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Epidemiology of Fatal Electrocutions in Japan 1992 to 1996

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Abstract

Electrical installation occasionally becomes the source of electrical accidents. The number of electrical, fatal accidents will exceed 8,000 fatalities by 2040-2050 in Japan. The reason is that electrically related fatal accidents have ranged from 10 to 20 fatalities annually, in recent years. The total number of electrically fatal accidents totaled 482 fatalities in 1961. Overall, electrically fatal accidents can be decreased by improving the operational safety. However, the complete prevention of fatal accidents by electric shock is not easy. The reason is that there are more than 60 million workers for all industries, 15 million of whom are in the construction and manufacturing industries. A new approach toward preventative measures for electrically fatal accidents is required because of such conditions. In this paper, 190 case studies of electrically fatal accidents from 1992 to 1996 are analyzed by the fatality rate. The results indicate that most of electrically fatal accidents occur at companies of fewer than 50 workers in the workplace. Moreover, the electrically fatal accidents of fewer than 30 workers are 65% and those of fewer than 50 workers are 75% of all of the fatal accidents for the period. The goal of this work is to save the valuable lives of workers, similar to those in the case studies, from electrically fatal accidents in the future.

Keywords: Epidemiology; Electrical installation; Electric shock; Electrically fatal accident; Electrical fatality rate; Case study

Introduction

The electrical power apparatus occasionally become the source of electrical accidents [1-32]. When maintenance work of the electrical power apparatus is performed, a worker occasionally touches an uncovered, charged (energized) conductor. When an electrical current of more than 50 mA flows through the hands or legs of a human body, a ventricular fibrillation can occasionally occur. The electrically fatal accidents are caused by ventricular fibrillation due to electric shock. The contact between the human body and the uncovered energized conductor of more than 35 V leads to an electrically fatal accident. Thus, most of the electrically fatal accidents in Japan are caused by electric shock.

The author reported the trends of electrically fatal accidents due to electric shock by industry, reporting the electrically fatal accidents for a 30-year period (1974-2003) in Japan [32-33]. The analysis is performed by the use of data from the Ministry of Health, Labour and Welfare (MHLW) and the Industrial Safety and Health Association (JISHA). The results of the analysis show that the electrically fatal accidents decrease since the Industrial Safety and Health Act (ISHA) and the Industrial Safety and Health Regulations (ISHR) were established in 1972 and since the installation of earth leakage current circuit breakers is required in 1969. Such analysis has never been performed, though it is necessary to analyze the detailed case studies.

After studying the electrically fatal accidents for the 30-year period, the detailed fatal accident analysis from 2002 to 2011 was performed with 174 case studies [34]. The results from 2002 to 2011 show that 81% of all fatal accidents by electric shock occur when the company size for the workplace is fewer than 50 workers. One of the reasons is that the assignment of a safety supervisor is not obligatory for a company of this size. Contact between a hand or a tool and a charged object accounts for 58% of all fatal accidents.

The next analysis after the period from 2002 to 2011 was focused on that from 1997 to 2001 of 175 case studies [35]. The reason is that the detailed analysis of past case studies is necessary for considering new preventive measures for the electrically fatal accidents. The detailed consideration may lead to the revision of the ISHA and ISHR. The results of the case studies from 1997 to 2001 show that the electrically fatality rates are 0.047 to 0.063. The mining industry in 1997-2001 shows an electrical fatality rate of 0.69, which is the highest rate among all industries in Japan. The second highest electrically fatality rate is the construction industry with and electrical fatality rate of 0.31, and the third highest rate is found in the fishery industry with a rate of 0.074.

This paper reports the detailed analysis of 190 case studies from 1992 to 1996. The detailed analysis for the period is needed because the analysis has not been performed. The results of the analysis would be useful for us to consider the cause of the electrically fatal accident. The difference between the case studies for the period of 1992-1996 and those for 1997-2011 is that there is no electrically fatal accident for the mining industry in former period. The highest electrical fatality rate is 0.36 for the construction industry and the second highest rate is 0.056 for the manufacturing industry. The average size of the workforce from 1992 to 1996 is 64,564,000 for all industries. The electrical fatality rates for the period are 0.048 to 0.068. The range of the electrical fatality rates from 1992 to 1996 is similar to that from 1997 to 2001. The electrically fatal accidents for companies smaller than 50 workers is 75% of all of the fatal accidents. Moreover, the electrically fatal accidents of fewer than 30 workers are 65% all of the fatal accidents for the period. A company size of fewer than 30 workers is not required for an overall safety and health controller. Thus, the prevention of the electrically fatal accidents is important for a company size of fewer than 30 workers and 50 workers. The results of this detailed analysis will be useful for such applications as considering new preventive measures of the electrically fatal accidents and proposing the revision of the regulation.

Data for Detailed Analysis of Electrically Fatal Accidents

All of the electrically fatal accidents in this work occur in Japan. The data of annual electrically fatal accidents is reported from the Ministry of Health, Labour and Welfare (MHLW) [36]. In this study, the detailed analysis of the electrically fatal accidents is performed from data of MHLW. The data of workers (number of workforce) for each industry from the Ministry of Internal Affairs and Communications (MIC) is used for obtaining the electrical fatality rate.

Trend of Electrically Fatal Accidents

Figure 1a shows the electrically fatal accidents from 1959 to 2015 in Japan. The electrically fatal accidents of U.S. [37] and Australia and New Zealand [38] are plotted in the figure. Most of the electrically fatal accidents are caused by electric shock in Japan. The highest number of electrical fatalities was 482 in 1961 for the period. Since 1961, the ISHA and ISHR etc. established preventive measures against fatal incidents. The replacement of distribution lines with insulated cables begin in 1965. The installation of earth leakage current circuit breakers was required in 1969. The establishment of some acts and regulations and some preventive measures are contributed to reduce electrically fatal accidents in Table 1. The electrically fatal accidents have decreased since 1961. The lowest number of electrical fatalities was 5 in 2013. The number of electrically fatal accidents in 2013 is 1% of that in 1969. We can say that the establishment of such acts and regulations overall contributes to keep the trend of the decrease of the electrically fatal accidents. However, there has never been zero fatalities in a year. The number of electrically fatal accidents were 15 in 2014 and 11 in 2015. Thus, the number of electrically fatal accidents have increased slightly since 2013. The total number of electrically fatal accidents was 7,615 from 1959 to 2015.

Year	Laws and acts	Establishment or the text
1964	The Electric Utility Industry Law	Establishment
1965	The Electric Installation Technical Standards	Establishment
1969	Ex-the Industrial Safety and Health Regulation	The obligation to a part of the installation of an earth leakage current circuit breaker
1972	The Industrial Safety and Health Act	Establishment
	The Industrial Safety and Health Regulation	

Table 1: Law and acts related to the prevention of electric shock

Figure 1b shows the electrical fatality rates from 1959 to 2015 in Japan. The electrical fatality rates of U.S. and Australia and New Zealand are plotted in the figure. Figure 1b is separated from Figure 1a because the number of workers is different every year. The electrical fatality rate is obtained from the following equation (1) [33-35,37].

Electrical fatality rate (fatalities per 100,000 workers)

$$= \frac{\text{Fatalities during a given year}}{\text{Employment (workforce)}} \times 100{,}000 \qquad (1)$$

In Figure 1b, the size of the workforce is obtained from data from the Ministry of Internal Affairs and Communications. The highest electrical fatality rate was 1.072 in 1961. The electrical fatality rate decreased since 1961. The lowest electrical fatality rate is 0.008 in 2013.

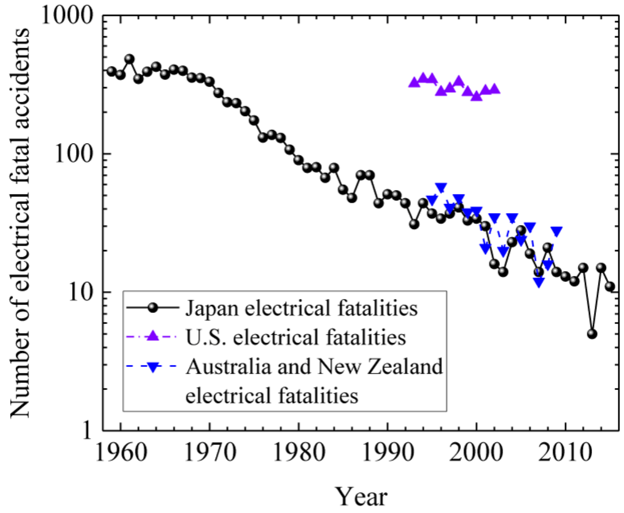

Figure 1a: Number of electrically fatal accidents, 1959-2015.

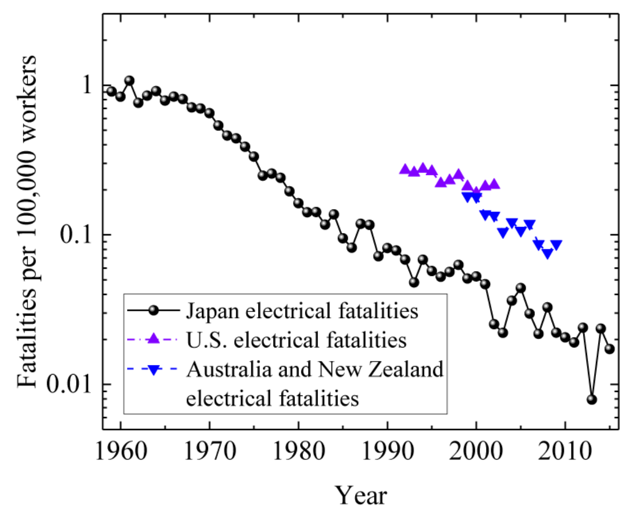

Figure 1b: Electrically fatality rate, 1959-2015.

Detailed Analysis of Electrically Fatal Accidents

Figure 2 shows the electrical fatality rate by company size for the workplace from 1992 to 1996. The value in the parenthesis shows the number of the electrically fatal accidents. The percentage of the company size of fewer than nine workers is 42%, and the electrical fatality rate for the company size is 0.025. The percentage of the company size of fewer than 30 workers is 65%, and the electrical fatality rate is 0.038. A company size of fewer than 30 workers is not required for an overall safety and health controller. The percentage of the company size of fewer than 50 workers is 75%, and the electrical fatality rate is 0.044. The electrical fatality rate decreases as the company size increases. The percentage for the company size of more than 50 workers is 25% of all of the company size. Thus, the electrical fatality rate for the company size of fewer than 50 workers, where a safety supervisor is not required, is higher than when a safety supervisor is required. The trend from 1992 to 1996 is similar to the analyzed results [34] from 2002 to 2011. Hence, we can say that an assignment of a safety supervisor is needed for not only more than 50 workers but also fewer than 50 workers. The author recommends the revision of a text of the ISHA would be needed for the prevention of the electrically fatal accidents by a company size of fewer than 50 workers.

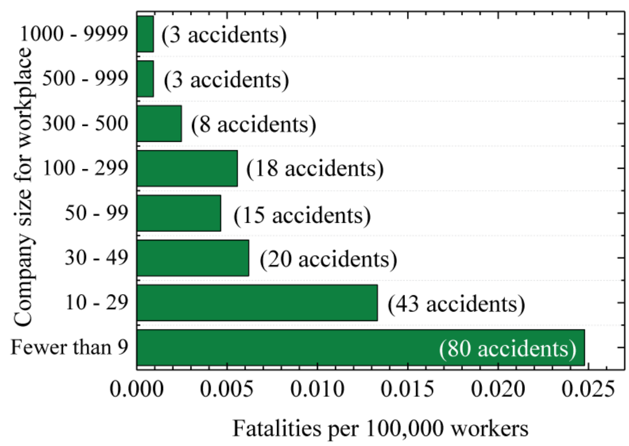

Figure 2: Electrically fatality rate by company size for workplace, 1992-1996. Value of parenthesis shows numbers of electrically fatal accidents.

Figure 3 shows the number of electrically fatal accidents by company size for each year from 1992 to 1996. The annual number of electrically fatal accidents shows the range of 14-20 accidents for the company size of fewer than nine workers. The annual electrically fatal accidents for the company size of 10-29 workers are 7-11. The annual electrically fatal accidents of the company size of fewer than 50 workers are 25-34. The percentages of the annual electrically fatal accidents to all of the fatal accidents show a range of 68% to 84% for the company size of fewer than 50 workers.

Figure 4 shows the electrical fatality rate by industry from 1992 to 1996. In the figure, the number in the parenthesis shows the number of electrically fatal accidents by industry. The electrical fatality rate for the construction industry is 0.36 and the number of electrically fatal accidents is 117 accidents. The percentage of electrically fatal accidents for the construction industry is 62% of all of the fatal accidents. The electrical fatality rate for the manufacturing industry is 0.056 and the number of electrically fatal accidents is 42 accidents. The percentage of the electrically fatal accidents for the manufacturing industry is 22% of all of the fatal accidents. Hence, the percentage of the electrically fatal accidents for both the construction industry and the manufacturing industry is 84% of all of the fatal accidents.

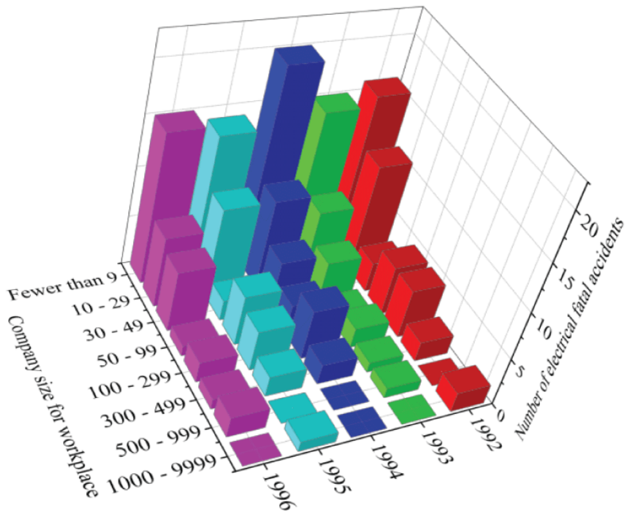

Figure 3: Electrically fatality rate by company size for each year, 1992-1996.

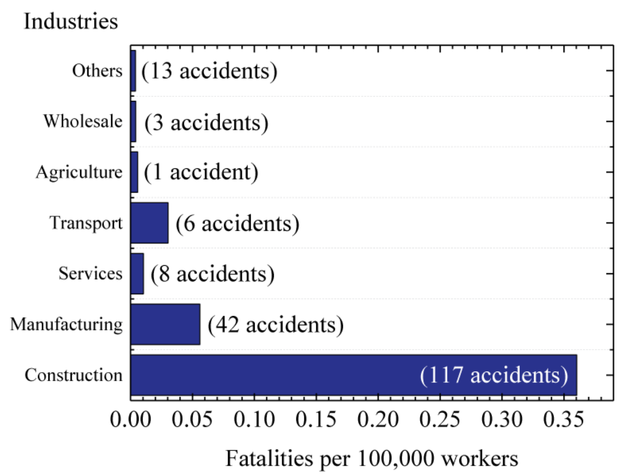

Figure 4: Electrically fatality rate by industry, 1992-1996.

Thus, for the prevention of electrically fatal accidents, both the construction industry and the manufacturing industry must be addressed so that fatal accidents can be reduced. If the prevention of electrically fatal accidents becomes possible, the goal would be to reduce the fatal accidents 25%, annually. The averaged workforce for the construction industry is 6,494,000 from 1992 to 1996 and the workforce is 43% of the manufacturing industry of 14,992,000. More electrically fatal accidents occur in the construction even though its workforce is smaller than the manufacturing workforce. The electrically fatal accidents for the construction industry contain the electrical construction industry and the industries related to electrical construction. The causes of the electrically fatal accidents for the construction industry are, for example, a conductive part touches a low, high, or extra-high voltage wire (live wire) and a part of a human body touches an energized conductor of a low voltage, a high voltage conductor, or power receiving equipment. This type of fatal accident indicates that the current preventive measures of electric shock are not sufficient. The ISHA is a safety standard for the workplace but there are areas that could improve for safer operation. The reason why many electrically fatal accidents in summer occur may be that there lapses in safety operations. Some workers occasionally use wet leather gloves and wet cotton gloves. A safety operation for the use of such gloves is not regulated though they could be a cause of an electrically fatal accident. The author recommends a regulation that leather gloves and cotton gloves not be used may be necessary to prevent electrical accidents though such regulation is not easy.

Table 2 shows an electrical installation when an electric shock occurs. In the table, 11 groups of the charged objects are used. The group I shows the group of handheld electric machines (e.g., electric sanders and grinders), group II of a rod and a body of an arc welding machine, group of III of live wires (low and high and extra-high voltages), group IV of trolley wires of overhead traveling crane or electric train, group V of the cubicle and power-receiving equipment, group VI of a switchboard and a control panel, group VII of an illuminator, group VIII of a transformer and a switchgear, group IX of an electric outlet, group of X of a lightning strike (thunderbolt), and group XI of the other electrical installation. Most of the electrically fatal accidents are caused by a touch between a part of the human body and a live wire (energized conductor). The number of fatal accidents is 82 by live wire. The percentage of electrically fatal accidents for group III is 43.2% of all of the fatal accidents. The second highest accidental type is a touch between a part of the human body and a transformer or switchgear. The number of fatal accidents for group VIII is 20 accidents and the percentage is 10.5% of all of the fatal accidents. The numbers of the electrically fatal accidents are 10 accidents (5.3%) for group II and 13 accidents (6.8%) for group IV and 12 accidents (6.3%) for group V, and 14 accidents (7.4%) for group VI.

Electrically fatal accidents occur in the following situations. When a worker is preparing an electrical installation, a part of the human body touches an uncovered charged (energized) object of switchgear of 6,600 V. When a worker cleans an insulator of a transformer of 77,000 V in an electrical substation, a part of the human body touches a charged object. A human body touches a pantograph of 1,500 V of an electrical train. When a crane is used for lifting a battery, a jib of the crane touches an extra high voltage wire (cable) of 22,000 V. When a worker uses an insulated rubber glove with a hole opened by a knife, a hand in the rubber grove touches a high voltage wire of 6,600 V. When a worker sets up a sign for a live wire, a human body touches an extra high voltage wire of 66,000 V. When maintenance of an electrical installation is performed, a part of the human body touches a charged object in a cubicle. A human body touches a charged object of a disconnecting switch though the switch is turned off when a worker is cleaning or a maintaining operation of a transformer of 6,600 V. A thunderbolt hits a human body under a tree. When a worker replaces old parts of a laser processing machine with new parts, a part of a human body can touch a charged object of the machine. When the setup of a fire alarm is performed, a part of the human body touches a trolley wire of 220 V of a crane. When a charged wire of 200 V of a fluorescent bulb is connected to another wire, a part of the human body touches the charged wire. The human body touches a charged object of an electrical hand grinder of 100 V. When a worker does an arc welding operation for an assembling of a ship, a part of the human body touches a charged object of the arc welding machine. When a worker does not use an insulated rubber glove when operating a live wire on a utility pole, a part of the human body touches a charged wire. A stainless-steel rod that a worker uses on a roof of a house touches a power transmission line. When a worker adjusts a terminal of 250 V of a pendant switch for a lift, a screwdriver that the worker uses touches the terminal. When a worker uses wet clothes, the right arm of the human body touches a high voltage wire. When a worker squats down, the head of the human body touches a low voltage wire of 200 V. When a worker, for instance, cleans a switch gear, a duster touches a high voltage wire. When a repair of a water pump is performed, a leakage of electricity occurs.

Group	Electrical installation	Number of electrically fatal accidents	Percentage against all of electrically fatal accidents
I	Hand power tools	3	1.60%
II	Welding rod and body of an arc welding machine	10	5.30%
III	Energized conductors from low or high and extra-high voltage	82	43.20%
IV	Trolley wires of an overhead traveling crane or an electric train	13	6.80%
V	Cubicle and power receiving equipment	12	6.30%
VI	Switchboard or control panel	14	7.40%
VII	Lighting fixture	5	2.60%
VIII	Transformer, switchgear and capacitor	20	10.50%
IX	Electric outlet	1	0.50%
X	Lightning strike	3	1.60%
XI	Other electrical installation	27	14.20%
Total		190	100%

Table 2: Touched electrical installation and number of electrically fatal accidents.

A worker cuts a live wire of 6,600 V on a transformer with pliers without an insulating safeguard. A worker touches an uncovered electrical wire (energized conductor) of an electric bulb. When the cover of a live wire is melted by heat, a part of the live wire touches a scaffold. When a worker goes down a duct, a part of the human body touches a welding rod of an arc welding machine. When a worker takes a measurement, a leveling pole touches an extra high voltage wire of 20,000 V. When a worker checks a wiring condition, for example, a cut live wire touches a part of a human body.

Table 3 shows the electrical fatality rate by voltage class. The voltage class of the electrical installation is estimated from the data in the case studies. When a human body touches a charged object of 100 V, the electrical fatality rate is 0.007 and its percentage is 11.6% of all of the fatal accidents. The number of electrically fatal accidents for 100 V level is 22 accidents. On the other hand, the electrical fatality rate for the 200 V level is 0.017. The percentage for 200 V level is 28.9% of all of the fatal accidents. The number of electrically fatal accidents for the 200 V level is 55 accidents. The electrical fatality rate for when the voltage is not defined (uncertainty and other voltages) is 0.005. The number of electrically fatal accidents for when the voltage is not defined is 16 accidents, and it is 8.4% of all of the fatal accidents. As a result, the electrical fatality rate for low voltage is 0.029. The number of electrically fatal accidents for low voltage is 93 accidents and it is 48.9% of all of the fatal accidents. The electrical fatality rate for high voltage and extra-high voltage is 0.028 and the number of electrically fatal accidents for this voltage class is 91 accidents. The percentage for the high voltage and the extra-high voltage is 47.9% of all of the fatal accidents. The percentage for the low voltage is almost equal to that for the high voltage and the extra-high voltage. In Table 3, the definition of each voltage class is noted in Japan. There are three fatal accidents by thunderbolt. The uncertainty in the number of electrically fatal accidents is three accidents.

Voltage class		Number of electrically fatal accidents	Fatalities per 100,000 workers	Percentage against all of electrically fatal accidents
Low voltage ($V_0 \leq$ 600 V_{AC}, $V_0 \leq$ 750 V_{DC})	100 V level	22	0.007	11.60%
	200 V level	55	0.017	28.90%
	Uncertainly and other voltages (Voltage not identified)	16	0.005	8.40%
	Subtotal	93	0.029	48.90%
High voltage (600 $V_{AC} < V_0 \leq 7$ KV_{AC}, 750 $V_{DC} < V_0 \leq 7$ KV_{DC}) and Extra High voltage (7 KV_{AC} and $_{DC} < V_0$)		91	0.028	47.90%
Lightning strike (thunderbolt)		3	0.001	1.60%
Uncertainty Cause of death not identified		3	0.001	1.60%
Total		190	0.059	100%

Table 3: Voltage class and electrically fatality rate when electrically fatal accidents occur.

Figure 5 shows a breakdown of the contacted parts of the human body against a charged object when electrically fatal accidents occur. In the figure, the author classifies the contacted parts of the human body into eight parts. The classified parts of the human body are head, neck, shoulder, body, hand and tool, an arm and elbow, foot, and uncertain. The electrically fatal accidents are defined as contact with a hand or a tool when the fatal accidents occur by an operation. The reason is that a worker occasionally operates a live wire or a charged object with their hand or a tool. The results show that most of the electrically fatal accidents occur by hand or tool. The number of electrically fatal accidents by hand or tool is 136 accidents and its percentage is 72% of all of the fatal accidents. The second highest fatal accidents occur by a body part touching a charged object. The number of electrically fatal accidents for body parts is 27 accidents, and its percentage is 14% of all of the fatal accidents. The electrically fatal accidents by touch of the head, arm, elbow or a foot are four accidents each. The number of electrically fatal accidents is one accident by the touch of a neck and two accidents by the touch of a shoulder. The electrically fatal accidents where the determination is uncertain are 10 accidents, regardless of whether a hand of a human body touches a charged object, and these numbers are included in the uncertainty. The electrically fatal accidents of uncertainty are 12 accidents.

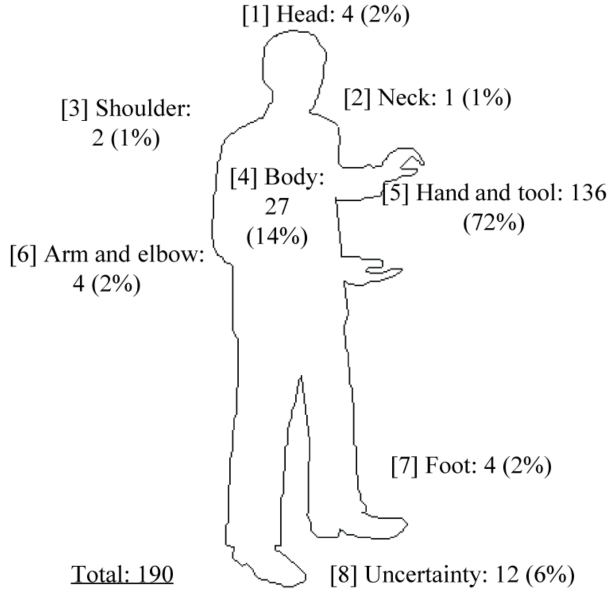

Figure 5: Contacted part of human body, 1992-1996.

Discussion and conclusions

Most of the electrically fatal accidents occur by electric shock [39-42] in Japan. When a human body touches a charged object of more than 35 V, a ventricular fibrillation occasionally occurs. Detailed analysis is needed for considering the prevention of electrically fatal accidents. However, detailed consideration has not been published by the use of case studies on electrically fatal accidents. In this study, detailed analysis from case studies of electrically fatal accidents is performed from 1992 to 1996 because the analysis for the period is needed.

Results show that the percentage of company size of fewer than 50 workers is 75% of all fatal accidents. The electrical fatality rate for a company size of fewer than 50 workers is 0.044. The reason why the percentage is high is that the assignment of a safety supervisor is not obligatory for the company size of fewer than 50 workers. We can say that the assignment of a safety supervisor is needed for reducing the electrically fatal accidents. Moreover, the percentage of the company size of fewer than 30 workers is 65%, and the electrical fatality rate is 0.038. A company size of fewer than 30 workers is not required for an overall safety and health controller.

The electrical fatality rate and number of electrically fatal accidents are high for the construction industry. These values for the construction industry are higher than those for the manufacturing industry. The reason is that the construction industry includes the electrical construction industry. Thus, the electrically fatal accidents for the construction industry include maintenance works and replacement works of an electrical installation, which is high or extra high voltage. Thus, when the electrically fatal accidents occur for maintenance works of electrical installation, the electrical fatality rate and the number of fatal accidents increase. A worker in the construction industry occasionally uses a leather glove and a cotton glove for low voltage. The leather glove and cotton glove do have not the dielectric strength of electrical insulation, especially when these gloves are wet. Hence, when these gloves are wet, the accident by electric shock can occur easily. Thus, the use of wet clothes is also harmful.

Most of the electrically fatal accidents occur when the human body touches an uncovered and charged (energized) object with a hand or a tool. The reason is that there are the problems with the use of a live wire and insufficient voltage checks. The preventive measures by the use of some insulating safeguards are not sufficient because there are electrically fatal accidents caused by deficiencies in insulating safeguards. The results are cleared from the detailed analysis of case studies.

The electrically fatal accidents for low voltage occur by the touch between a part of the human body and a charged object of 100 V level or 200 V level. The reason is that most of the working voltages of the electrical installations are 100 V level and 200 V in Japan. The percentage of electrically fatal accidents for low voltage is almost equal to that for high voltage and the extra-high voltage from 1992 to 1996. The causes of the electrically fatal accidents are that certain insulated safeguards are not sufficient. A worker occasionally uses wet gloves and wet clothes. A worker uses a screwdriver and cuts a live wire without a voltage check.

The thorough prevention of electrically fatal accidents by electric shock is not easy because the workforce exceeds 60,000,000 individuals. Thus, the preventive measures, including the use of insulating safeguards and safety training, are not sufficient to reduce electrically fatal accidents. A partial revision of the ISHA and the ISHR may be needed in order to decrease electrically fatal accidents. The results of this study will be helpful to consider electrical safety regulation and design insulating safeguards.

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