction helpers in the electrical work industry. These workers are included among electrical workers because they are performing electrical work. Similarly, because the construction population at-risk of coming to the GWU ED in the event of an injury is not known, comparative analyses are based on proportions.

Chi-square tests are used to compare differences in proportions, except where an expected cell value is less than five and Fisher Exact is used instead. A simple linear regression model (using the least-squares method) was used to look for trends in electrical deaths by year.

RESULTS

Between 1992 and 1998, CFOI data revealed that contact with electrical current caused 1,002 of 7,489 (13.4%) construction industry deaths and arc flash/blasts caused 17 deaths (0.2%).

Table I shows that, for 1992–1998, one-third of the electrical deaths occurred among electrical workers, mostly electricians. Construction laborers, carpenters, and painters comprised another one-quarter of the electrical deaths.

TABLE I. Electrical Deaths Among Construction Workers, by Trade, 1992–1998

| Trade | No. | % |
|---|------|--------------|
| Electrical workers | | |
| Electricians | 256 | 25.1 |
| Electrical power installers and repairers | 47 | 4.6 |
| Electrician apprentices | 16 | 1.6 |
| Construction helpers doing electrical work | 15 | 1.5 |
| Supervisors, electricians/power installers | 17 | 1.7 |
| Total electrical workers | 351 | 34.4 |
| Non-electrical workers | | |
| Construction laborers | 165 | 16.2 |
| Carpenters and apprentices | 63 | 6.2 |
| Painters, construction and maintenance | 50 | 4.9 |
| Non-electrical supervisors | 48 | 4.7 |
| Roofers | 41 | 4.0 |
| Heating, air conditioning and refrigerating technicians | 26 | 2.6 |
| Plumbers, pipefitters and steamfitters | 24 | 2.4 |
| Other trades | 251 | 24.6 |
| Total non-electrical workers | 668 | 65.6 |
| All construction workers | 1019 | ^a |

^aDoes not add up to 100 due to rounding.
Source: U.S. Bureau of Labor Statistics CFOI data.

Figure 1 shows the number of electrical deaths of electrical and non-electrical construction workers by year of injury. There was no detectable trend in the number of such deaths by year, using linear regression model with least-squares method (electrical workers: slope = 1.89, *P* = 0.158; non-electrical workers: slope = 1.64; *P* = 0.456).

Electrical Workers

Table II shows that the main cause of deaths among electrical workers was direct contact with “live” electrical equipment, wiring, and light fixtures, together accounting for 53% of the 351 electrical deaths among these workers. Contact with overhead power lines was the second leading cause, accounting for 30% of the above. Because many previous studies have focused extensively on overhead power line fatalities, we will focus in this article on the electrical injuries that resulted from other causes.

The major types of electrical equipment involved in energized equipment deaths were electrical control panels, switching equipment, transformers, circuit breakers, and junction boxes. Thirteen of the 17 burn deaths from electrical arc flashes and blasts were due to electrical equipment. These burns were attributed to fires and explosions while working inside or near electrical cabinets, testing transformer voltages, changing fuses or circuit breakers, and energizing or de-energizing electrical equipment.

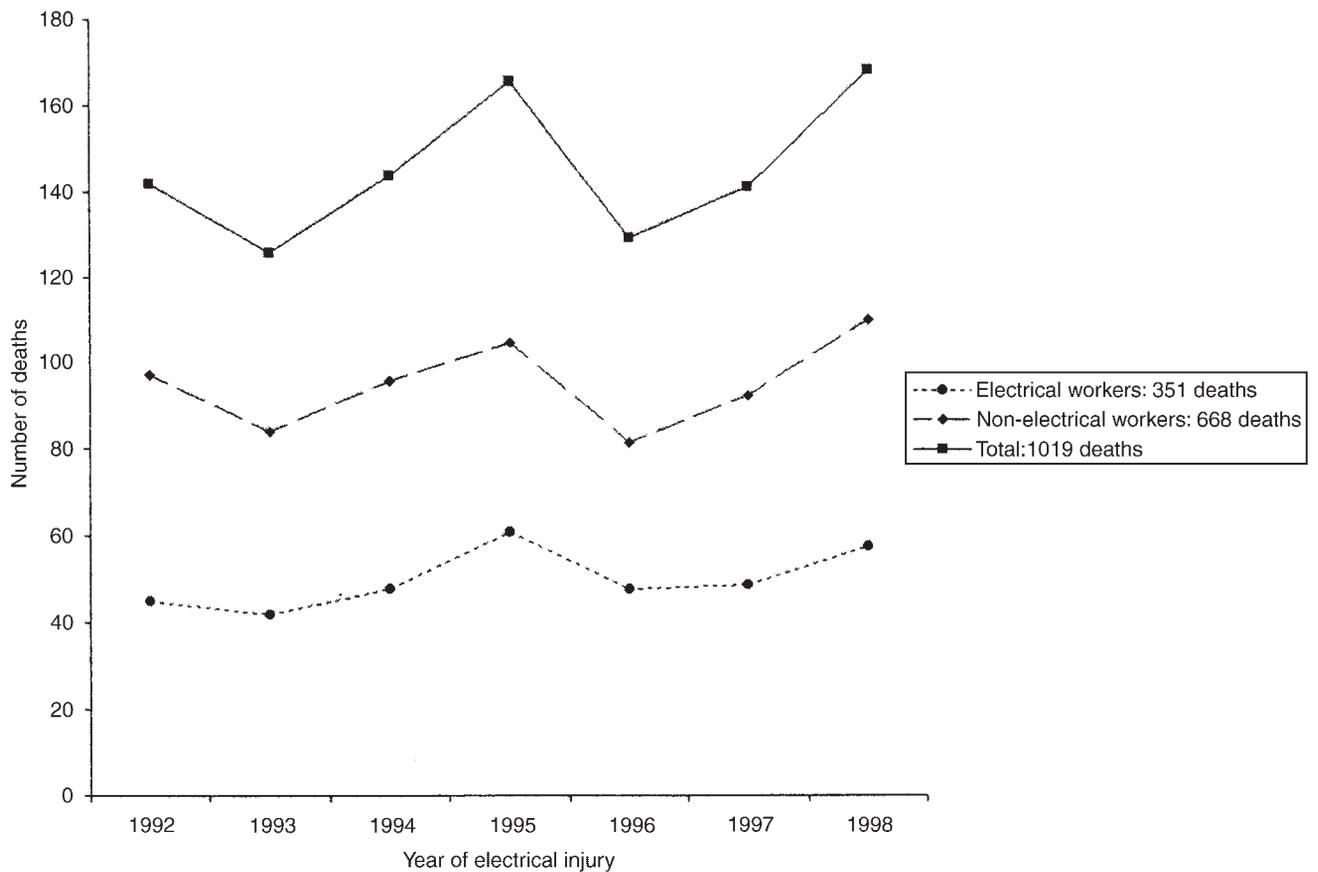


FIGURE 1. Electrical deaths of construction workers by year of injury, 1992–1998. Source: U.S. Bureau of Labor Statistics data.

TABLE II. Causes of Construction Electrical Deaths, 1992–1998

| Contact with | Electrical workers | | Non-electrical workers | |
|--------------------------------|--------------------|--------------|------------------------|--------------|
| | No. | % of total | No. | % of total |
| Electrical equipment | 80 | 22.8 | 31 | 4.6 |
| Electrical wiring | 60 | 17.1 | 69 | 10.3 |
| Light fixtures | 46 | 13.1 | 10 | 1.5 |
| Overhead powerlines | 107 | 30.4 | 369 | 55.2 |
| Energized objects | 31 | 8.8 | 52 | 7.8 |
| Appliances/machinery | 13 | 3.7 | 45 | 6.7 |
| Power tools | 0 | 0 | 12 | 1.8 |
| Portable lights | 0 | 0 | 11 | 1.6 |
| Underground, buried powerlines | — | — | 15 | 2.2 |
| Lightning | 0 | 0 | 30 | 4.5 |
| Unknown cause | 11 | 3.1 | 24 | 3.6 |
| Total | 351 | ^a | 668 | ^a |

Note: Dashes indicate that data do not meet BLS publication criteria.

^aPercentages do not add up to 100 due to rounding.

Source: U.S. Bureau of Labor Statistics CFOI data.

Almost three-quarters of the deaths of electrical workers from installing or repairing light fixtures involved building light fixtures (especially 277 V office fluorescent lighting); airport runway lights, neon signs, and street lights comprised the rest.

Energized object deaths involved contact with metal objects energized by contact with live electrical circuits or equipment. This event occurred when a worker accidentally cut live wires (e.g., with electric drills) or energized an electrical wire being worked on by accidental contact with a live wire. Other energized-object deaths were caused by deliberately cutting live wires and by stripping live wires with non-insulated tools. Additional light fixture deaths were included among these energized object events.

Five percent of all electrical worker deaths from electrical exposure involved working in attics and above dropped ceilings; 2% occurred when the worker was working under a house or in a basement crawlspace. Most of these involved inadvertent contact with live electrical wires in the enclosed space. Of the 29 electrocutions, which occurred among electrical workers in residential settings, 10 occurred in attics and 6 under houses or in crawlspaces.

Non-electrical workers

Contact with overhead power lines was the major cause of electrical deaths in this group. There were far fewer deaths due to contact with light fixtures and electrical equipment

among the non-electrical workers compared to electrical workers (Chi-square test, $P < 0.001$).

One-fifth (10 deaths) of the electrocutions due to energized objects involved contact with energized metal ladders. Other examples included contact with energized metal pipes, accidentally cutting live wires, and contact with energized hand and powered tools.

Among non-electrical workers, almost half of the 45 appliance- and machinery-related electrical deaths involved air conditioning units. Thirteen of the 25 deaths involving heating, air conditioning and refrigeration technicians fell into this category. Other machinery involved in electrical deaths included arc-welding units, home appliances, pumps, and elevators. Five of the 12 power tool deaths involved electric drills; five of these power tool deaths involved carpenters.

While most of the electrical deaths described above for non-electrical workers occurred in commercial or industrial settings, 11% occurred in residential settings. Twelve of these residential deaths involved air conditioning units and nine involved portable lights.

Voltage

Voltages could not be determined for many workers killed by electrical exposure. Figure 2 shows that at least one-third of all electrical deaths of electrical workers and one-fifth of electrical deaths of non-electrical workers involved

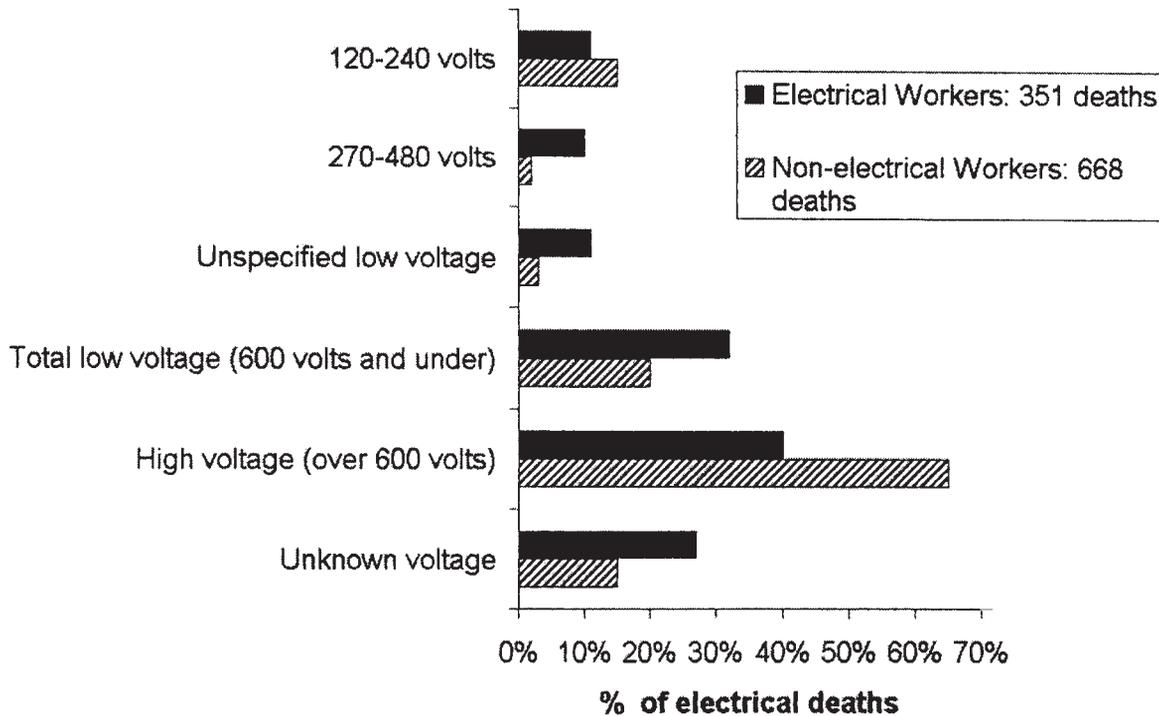


FIGURE 2. Electrical deaths of construction workers by voltage, 1992–1998. Source: U.S. Bureau of Labor Statistics data.

exposure to low voltage (under 600 V). The unspecified low voltage electrical deaths were mostly due to light fixtures in commercial buildings. Substantial numbers of both electrical and non-electrical workers were killed by 120/240 V (household voltage).

ED Surveillance Data

In order to gain more comprehensive insight into electrical injuries across the severity spectrum, we also analyzed data from construction worker visits to the GWU ED [Hunting et al., 1994, 1999]. The construction workers treated in this setting worked mostly on large, urban construction projects. Of 3,395 injuries identified during this time period, 61 (1.8%) were caused by electrical exposures. Twenty percent (12/61) of all ED-treated electrical injuries in our data set required hospital admission, and one of these was fatal. In contrast, only 3.1% of ED-treated injuries due to other causes required hospital admission (Fisher Exact, $P < 0.001$).

The following results describe information obtained from the medical records of 61 workers with electrical injuries. More detailed data describing the incident were also available for eight of these workers who completed telephone interviews (five electricians and three workers from other trades).

In contrast to the fatality data, where two-thirds of the deaths were among non-electrical workers, two-thirds of the non-fatal electrical injuries were among electrical workers (Table III). Electrical exposure was an important cause of ED visits among electrical workers, accounting for 8.7% of all ED-treated injuries for this group during the study period, versus only 0.7% of injuries among non-electrical workers (Chi-square, $P < 0.001$).

Two-thirds of the non-fatal electrical injuries resulted from exposure to electrical current, while one-third were due to arc flashes or arc blasts. Electrical equipment caused half of these arcing incidents among electrical workers, while live wiring and power tools were the sole causes among non-electrical workers.

Working on or near live electrical wiring or equipment caused the largest proportion of electrical injuries in both trade groups, as shown in Table IV. Although the results are limited by small numbers, each case does describe a circumstance that may be typical of hazards experienced by other construction workers. As with electrical fatalities, light fixtures were a common source of electrical exposure injuries for electricians, but not for workers from other trades. Several injuries occurred while individuals were working on panel boxes, fuse boxes, junction boxes, or switchboards.

Two of the three energized object injuries involved electricians, one using a wrench that was not insulated and one using a probe; the other involved a field engineer standing in water and holding a metal ladder that contacted a live wire.

TABLE III. Trades of 61 Construction Workers Requiring ED Treatment for Electrical Injuries, GWU Construction Worker Surveillance Program, 1990–1998

| Trade | Total | |
|--|-------|------------------|
| | No. | % |
| Electrical workers | | |
| Electrician | 37 | 61 |
| Electrical supervisor/foreman | 2 | 3 |
| Electrical power installer/repairer | 1 | 2 |
| Total electrical workers | 40 | 66 |
| Non-electrical workers | | |
| Laborer or unspecified construction worker | 6 | 10 |
| Engineer/inspector | 5 | 8 |
| Carpenter | 4 | 7 |
| Supervisor/foreman | 1 | 2 |
| Carpet/floor layer | 1 | 2 |
| Drywall worker | 1 | 2 |
| Heavy equipment operator | 1 | 2 |
| Plumber/pipefitter | 1 | 2 |
| Sprinkler fitter | 1 | 2 |
| Total non-electrical workers | 21 | 34 ^a |
| All Construction workers | 61 | 100 ^a |

^aPercentages do not sum accurately because of rounding.

Power tools electrical injuries included a carpenter cutting metal with an electric saw from a metal ladder, a floor installer using a sander with wet hands, and an equipment operator operating a jackhammer which hit a live wire, causing an arc flash. In one-quarter (16/61) of the electrical injury cases, the electrical exposure resulted in falls (including two jumps) from ladders. One of these workers was fatally electrocuted; he had been working on wiring and was found on the ground by a co-worker. All but one of these falls occurred as a result of electrical shock. Some of these falls may have prevented fatal electrocutions since the falls broke contact with the current sources.

The voltages (when known) that caused the injuries of the electrical workers were higher than the voltage exposures of workers in other trades, although the numbers were small and almost half of the injured workers had no mention of voltage in their medical charts. The two electrical workers with exposure to the highest voltages (1,300 and 13,000 V) were both hospitalized.

The 61 injured workers were treated for 67 diagnoses. As expected, these diagnoses most commonly included skin burns (41% of injured workers). In 26% of medical records, electric shock was noted as the sole diagnosis. Ten workers (16%) sustained corneal burns or other eye injury, all but one of these due to arc flash. Two of these individuals reported wearing safety glasses or goggles.

TABLE IV. Circumstances of Electrical Injuries Requiring ED Treatment, GWU Construction Worker Surveillance Program, 1990–1998^a

| Circumstances | Electrical workers (n = 40) | | Non-electrical workers (n = 21) | | Total no. | % |
|----------------------|-----------------------------|-----------|---------------------------------|-----------|-----------|--------------|
| | Electrical shock | Arc flash | Electrical shock | Arc flash | | |
| Source of exposure | | | | | | |
| Electrical wiring | 13 | 4 | 6 | 1 | 24 | 39 |
| Electrical equipment | 2 | 8 | 0 | 2 | 12 | 20 |
| Light fixtures | 4 | 2 | 0 | 0 | 6 | 10 |
| Energized objects | 2 | 0 | 1 | 0 | 3 | 5 |
| Power tools | 0 | 0 | 2 | 1 | 3 | 5 |
| Appliances/machinery | 0 | 0 | 0 | 0 | 0 | 0 |
| Unknown | 4 | 1 | 8 | 0 | 13 | 21 |
| Total | 25 | 15 | 17 | 4 | 61 | ^b |
| Voltage | | | | | | |
| 120–240 V | 2 | 2 | 3 | 0 | 7 | 11 |
| 270–480 V | 11 | 5 | 6 | 0 | 22 | 36 |
| >600 V | 1 | 1 | 1 | 0 | 3 | 5 |
| Not specified | 11 | 7 | 7 | 4 | 29 | 48 |

^aMedical record data supplemented by interview data for 8 of 61 workers.

^bPercentages do not sum to 100 because of rounding.

Telephone interviewers elicited workers' ideas about how the injury could have been prevented. Seven of the eight workers interviewed provided such ideas. Although this is a small sample, the anecdotal information is illustrative of prevention challenges for electrical injuries. The suggestions from electrical workers primarily involved shutting down power and properly testing circuits. In one case, two apprentice electricians were working together on a live circuit, and the interviewed worker indicated that the foreman had made an inappropriate work assignment. The comments from interviewed workers from non-electrical trades reinforced the need to obtain expert assistance when working around wiring. In one case (an electrical panel short circuit), the engineer we interviewed indicated that wiring had been installed improperly when the building was constructed.

DISCUSSION

The 1998 NIOSH FACE study [Casini, 1998b] found at least one of the following five factors present in all 224 electrocution incidents it evaluated: (1) established safe working 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.

Both the CFOI data and the GWU ED electrical injury data show that, for electrical workers, working “live” or near live electrical wiring and equipment was a major cause of

injury or death. Working “live” should only be done if the employer can demonstrate that de-energizing creates additional or increased hazards, or is not feasible due to equipment design or operational limitations, as required in NFPA 70E (NFPA, 2000).

It is apparent from the CFOI data narratives that in many cases it was not necessary to work live. For example, there is no reason to work live during the installation and repair of light fixtures. Possible reasons for this include schedule pressures from supervisors, a reluctance on the part of contractors or owners of buildings to shut down power during working hours, a reluctance to pay overtime to do electrical work after hours, and the existence of a “macho” attitude on the part of many electrical workers about “working live.”

One possible area for future research would be evaluation of a permit system for situations where it is absolutely necessary to work live. This permit would specify who would perform the work, safe working procedures, and adequate personal protective equipment (such as voltage-rated rubber gloves, FR (fire-resistant) clothing, flash hoods, etc.).

In several instances, the CFOI data narratives indicated that the worker mistakenly thought the circuit or equipment was de-energized. The use of personal locks to lock out electrical equipment and ensure it stays de-energized—a mainstay of lockout/tagout—is not common in construction, and is not required by OSHA for the construction industry. Lockout/tagout would have prevented these deaths.

Our analysis indicates a need for better education of electrical workers about the hazards of working live and about methods to de-energize properly. Strengthening the OSHA construction standard through adoption of a lockout/

tagout standard should result in a decrease in electrocutions of construction workers as happened when a lockout/tagout standard was promulgated for General Industry.

Among non-electrical workers, contact with live electrical wiring or equipment, although much less frequent among non-electrical workers, still resulted in many electrocutions. Non-electrical workers need to be aware of the location of live wires, and when possible have them de-energized while working in the vicinity of such wires. This is particularly important where workers are drilling into walls or performing similar activities.

Electrocutions involving power tools, portable lights, electrical and extension cords could be prevented with daily inspections, electrical maintenance programs, and GFCIs (ground fault circuit interrupters). There is a need for better enforcement of OSHA regulations on these topics.

The high number of electrocutions of non-electrical workers involving energized objects and contact with water, especially in residential situations, show a basic lack of knowledge of electrical safety and conducting paths. Training of non-electrical construction workers in electrical safety is essential.

Workers may interpret “low voltage” to mean “not dangerous.” Like previous studies [Kisner and Casini, 1998; Capelli-Schellpfeffer et al., 2000], this study shows that a large percentage of electrical injuries are due to low voltage, particularly household voltage, and further demonstrates the need for electrical safety training among all construction trades.

In the CFOI fatality analysis, 17 deaths were from arc flashes or arc blasts (1.7% of all electrical deaths). The GWU ED study identified a total of 19 electrical injuries from arc flashes or blasts out of a total of 61 electrical injuries (31%). Burns and eye injuries were the most common type of injury. Prevention of these serious burn injuries requires de-energizing or specialized personal protective equipment that should be provided by the employer, as discussed in NFPA 70E.

Finally, the importance of fall protection is raised by the observation that a considerable proportion of the non-fatal electrical exposures caused workers to fall or jump from ladders.

CONCLUSION

Electrocutions are the fourth leading cause of death among construction workers. However, analyzing only electrical deaths would have missed the high percentage of serious burn injuries due to electrical arc flashes. Analysis of CFOI records for 1992–1998 and injury records for construction workers from the GWU ED for 1990–1998 showed that working “live” was the major cause of fatal and non-fatal electrical injuries of electrical workers. Electrical workers need: training on proper lockout/tagout procedures;

and further research into ways both to decrease “live” work and to institute safer working procedures where it is necessary. For non-electrical workers, the major causes of electrical injuries and deaths—aside from overhead power lines—were contact with energized electrical wiring and equipment, and contact with defective electrical appliances and machinery. Recommendations to decrease the number of non-electrical worker electrical injuries and deaths include: training in electrical safety; training on lockout/tagout; and de-energizing accessible electrical circuits in the work area.

Adoption of a lockout/tagout standard for the construction industry, as exists for general industry, could prevent many electrical deaths of both electrical and non-electrical construction workers.

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