International Journal of Occupational Safety and Ergonomics
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tose20

Electric Accidents in the Production, Transmission, and Distribution of Electric Energy: A Review of the Literature

Paraskevi E. Batra[a] & Maria G. Ioannides[b]
[a] Department of Applied Physics and Mathematics, National Technical University of Athens, Greece
[b] Department of Electrical and Computer Engineering, National Technical University of Athens, Greece
Published online: 08 Jan 2015.

INTERNATIONAL JOURNAL OF
OCCUPATIONAL SAFETY AND ERGONOMICS 2001, VOL. 7, NO. 3, 285–307

Electric Accidents in the Production, Transmission, and Distribution of Electric Energy: A Review of the Literature

Paraskevi E. Batra

Department of Applied Physics and Mathematics, National Technical University of Athens, Greece

Maria G. Ioannides

Department of Electrical and Computer Engineering, National Technical University of Athens, Greece

Many work related electric accidents occurred in electric energy industries and they were very often fatal. The situation of electric accidents in electric companies worldwide is investigated by reviewing the scientific literature, to offer perspectives on the types and kinds of statistics available, the factors regarded as influencing their occurrence, their consequences, and also methodological shortcomings.

Worldwide, reliable comparable data exist and indicate a downward trend in fatal electric accidents. Difficulties were encountered in compiling international statistics because of differences in how accident data were defined and recorded, variations in mandatory practices, lack of suitable data and indices, accident insurance systems, and lack of correlation between technical, financial, and medical aspects.

---

occupational electric accident   occupational accident statistics
production, transmission, distribution of electric energy
occupational electrocutions

The authors thank Public Power Corporation and Greek Secretariat of Research and Technology for their kind financial support.

Correspondence and requests for reprints should be sent to: Maria G. Ioannides, National Technical University of Athens, Department of Electrical and Computer Engineering, Industrial Electric Devices and Decision Systems Division, Heroon Polytechniou 9, 15773, Athens, Greece. E-mail: <mioannid@ece.ntua.gr>.

1. INTRODUCTION

As documented by statistics, work related accidents due to electricity do not represent a high percentage of the total number of occupational accidents occurring every year world wide, but they have the particularity to be fatal in great number. The sectors, where the majority of electric accidents occur, is the production, transmission, and distribution of electric energy, due to the fact that a great number of employees in this sector performs duties having direct or indirect relation to electricity.

The purpose of this paper is to investigate the situation in electric companies world wide. A review of the scientific literature concerned with electric accidents is conducted. The aims of this review are to offer perspectives on the types and kinds of statistics available; the factors, presented in the literature, that have been regarded as influencing the occurring of electric accidents; the consequences of electric accidents; several methods proposed for analysis of electric accidents. An attempt is made to adopt a method combining both technical and medical aspects.

2. OBJECTIVES

The literature of the past six decades was considered. Searching, without time limitations, was carried out in the international databases HSELINE, CISDOC, and NIOSHTIC, as they appeared on the OSH-ROM CD, produced by Silver Platter (London, UK). The keywords employed were trauma, shock, injury, fatality, accident, burn, industry, transmission, supply, delivery, lineman, distribution, line, company, production, electrician, electrocution, high voltage. They were used in all their grammar forms and in conjunction with the words electrical, electricity, electric, power (except for the last three). To complete this search, 369 queries were employed, which produced 1,262 records. After the elimination of duplicated records, 746 records remained. In the first stage, we divided the type of work activities they concern into three categories: electric energy industry (production, transmission, and distribution of electric energy—PTDEE), nonelectric industries (chemical industry, farming, construction, mining, etc.), and not specified (Figure 1). We selected the 385 records concerning PTDEE and general activities to examine them on the basis of their abstract. After reviewing all of them and eliminating those referring to the same facts and cases, 248 records remained. We decided to study them on the basis of the country they concerned. In this way it was easy to make up a clear picture about the kind of information collected and published in each country. Each record was classified in one of the following six groups, according to its content: electric companies data, general statistical data, general medical information, medical statistical data, technical information, Fatal Accident Circumstances and Epidemiology (FACE) reports (Figure 2). There was no statistical information in the general medical information and technical information categories, so we decided to study more analytically the other 148 records (12 electric companies data + 47 general statistical data + 16 medical statistical data + 73 FACE reports).

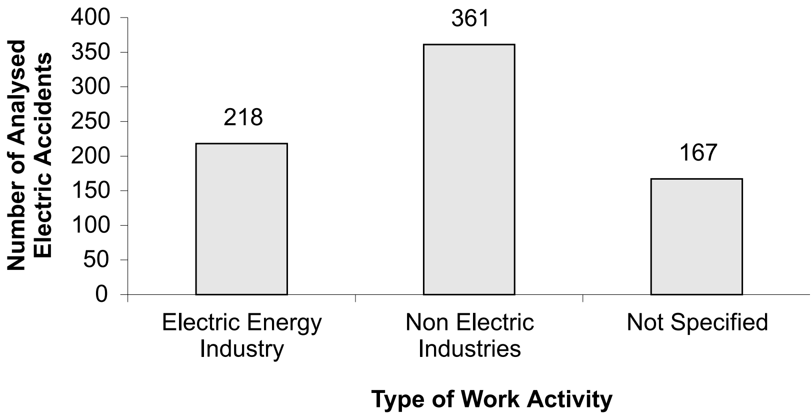

Figure 1. Number of analysed electric accidents per type of work activity.

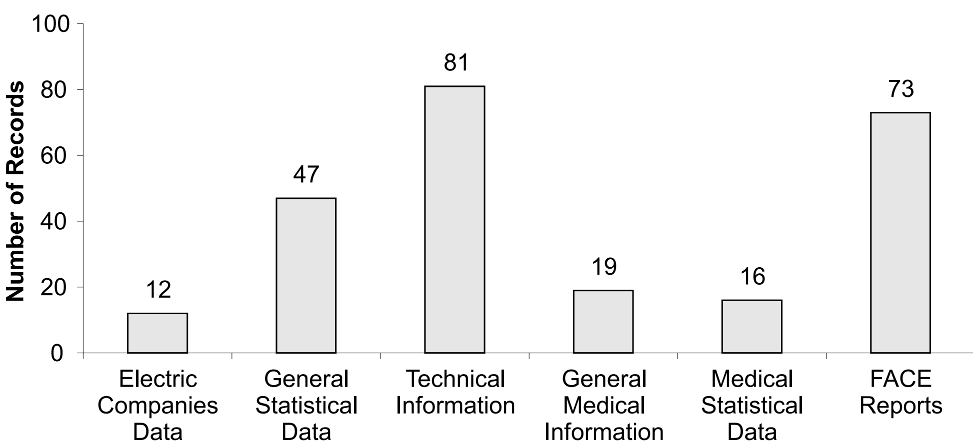

Figure 2. The total number of records found. *Notes*. FACE—Fatal Accident Circumstances and Epidemiology.

3. REVIEWING THE LITERATURE

3.1. Electric Companies and General Statistical Data

The National Electricity and Gas Company of Algeria refers to the statistics covering all occupational accidents during 1984 within the company. Breakdown is by geographical region, cause, age and professional qualification of the victim, fatal and nonfatal accidents, accident frequency and seriousness (Bouakouir, 1984).

Work related electrical fatalities were studied as part of a larger investigation of all work related fatalities in Australia from 1982 to 1984. The results indicated that electricity was the fifth highest cause of work related deaths in Australia (Harvey, Driscoll, Frommer, & Harrison, 1992). This study was repeated recently for the 1990s. Highlighting the dangers of working with or near electricity, “A Fatal Flash Above” (1992) shows that many electrocutions occur when tools or machinery come into contact with live overhead power lines and lists safety recommendations that could help to avoid future accidents.

A report on the activity of the Austrian Transport Inspectorate for the year 1972, with emphasis on electric accidents occurring between 1950 and 1970 in high-voltage electric traction installations is Bundesministerium für Verkehr (1973). Steinbauer (1976) presents the noteworthy electric accidents occurring in Austria, with special attention being paid to errors committed and violations of the five basic rules of electrical safety.

Pineault, Rossignol, and Barr (1994) and Rossignol and Pineault (1994) performed an analysis to determine whether the Haddon method, developed for analysing motor vehicle accidents, could be applied to analysing occupational electrocutions. The files of the Quebec Workers Compensation Board, Canada, were searched to identify all fatal occupational electrocutions that occurred between 1981 and 1988. Seven major variables were kept: electrical task, work above ground, average height above ground, passage of current through the hands or feet, direct contact without a vector, presence of electric distribution cable, fall to different levels.

An analysis of 184 electric accidents affecting employees of Electricité de France (EDF) between 1965 and 1969 shows clearly that the number of accidents remains constant. There are two basic categories of accidents: those resulting from work being performed in the vicinity of live installations without adequate precautions being taken and those occurring during work carried out on installations that are thought to be dead ("High Voltage Electric Accidents," 1970). Schlegel (1970) presented a brief description of several electrocutions that occurred during work in the vicinity of overhead lines. The author quotes from the French Decree of January 8, 1965, and recalls the main measures to be applied to avoid further accidents. A brochure indicates in tabular, graph, and diagrammatic form the accidents that occurred to French Electricity Board employees in 1970 (Electricité de France—Direction des affaires générales—Service prévention et sécurité, 1971). An analysis of severe and fatal accidents during the construction of first and second category overhead lines describes the circumstances of 89 accidents that occurred between 1964 and 1974 (Moreau, 1976, November-December). The same author (1976, September-October) analysed the circumstances of 46 accidents that occurred in French line-workers during the construction of very high voltage lines in 1964–1974. The chief cause of accidents was falls, followed by electric accidents, crushing, and being struck by objects. Whereas accidents with a human factor account for almost half of the accidents, the author contests that they are inevitable.

Severe and fatal accidents on construction sites for transformer stations, public lighting systems, telephone lines, and on railway traction wire construction sites, with statistical graphs of severe and fatal accidents that occurred between 1964 and 1974 in France were analysed in Moreau (1977). Statistics of the French National Electricity Board with overall data, fatal and nonfatal accidents at work and during commuting, frequency and severity of accidents were given for 1981–1983 (Electricité de France, 1982, 1983). Analysis was made by causal agent, nature of work, factors favouring accidents, accident type, location and nature of injury, occupational class. All electrical injuries suffered by workers of Electricité de France (EDF) from 1970 through 1989 were recorded by Gourbiere, Corbut, and Bazin (1994). A detailed personal record of each victim was prepared. The mean number of victims per year was 104 for the 20-year period and the cases reported by EDF. Most of the electrocuted people were linemen or electrical fitters. The main causes of injuries were human errors, in particular not wearing protective clothes or glasses or not using safety devices.

Berufsgenossenchaften (1974) presented a method followed for the evaluation of 10,000 electric accidents that occurred in the German industry between 1967 and 1970. The data had been taken from medical case histories compiled by practitioners appointed by the Mutual Accident Insurance Association for the Precision Engineering and Electrical

Equipment Manufacturing Industry of Germany (Berufsgenossenchaften). Each case was classified according to age of injured person, cause of accident (voltage intensity), clinical sequelae, and treatment given. Work on distribution equipment was found to be the most common cause of electric accidents over the period 1969–1975 (Kieback, 1978). Three possible causes of this rising trend were analysed: inadequate training and qualification, increased frequency of such work, installation design modifications.

The Chief Executive's Safety Committee—Electricity Supply Board (1973) presented a report of the fatal electric and nonelectric accidents for Irish electrical workers during 1973, along with a summary of all fatal accidents occurring over the period 1929–1973.

A brief review of electric accidents reported in the Netherlands between 1960 and 1969 pointed out that trained electricians were exposed to the same hazards as untrained electricians with the example of an accident that occurred in a transformer station (Slob, 1969). Statistical reports of the Ministry of Social Affairs of the Netherlands with data on electric accidents notified during the period 1951–1977 examine causes of accidents, type of electrical equipment, occupational categories of injured persons, nature of injury (Ministry of Social Affairs, 1977, 1978, 1979).

After Hurricane Hugo crossed Puerto Rico (1989), approximately 85% of the country was without electric power because of damage to power lines and poles. Five occupational electrocutions occurred during operations to restore power. A National Institute for Occupational Safety and Health (NIOSH) Fatal Accident Circumstances and Epidemiology (FACE) team assisted local public health officials in investigating these electrocutions (Rechani & Rullan, 1989).

An analysis of causes of electric accidents in the main economic fields was carried out at the Leningrad (the USSR) Occupational Safety Research Institute in 1966. The conclusions indicated a need for better training, stricter application of safety regulations and increased safety propaganda (Filippov, 1966).

Statistical reports of the Swiss Inspectorate of Heavy-Current Electrical Installations concerned the electric accidents in high-power electric installations that occurred in Switzerland during the periods 1966–1971 and 1982–1984. Data were analysed in terms of the voltage involved, the severity of the accidents, the training of the victims, and the nature of the installations where the accidents occurred (Buchler, 1985; Class, 1970, 1973).

Data given by the Factory Inspectorate of the United Kingdom (UK) referred to the causes of electric accidents that occurred in the UK from

1930 to 1961 (Ministry of Labour and National Service—HM Factory Inspectorate, 1930, 1952–1962, 12 references). Unfortunately, abstracts were not available for any of these references to highlight their contents. Three other records referred to individual cases: the first was a case law, related to an electrician putting a new cable into a fuse box 10 feet above ground ("Turner v Associated Electrical Industries," 1971), the second was about an electrician who died when he was working on a 240-V lighting circuit fed by a double pole sub-fuse-board ("Fuseboard Fatality," 1991), and the third was about an electrician electrocuted while investigating a fault in a light fitting ("Death of Electrician," 1996).

Hazards from accidents involving damage to the network of underground electricity cables in London, UK, were investigated (Health and Safety Executive, 1983). The survey was conducted to analyse responses from the London Electricity Board, which completed forms following any third-party damage to their cables, and forms completed by any contractors who damaged such cables. Bonnell (1987) discussed the safety procedures established in the electrical generating industry in the UK with safety rules drafted by the management in consultation with the trade unions. A tabular presentation was included of the accidents that occurred to employees in the electricity supply industry in England and Wales during 1984–1985. Mason (1996) presented an attitude survey, developed and applied to all electricians in the Nottinghamshire coal-field that investigates what new approaches to safety were needed to address the continuing problem of small numbers of electricians being electrocuted by failing to isolate equipment correctly.

A review of Texas, USA, death certificates yielded a total of 710 deaths associated with occupational injuries in 1982. Electrocutions were among the leading causes of death and electricians were among the occupations with the highest risk (Suarez, Carroll, Barrington, & Alexander, 1985). Concerning the potential for electrocution by undetected electrical feedback in power lines, two cases, which occurred in 1987, were described in detail and other cases that were very similar were cited (NIOSH, 1987). Data regarding worksite fatalities due to electrocution for 1984–1986 were obtained from Occupational Safety and Health Adiministration (OSHA)'s Integrated Management Information Systems database and the Health and Safety Analysis Centre of the Mine Safety and Health Administration (Suruda, 1988). The data were categorised according to the type of voltage and the involvement of electrical work as the primary activity. Industries with high rates of electrocution included power line contractors, steel erection, construction, painting, and electricians.

An epidemiological evaluation was performed to examine the characteristics of fatal and nonfatal electrical injuries among Virginia, USA, workers and strategies were suggested to prevent occupational electrical deaths. Cases were taken from computerised Worker's Compensation files for the period 1977–1985. Most electrocutions were occupational. Power line contact caused most of them (Jones & Armstrong, 1991). From 1980 to 1988, NIOSH reported that 181 workers died from tree trimming (NIOSH, 1992). The two leading causes of death were electrocutions and falls.

Occupations and industries with the highest job related death rates were identified and the causes of deaths within occupations and industries were investigated by the Department of Economics of the San Jose State University of California, USA. Data were gathered from 1979–1983, 1985, and 1986 Bureau of Labor Statistics Supplemental Data System. The estimated number of annual deaths was 5,601. For men and women combined the occupations with the highest rates per 100,000 included stone cutters, 351; blasters, 123; airplane pilots, 117; motormen, 111; surveying assistants, 81; lumberjacks, 80; miscellaneous laborers, 67; asbestos workers, 65; and electric power linemen, 55. Electric power linemen were among the occupations with the highest rates and electrocutions were among the most common injuries (Leigh, 1992). Other epidemiological studies have shown that approximately 67% of all electrocutions are work related. The NIOSH National Traumatic Occupational Fatality Database indicates that approximately 7% of the nearly 6,500 work related traumatic fatalities that occur annually are electrocutions (Casini, 1993). The most common scenarios resulting in electrical injury included the use of portable power tools, the use of faulty power tools, electrical outlets and connectors, the use of portable arc welding equipment, and contacting power lines with ladders, cranes, scaffolding, irrigation, or tree trimming equipment. Risk factors included contact with moisture or working on damp ground (Pasternak, 1994).

A survey of 70 fatalities due to electrocution, which occurred from 1959 through 1969 in Yugoslavia, shows that 36 of them occurred at a worksite (Hristitj, Michitj, & Dozhitj, 1973). It is noted that although the total number of accidents has increased, the number of fatal electrocutions has remained the same.

The difficulties in the comparison of statistics from different countries on electric accidents are discussed by Kieback (1988). The International Electrotechnical Commission (IEC), the section of the International Social Security Association (ISSA) dealing with electric accidents, and the International Union of the Power Supply Companies have produced data on fatal electric accidents from 20 countries for the period 1972–1983. The data indicated a downward trend in fatal accidents in those years. It is concluded that apparently reliable internationally comparable data on fatal electric accidents do exist. Data on nonfatal accidents do not exist due to non-uniform collection methods and lack of common reference values.

Electricity is the greatest killer among electric utility workers. A total of 66 employees were killed in 1975, 36 from electric shocks and burns (Odlin, 1977). A case report of two workers who experienced high-voltage electrical burns when their aluminium ladder came into contact with a high-voltage power line, the circumstances surrounding the injuries, clinical management of the case, and possible methods of prevention are presented and discussed by Moghtader and Himel (1995). Cases of accidents when electricity workers and members of the public were injured on overhead electricity lines, the causes of these accidents, and ways of preventing them from occurring in the future are discussed in “Accidents: Electricity” (n.d.).

3.2. Medical Statistical Data

A consideration of two cases of electric cataract resulting from high-voltage electric accidents establishes the points concerning the etiopathology of these electrical lesions (Aouchiche, 1968). Myelopathy following electrocution is examined by Murthy, Chopra, and Sawhney (1980). The results of clinical observations of 140 patients with electric burns show that cardiovascular and neurocirculatory disorders are remarkable (Panova & Ivanova, 1974). The histological examination of two men who died from electrical arch flash burns is discussed by Moar and Hunt (1987).

From the experience of the Plastic Surgery Department of Uppsala University Hospital, Sweden, are reported the occurrence, clinical features, and treatment of electrical trauma (Skoog, 1970). A case of cardiac arrest following an electrical alternating current shock is examined by Herlevsen and Andersen (1987). A review of 116 cases of high tension wire electric accidents in patients admitted to the Burn Unit of the University of Kansas Medical School (USA) analyses the neurological effects of high-voltage injuries (Varghese, Mani, & Redford, 1986).

To identify methods of prevention, 1,076 outpatients of the Regional Burn Treatment Centre of the University of California at San Diego Medical Centre (USA) treated between 1977 and 1982 were studied by Inancsi and Guidotti (1987). A total of 232 cases were identified as work related and were characterised by age, gender, ethnicity, occupation, extent of burn, body parts affected, length of hospital stay, disability, and time away from work.

Reliable quantitative data about electric shock to humans at power transmission frequencies are available for three physiological responses to electrical stimulation: perception, uncontrollable muscular contraction, and death (Keesey & Letcher, 1970). Low voltage, high voltage, and flash burns of the hand are evaluated by Parks and Horner (1973). A survey on 64 patients suffering from electrical flash burns exclusively show that these patients sustained relatively small burns (Solem, Fischer, & Strate, 1977). A case report of an electrical worker who survived a normally fatal high-voltage electric shock is described by Iob et al. (1986). After 7 years of experience in the area of electrical injuries resulting from contact with high-voltage lines, 82% were work-related. The two most common complications were sepsis and neurologic impairment (Hammond & Ward, 1988). A case of peripheral nerve injury and Raynaud's syndrome following an electric shock is discussed by Kinnunen, Ojala, Taskinen, and Matikainen (1988). The neurologic problems of 86 patients admitted to a Burn Centre with low- or high-voltage injuries are presented by Grube, Heimbach, Engrav, and Copass (1990). An investigation of electrical contact and pregnancy reports that low-voltage electric shock to a pregnant woman has the potential to harm the foetus, including foetal death (Moore, 1991).

3.3. Fatal Accident Circumstances and Epidemiology (FACE) Reports

The 73 FACE reports are all individual cases of fatal electric accidents; 72 of them occurred in the USA and 1 in Puerto Rico, between 1983 and 1996. They come from NIOSH Fatal Accident Circumstances and Epidemiology (FACE) project, established by NIOSH in the early 1980s to investigate the circumstances under which fatal work accidents occur in the USA. They provide valuable and uniform data.

4. RESULTS

4.1. General Remarks

The 81 "technical information" records cover the majority of the references (Figure 2). That fact is a reflection of the reality. Actually, nowadays all the technical preventive aspects are well known, although electric accidents continue to occur. The prevention of electric accidents has been viewed primarily as a technical issue, which can be improved by better engineering. Thus, correct design and construction of electrical installations have been the primary means for protecting workers from electricity. However, it can be argued that the general principle of separating workers in time and space from any hazards has been long known. Given this and the efforts on workers' protection from electricity in the last two or three decades, one might well ask why electric accidents are still a major problem. Various possibilities have been suggested. One is that technical instructions must be followed by suitable workers' training. Another one argues that the identification of the causes of the accidents and the study of their consequences are good lessons for not repeating the same accidents; one way to achieve that is giving recommendations for the prevention of each one accident. There does exist literature on these topics. That is why another classification of the records was made according to the following factors: causes, consequences, recommendations, training, to evaluate the relative information. The results can be seen in Figure 3. (The analysis was made on 248 records. The sum of the numbers in this graph is greater than the total number of records, because some records give more than one of the aforementioned factors).

The 35 medical references (Figure 2) signify that the level of medical research of electric accidents is quite satisfactory. Of them, 19 give medical information about the consequences of electric accidents and proper remedies; the other 16 give, additionally, statistical data. The 47 records providing

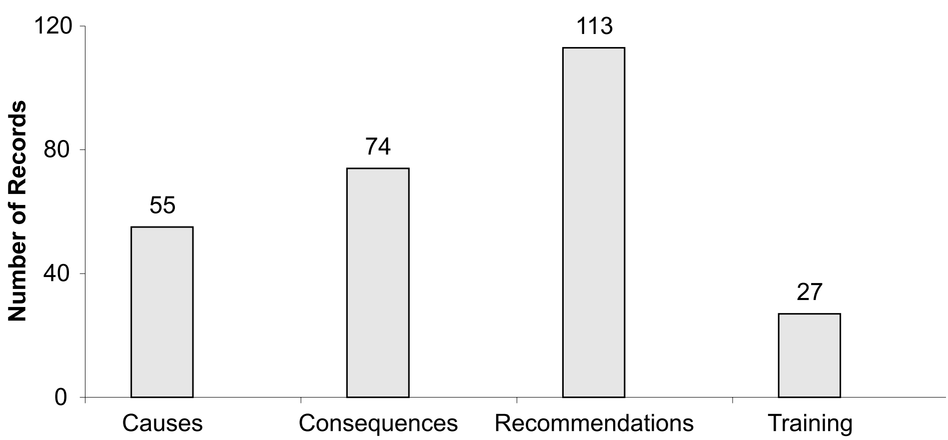

Figure 3. Records regarding causes, consequences, recommendations of electric accidents, and workers' training.

statistical data about occupational electric accidents generally reveal that electricity is a great killer among workers, especially those performing electrical tasks. This is the main information that the majority of them give, as they are general statistics, not specialised in electric accidents. The 12 records giving data from electric companies include more technical and specific electric accident analyses.

4.2. Electric Companies, General Statistical and Medical Statistical Data

For the 75 statistical records a comparison was made between the information provided by Electric Companies and General Statistical References (ECGSR—59 records) on one hand and Medical Statistical References (MSR—16 records) on the other hand. This was decided, because of the different kind of information these two categories give. All the numbers in Figures 4–9 are percentages. In some cases the total of them is not 100, due to the fact that in each record more than one kind of studied factors were found.

The type of accident constitutes important information. As it is well known, most accidents can be characterised as occupational accidents, occupational electric accidents, electric accidents, and commuting accidents. All MSR report with emphasis cases of occupational electric accidents and of electric ones. At the same time, the ECGSR report cases from all four categories of accidents. Thus, electric companies face occupational electric accidents as one of the four categories of all accidents that occur. So, the corresponding percentages of occupational electric accidents and electric ones are lower that in the MSR cases (Figure 4). The frequency and severity of accidents, usually given by the employers, are very important, too. In most cases the total number of fatal and nonfatal accidents is kept, but other indicators (number of workers, number of working hours, number of lost working hours) necessary for calculating accident frequency and severity, as well as accident frequency and severity themselves, are not frequently kept by the authors or not given by the employers. The MSR do not give information for calculating accident frequency and severity (Figure 5).

Another kind of useful information is the personal and professional victim’s characteristics: age, gender, race, professional qualification, work task, training. The ECGSR give better information for victim’s professional qualification and work task and the MSR for age and gender. None of the MSR give information about victim’s training and none of the ECGSR

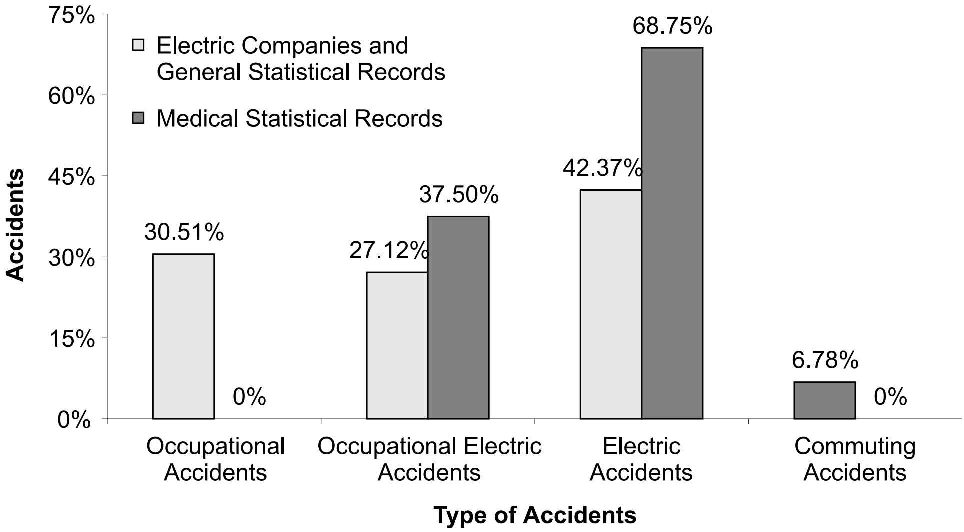

Figure 4. Sources of records (in %) that give information on the category of accidents.

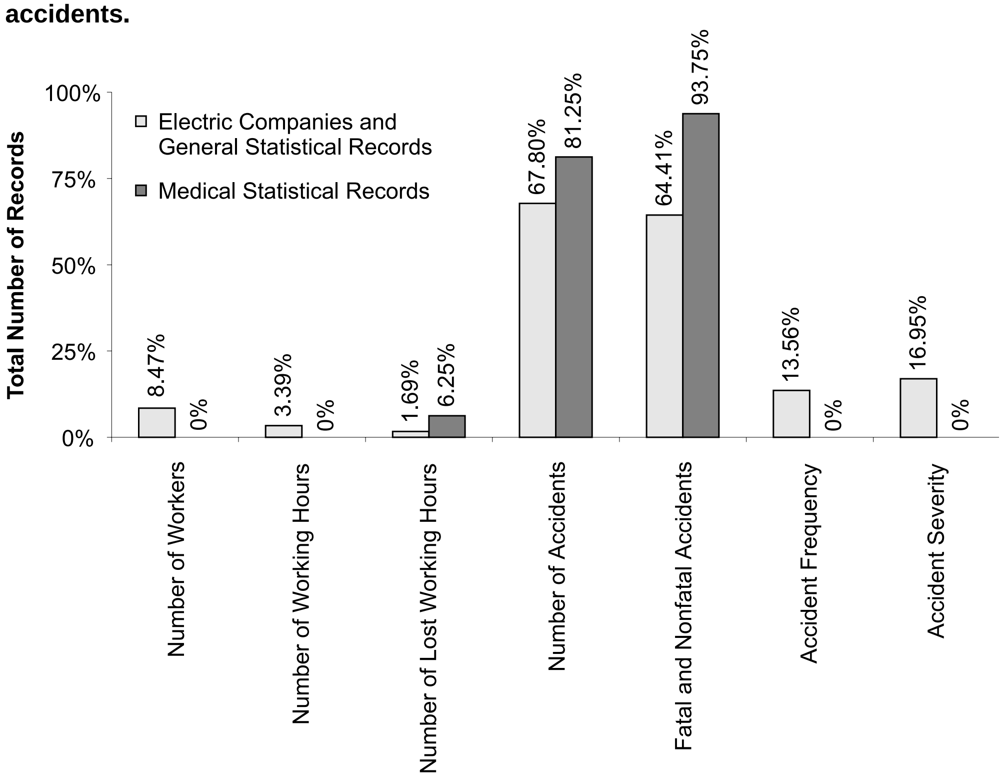

Figure 5. The kind of information reported by the employers in literature referred to the total number of records found.

about victim's race (Figure 6). Another kind of useful information is the electrical injury and the electric accident characteristics. The MSR give more specific information about the injury location and nature, as well as the given treatment and first aid, whereas the ECGSR are poorer in this kind of information (Figure 7). Voltage is the electric factor that most of the MSR give, following by the current path through the victim's body, the kind of contact, and the kind of current. The same information is given by

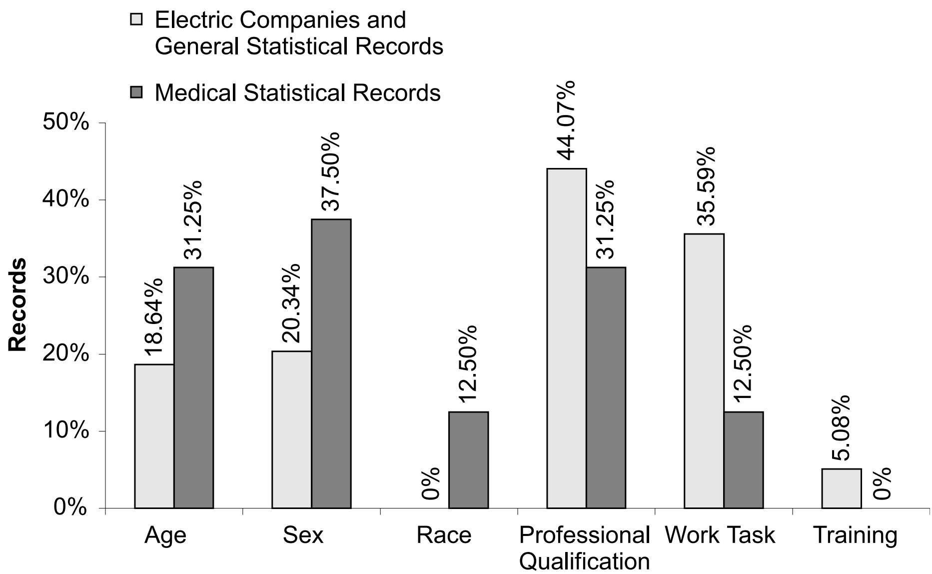

Figure 6. Records (in %) giving information regarding the personal characteristics of electric accidents victims.

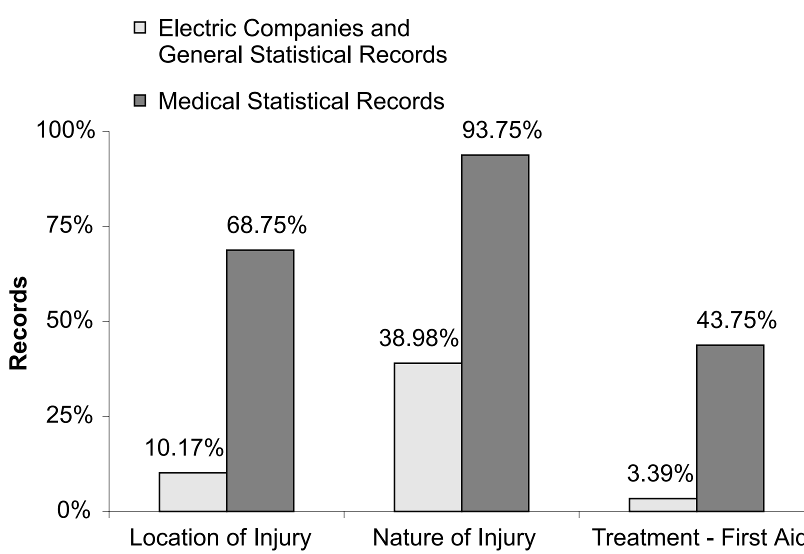

Figure 7. Records (in %) giving information regarding the injury characteristics.

ECGSR, too, plus some other technical factors, like presence of electric line, handling of objects, height above ground, and fall to a different level (Figure 8).

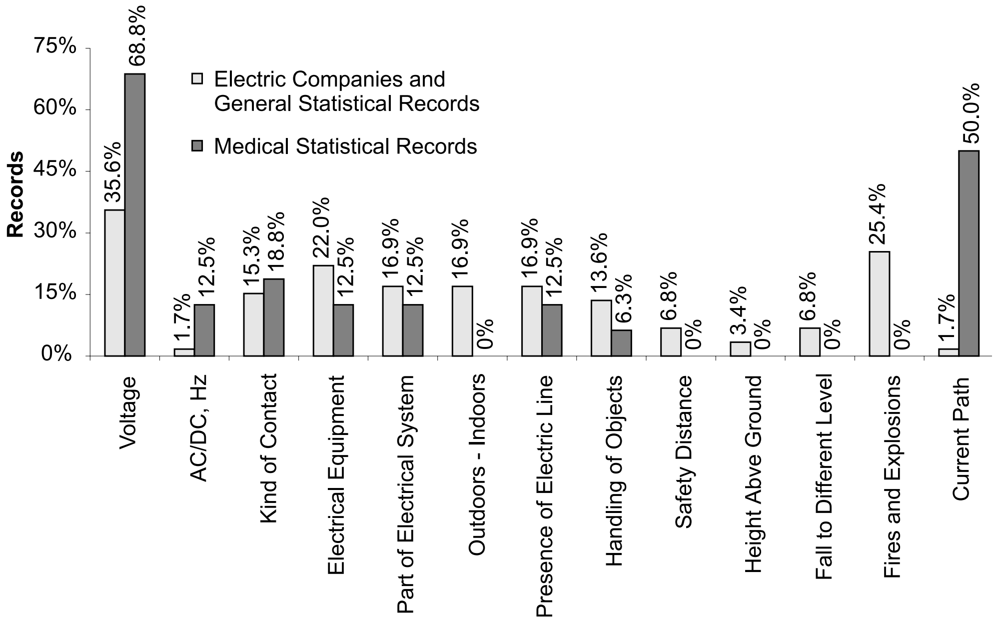

Figure 8. Records (in %) giving technical and electrical characteristics of electric accidents.

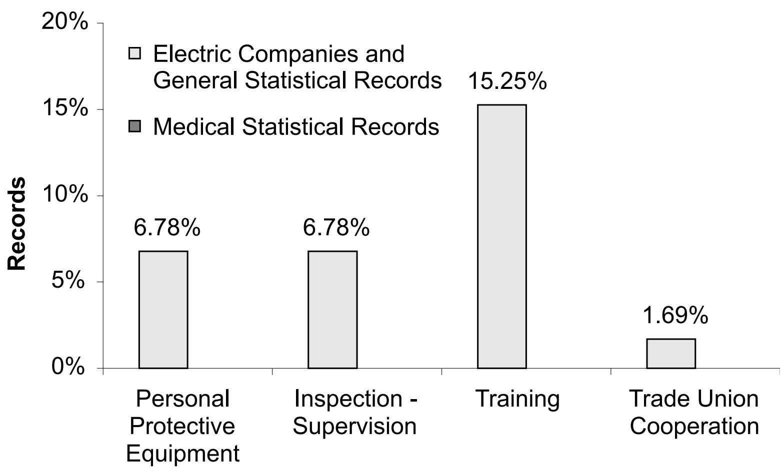

Figure 9. Records (in %) giving information on other factors related to companies' management.

The use of personal protective equipment (PPE) by workers, inspection and supervision of workplaces, workers' training needs, and co-operation with trade unions are senior management basic duties. The MSR do not give such information at all (Figure 9). Most of the ECGSR give information about the economic sector, whereas the MSR do not give the geographical region where the electric accidents happened (Figure 10).

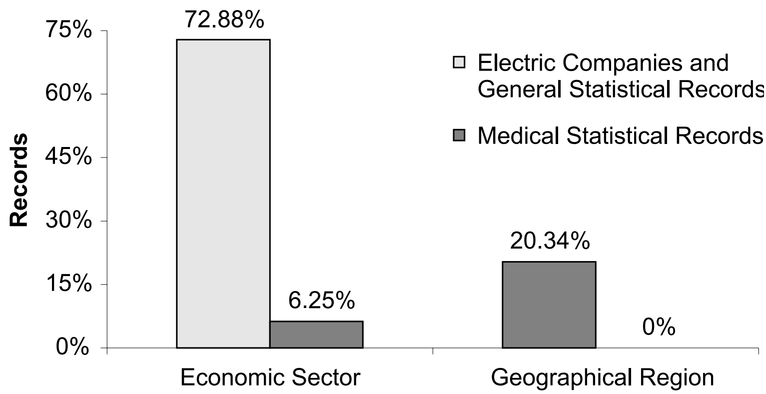

Figure 10. Records (in %) giving information regarding economic and geographical data.

4.3. FACE Reports

The 73 FACE reports were put in a spreadsheet, producing a database. As 2 of them referred to double accidents, the total number of cases is 75. For each case the following data were kept: victims' age, victims' work speciality, victims' working experience, employer, voltage, if the victim was working alone, major accident etiology, special recommendations for training and safety policy needs made.

The victims' age was not reported in 30.67% of the cases. For the other cases, the age was grouped in decades. The majority of the electrocuted workers were between 20 and 40 years old, that is the most productive period in one worker's occupational life (Figure 11). The victims' work speciality was grouped in the following categories: apprentice, lineman, electrician, repairman, foreman, technician, groundman, tree trimmer, journeyman, worker. The majority of the victims were among linemen, followed by apprentices and electricians (Figure 12). Concerning the victims' working experience, the given data were not suitable for conclusions, as this information was not kept in most cases.

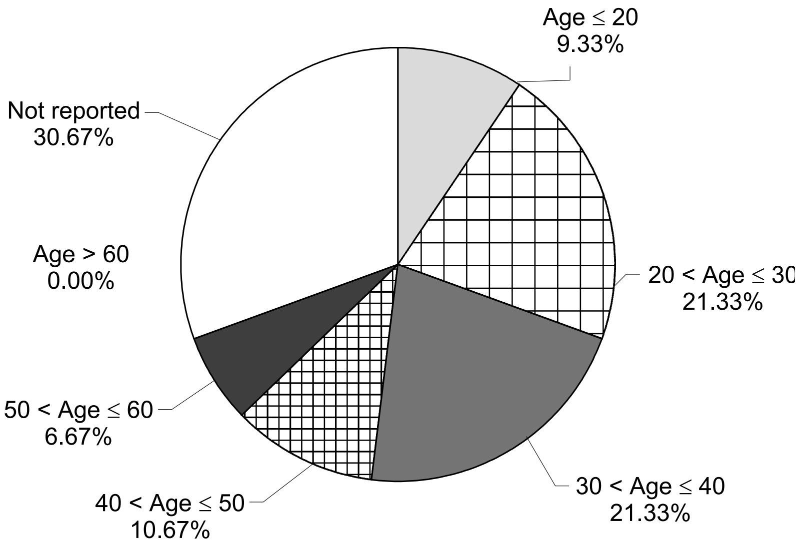

Figure 11. Fatal electrocutions (in %) for each age group.

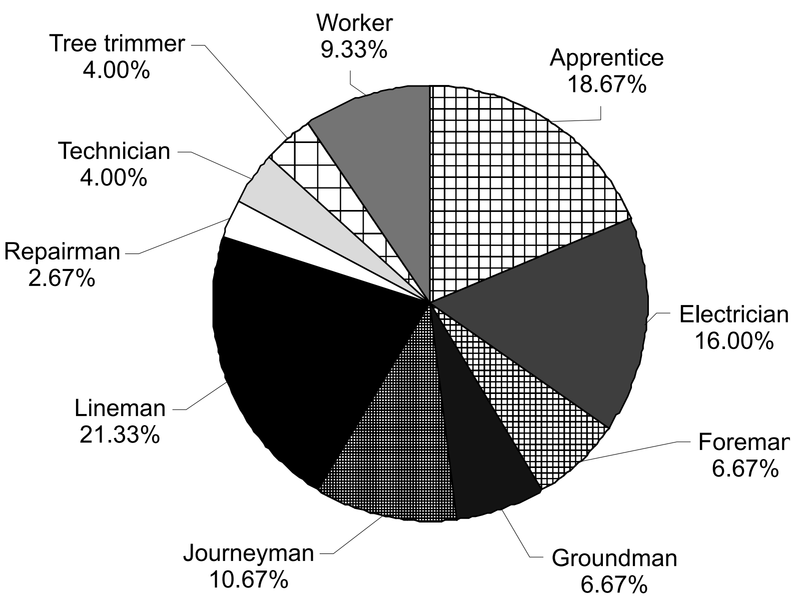

Figure 12. Fatal electrocutions (in %) for each work speciality.

The employers were grouped in the following categories: coal fired power plant, electric company, public electric company, electrical contractor, equipment company, local electric company, power line construction and maintenance company, tree service company, not reported. The majority of the electrocutions occurred in electrical contractors (Figure 13). The voltage, under which the electrocutions occurred, was not reported in 24.0% of the cases. For the other cases, the voltage was divided into 10 ranges, according to the Greek law concerning live work on electrical installations. Most electrocutions occurred between 6.600 and 15.000 V (Figure 14).

The major reasons leading to the accidents were grouped in the

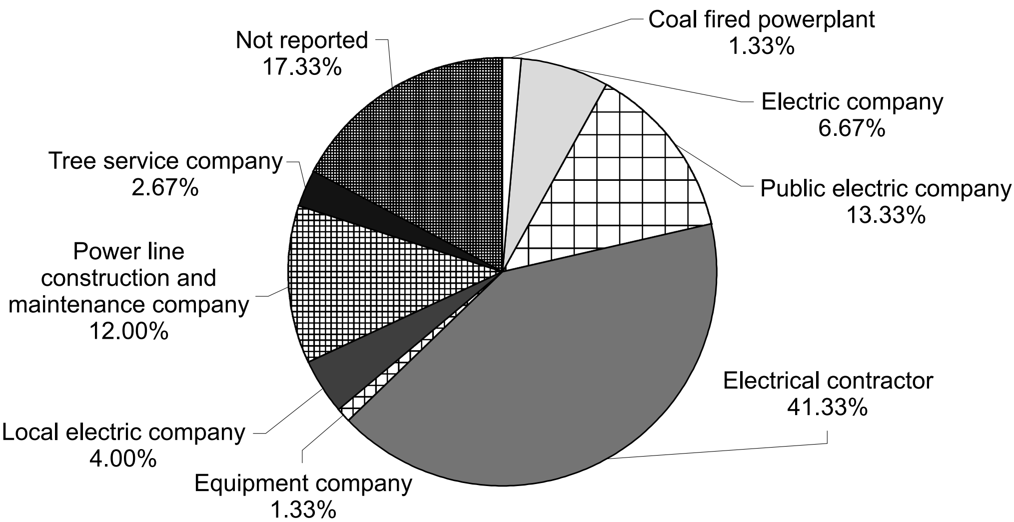

Figure 13. Fatal electrocutions (in %) and their industrial sector of employment.

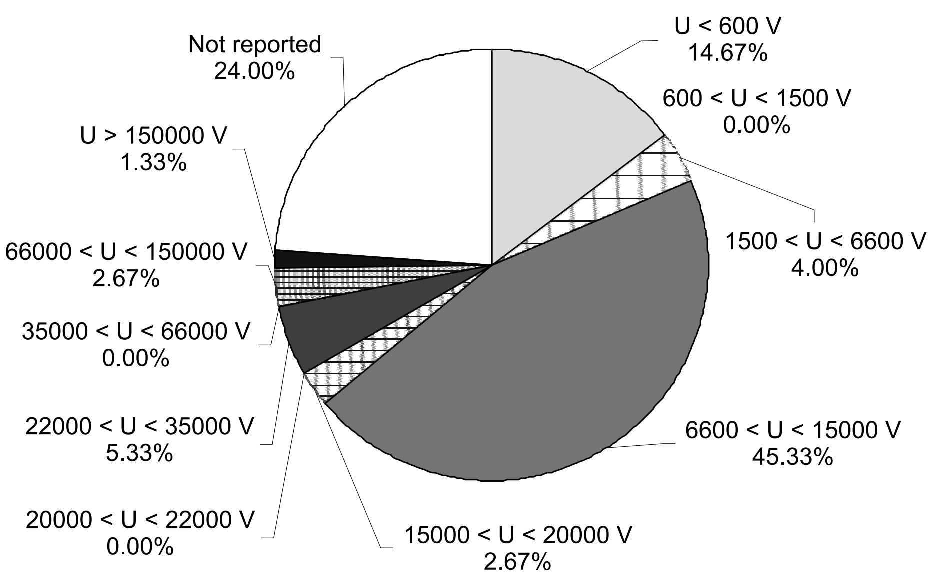

Figure 14. Fatal electrocutions (in %) and the level of voltage (U) where they occurred.

following categories: inadequate locked out or tagged out procedures, inadequate safe work procedures, inadequate training, no compliance with child labor laws, no existing written safe work procedures, not following established safe work procedures, not wearing PPE, not wearing PPE plus another reason. It is characteristic that most electrocutions were caused by workers not following established safe work procedures and also by people not wearing PPE (Figure 15).

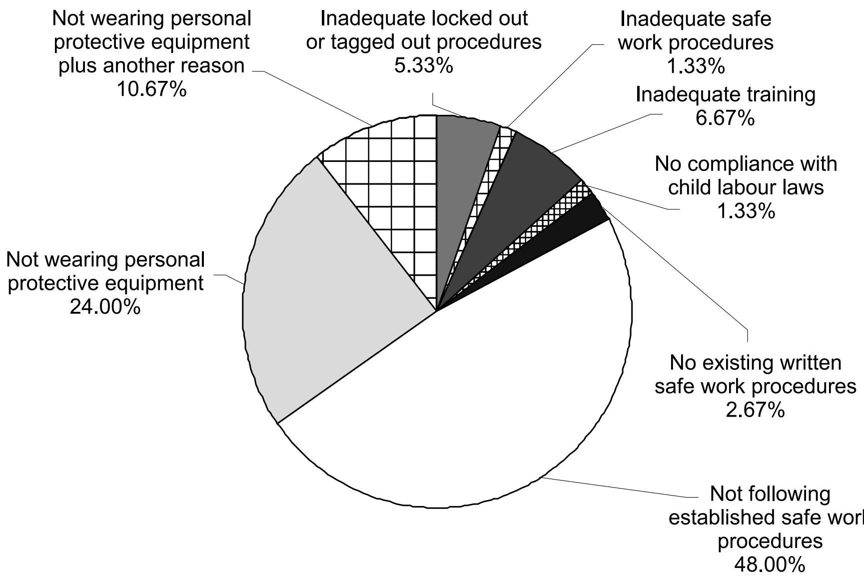

Figure 15. Fatal electrocutions (in %) and their major etiology.

In most cases (82.67%) the victims did not work alone. Special recommendations for training and safety policy needs were made by the investigators in most cases (54.67%).

5. DISCUSSION AND CONCLUSIONS

Statistical data reveal that electricity is a great killer among workers, especially those performing electrical tasks. It would be expected that electric companies, knowing this first hand, would publish much more and more detailed data. But only 12 records gave electric company data and none of them were recent. Important questions thus arise. Why electric companies do not publish accident statistics? Why those electric companies that used to publish accident statistics (e.g., EDF) no longer do so? Why is electricity no longer statistically attractive as an occupational risk although electric accidents continue to represent a great portion of fatal occupational accidents and new factors (e.g., environmental, human, medical, epidemiological) attract the interest of electric company management?

There are difficulties in the comparison of statistics from different countries on electric accidents. Problems encountered in compiling international accident statistics in a consistent way resulted from differences in the accident insurance systems between countries, in how accident data were recorded, in how accidents were defined, in obligatory notification practices, in defining and recording fatal accidents and lack of suitable reference data and indices. Data indicate a downward trend in fatal accidents. It is concluded that apparently reliable internationally comparable data on fatal electric accidents do exist. Data on nonfatal accidents do not exist due to nonuniform collection methods and lack of common reference values.

In general, it can be stated that much remains to be done concerning the methods under which electric accident statistics and analyses are formed. The kind of information they give is vital for accident reoccurring prevention. Whereas there is no easy to implement solution for preventing all electrocutions, knowing the magnitude of the danger and its components is a first step. Nowadays all the technical preventive aspects are well known, although electric accidents continue to occur. The level of medical research on electric accidents is quite satisfactory. The studies reviewed are informative in several methods proposed for the electric accident analysis; but a method combining both technical and medical aspects has not been adopted. The kind of information given by technical analyses is different from that given by medical analyses. This absence as well as the need of combined analyses become clear after this review.

REFERENCES

Accidents: Electricity. (n.d.). *Safety Review, 34,* 3–8.

A fatal flash above. (1992). *Australian Safety News, 63*(8), 41–43.

Aouchiche, O. (1968). Considerations on two cases of electric cataract. *Archives des maladies professionnelles, 29*(12), 706–709. (In French).

Berufsgenossenchaften. (1974). Sequelae of electric accidents. In *Medizinischer Bericht 1973.* Köln-Baenthal, Germany: Institut zur Erforschung elektrischer Unfalle bei der Berufsgenossenschaft der Feinmechanik und Elektrotechnik. (In German).

Bonnell, J.A. (1987). The electricity supply industry. *Recent Advances in Occupational Health, 3,* 37–54.

Bouakouir, B.S. (1984). *Statistics on occupational accidents* (*electricity and natural gas industries*). Alger, Algeria: Société Nationale de l'Electricité et du Gaz—Prévention et Sécurité. (In French).

Buchler, O. (1985). Accidents in high-power electric installations in Switzerland, 1982–1984. *Bulletin des Schweizerischen elektrotechnischen Vereins—Bulletin de l'Association Suisse des Electriciens, 76*(23), 1381–1389. (In German and French).

Bundesministerium für Verkehr. (1973). *Report on the activity of the transport inspectorate for the year 1972*. Wien, Austria: Author. (In German).

Casini, V.J. (1993). Occupational electrocutions: Investigation and prevention. *Professional Safety, 38*(1), 34–39.

Class, H. (1970). Accidents caused in Switzerland by heavy-current electrical installations during the period 1966–1968. *Bulletin des Schweizerischen elektrotechnischen Vereins—Bulletin de L'Association Suisse des Electriciens, 61*(24), 1135–1147. (In German and French).

Class, H. (1973). Accidents caused by heavy-current electrical installations during the period 1969–1971. *Bulletin des Schweizerischen elektrotechnischen Vereins—Bulletin de l'Association Suisse des Electriciens, 64*(11), 693–707. (In German and French).

Death of electrician. (1996). *Occupational Health, 48*(8), 273.

Electricité de France. (1982). *Accident statistics—French National Electricity Board employees, 1982*. Paris, France: Author. (In French).

Electricité de France. (1983). *Accident statistics—French National Electricity Board employees, 1983*. Paris, France: Author. (In French).

Electricité de France—Direction des affaires générales—Service prévention et sécurité. (1971). *Accident statistics of the French Electricity Board.* Paris, France: Author. (In French).

Filippov, V. (1966). Electrical safety: Analysis and proposals. *Ohrana truda i social'noe strahovanie, 7,* 22–23. (In Russian).

Fuseboard fatality. (1991). *Royal Society for the Prevention of Accidents Bulletin, 21*(9), 4–5.

Gourbiere, E., Corbut, J.P., & Bazin,Y. (1994). Functional consequence of electrical injury. *Annals of the New York Academy of Sciences, 720,* 259–271.

Grube, B.J., Heimbach, D.M., Engrav, L.H., & Copass, M.K. (1990). Neurologic consequences of electrical burns. *Journal of Trauma, 30*(3), 254–258.

Hammond, J.S., & Ward, C.G. (1988). High-voltage electrical injuries: Management and outcome of 60 cases. *Southern Medical Journal, 81*(11), 1351–1352.

Harvey, P.L., Driscoll, T.R., Frommer, M.S., & Harrison, J.E. (1992). Work-related electrical fatalities in Australia 1982–1984. *Scandinavian Journal of Work, Environment and Health, 18*(5), 293–297.

Health and Safety Executive. (1983). *Underground cable damage survey* (Occasional Paper Series, OP6). London, UK: HMSO.

Herlevsen, P., & Andersen, P.T. (1987). Constitutional predisposition to vasovagal syncope: An additional risk factor in patients exposed to electrical injuries. *British Heart Journal, 57*(3), 284–285.

High voltage electric accidents at the French Electricity Board. (1970). *Vigilance, 38,* 18–21. (In French).

Hristitj, L., Michitj, S., & Dozhitj, V. (1973). Fatal electrocutions during work. *Srpski Arhiv za Celokupno Lekarstvo, 101*(6), 431–434. (In Serbo-Croatian).

Inancsi, W., & Guidotti, T.L. (1987). Occupation-related burns: Five-year experience of an urban burn center. *Journal of Occupational Medicine, 29*(9), 730–733.

Iob, I., Salar, G., Ori, C., Mattana, M., Casadei A., & Peserico, L. (1986). Accidental high voltage electrocution: A rare neurosurgical problem. *Acta Neurochirurgica, 83*(3–4), 151–153. (In German).

Jones, J.E., & Armstrong, C.W. (1991). Fatal occupational electrical injuries in Virginia. *Journal of Occupational Medicine, 33*(1), 57–63.

Keesey, J.C., & Letcher, F.S. (1970). Human thresholds of electric shock at power transmission frequencies. *Archives of Environmental Health, 21*(4), 547–552.

Kieback, D. (1978). Electric accidents during work on low-voltage distribution installations. In *Technischer Bericht 1978*. Köln-Baenthal, Germany: Institut zur Erforschung elektrischer Unfalle. (In German).

Kieback, D. (1988). International comparison of electric accident statistics. *Journal of Occupational Accidents, 10*(2), 95–106.

Kinnunen, E., Ojala, M., Taskinen, H., & Matikainen, E. (1988). Peripheral nerve injury and Raynaud's syndrome following electric shock. *Scandinavian Journal of Work, Environment and Health, 14*(5), 332–333.

Leigh, J.P. (1992). *Probabilities of job-related deaths and disabilities*. San Jose, CA, USA: San Jose State University, Department of Economics.

Mason, S. (1996). Measuring attitudes to improve electricians' safety. *Mining Technology, 78*(898), 66–170.

Ministry of Labour and National Service—HM Factory Inspectorate. (1930, 1952–1962, 12 references). *Electric accidents and their causes*. London, UK: HMSO.

Ministry of Social Affairs. (1977). Accidents due to electricity in 1975. In *Verslagen en rapporten 1977–2*. Den Haag, The Netherlands: Author. (In Dutch).

Ministry of Social Affairs. (1978). Accidents due to electricity in 1976. In *Verslagen en rapporten 1978–3*. Den Haag, The Netherlands: Author. (In Dutch).

Ministry of Social Affairs. (1979). Electric accidents in 1977. In *Verslagen en rapporten 1979–2*. Den Haag, The Netherlands: Author. (In Dutch).

Moar, J.J., & Hunt, J.B. (1987). Death from electrical arc flash burns. *South African Medical Journal, 71*(3), 181–182.

Moghtader, J.C., & Himel, H.N. (1995). Electrical burn injuries of workers using portable aluminium ladders near overhead power lines. *Burns, 19*(5), 441–443.

Moore, A.B. (1991). Electrical contact and pregnancy. *Journal of Occupational Medicine, 33*(7), 827–828.

Moreau, J.C. (1976, November-December). Severe and fatal accidents during the construction of 1st and 2nd category overhead lines. *Cahiers des comites de prévention du bâtiment et des travaux publics et des travaux publics* (*Issy-les-Moulineaux, France*), *6*, 287–291. (In French).

Moreau, J.C. (1976, September-October). Severe and fatal accidents in construction of very high voltage lines. *Cahiers des comites de prévention du bâtiment et des travaux publics et des travaux publics* (*Issy-les-Moulineaux, France*), *5*, 224–228. (In French).

Moreau, J.C. (1977, March-April). Severe and fatal accidents on construction sites for transformer stations, public lighting systems and telephone lines and on railway traction wire construction sites. *Cahiers des comites de prévention du bâtiment et des travaux publics et des travaux publics* (*Issy-les-Moulineaux*, *France*), *2*, 95–100. (In French).

Murthy, J.M.K., Chopra, J.S., & Sawhney, C.P. (1980). Myelopathy following electrical injury. *Neurology India*, *28*(1), 41–44.

National Institute for Occupational Safety and Health (NIOSH). (1987). *NIOSH alert: Request for assistance in preventing electrocutions by undetected feedback electrical energy present in power lines* (DHHS [NIOSH] Publication No. 88–104). Cincinnati, OH, USA: U.S. Department of Health and Human Services (DHHS), NIOSH.

National Institute for Occupational Safety and Health (NIOSH). (1992). *NIOSH update: NIOSH issues nationwide alert on dangers of tree trimming* (DHHS [NIOSH] Publication No. 93–122). Cincinnati, OH, USA: U.S. Department of Health and Human Services (DHHS), NIOSH.

Odlin, W.S. (1977). Electric utilities light into job hazards. *Job Safety and Health*, 8–14.

Panova, J., & Ivanova, I.G. (1974, May). Cardiovascular changes due to electric burns. *Sovetskaja Medicina*, *5*, 58–63. (In Russian).

Parks, B.J., & Horner, R.L. (1973). Electrical burns of the hand. *Journal of Occupational Medicine*, *15*(12), 967–970.

Pasternak, G. (1994). Occupational electrical and lightning injuries. In T.N. Herington & L.H. Morse (Eds.), *Occupational injuries. Evaluation, management, and prevention* (pp. 469–477). St. Louis, MO, USA: Mosby-Year Book.

Pineault, M., Rossignol, M., & Barr, R.G. (1994). Inter-rater analysis of a classification scheme of occupational fatalities by electrocution. *Journal of Safety Research*, *25*(2), 107–115.

Rechani, P., & Rullan, J.V. (1989). Update: Work-related electrocutions associated with Hurricane Hugo—Puerto Rico. *Morbidity and Mortality Weekly Report*, *38*(42), 718–720.

Rossignol, M., & Pineault, M. (1994). Classification of fatal occupational electrocutions. *Canadian Journal of Public Health*, *85*, 322–325.

Schlegel, H.J. (1970). Safety on construction sites near power lines. *Prévention et sécurité du travail*, *83*, 8–14. (In French).

Skoog, T. (1970). Electrical injuries. *Journal of Trauma*, *10*(10), 816–830.

Slob, G.G. (1969). Electrical hazards. *De veiligheid*, *44*(6–8), 11. (In Dutch).

Solem, L., Fischer, R.P., & Strate, R.G. (1977). The natural history of electrical injury. *Journal of Trauma*, *17*(7), 487–492.

Steinbauer, E. (1976). Preventing electrocution. *Osterreichische Zeitschrift für Elektrizitatswirtschaft*, *29*(6), 267–272. (In German).

Suarez, L., Carroll, W.D., Barrington, W.E., & Alexander, C.E. (1985). Fatal occupational injuries—Texas, 1982. *Morbidity and Mortality Weekly Report*, *34*(10), 130–134.

Suruda, A. (1988) Electrocution at work. *Professional Safety*, *33*(7), 27–32.

Turner v Associated Electrical Industries Ltd. Decided case. (1971). *Knights Industrial Law Reports*, *11*, 1.

The Chief Executive's Safety Committee—Electricity Supply Board. (1973). *Safety Bulletin 1973*. Dublin, Ireland: Electricity Supply Board.

Varghese, G., Mani, M.M., & Redford, J.B. (1986). Spinal cord injuries following electric accidents. *Paraplegia*, *24*(3), 159–166.