Journal of Biomedical Systems & Emerging Technologies

Ichikawa N et al., J Biomed Syst Emerg Technol 2018, 5:2

Editorial

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Human-Body Impedance and Electric Shock

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Received date: July 07, 2018; **Accepted date:** July 25, 2018; **Published date:** August 01, 2018

Abstract

The electric current of an electric shock can often cause death. There have been a total of 7,626 fatalities by electrocution in Japan between 1959 and 2016. The average internal human-body impedance has been measured to be 1,000 Ω in 60 human cadavers (male and female) and 500 Ω in live bodies. By accepting the cost of replacing voltage-distribution cables with insulated cables, electrical safety levels can be significantly increased. When handling a live wire with a low voltage using cotton gloves, electric shocks can be milder than when using bare hands. Wearing fully covering insulative clothing can also reduce the likelihood of electrocution in the summer heat. These results will be useful to prevent electrocution accidents.

Keywords Electric shock; Human-body impedance; Human body current; Electrical fatal accident

Introduction

The electric current of an electric shock can often cause death when it is orders of magnitude greater than normal physiological currents. Physiological processes in the human body sometimes involve microampere-level currents, whereas electric shocks can be at the milli ampere level. Electric currents in excess of 50 mA between the left hand and both legs can cause ventricular fibrillation, which can be fatal. Fatality by electric burns are rare in Japan (15 accidents occurred in 2014, 11 in 2015, and 11 2016, and a total of 7,626 fatalities in 1959-2016 due to electric shocks and lightning).

Electric-current flow in the human body is governed by its electrical resistance (impedance). Resistance measurements have been performed on cadavers, yielding an internal human-body impedance of 1,000 Ω, averaged over 60 real male and female cadavers. However, some of those bodies may have not a human head. The reason is that the data of the human head of the human body is insufficient. The internal impedance is lower in a living body (typically 500 Ω) than in a cadaver. Thus, the internal human body impedance of the living human body is used frequently. We can estimate the current through the human body, in terms of the body impedance, during an electric shock. Such estimations are crucial for understanding real accident conditions.

Electrocutions are very common and require new preventive measures. Present preventive measures are inadequate, as some fatal accidents occur even when wearing protective insulating gloves and applying insulating safeguard.

This paper reports a basic consideration of preventive measures for avoiding electrocution accidents. Handling electrical equipment is a little safer when wearing cotton gloves than when using bare hands. These results will assist in the development of new preventive measures.

Difference of Electrical Safety in Japan and U.S.A

The reason for the decrease in electrocution accidents can be attributed to the implementation of safety legislation and of the regulations of the Industrial Safety and Health Act and the Industrial Safety and Health Regulations established in 1972. The installation of earth-leakage-current circuit breakers has been required since 1969. Voltage-distribution lines with insulated cables carrying voltages less than 6,600 V have been used since 1965. The use of voltage-distribution lines with insulated cables is now ubiquitous in Japan. Electrocution-related fatalities occur more often in the U.S.A., where insulated cables are not used. Many such fatalities would thus be avoided by replacing voltage-distribution lines with insulated cables, as used in Japan. By accepting the cost of replacing the distribution cables with insulated cables, electrical safety standards can be significantly increased. Nonetheless, despite these guidelines, fatal electrocution accidents still occur when an unprotected part of the body touches an electrical component that is missing insulation.

Use of Cotton or Leather Gloves

Cotton or leather gloves may be worn when handling electrical equipment. The use of cotton or leather gloves is encouraged even when handling low-voltage equipment, as they provide some insulating protection when dry. Dry cotton gloves are as insulating as tissue paper but lose this property when they are wet, for example as a result of perspiration, which decreases protection against electric shocks. Fatal accidents may thus occur, for example when cutting a live wire with a metallic cutting tool while wearing cotton or leather gloves. Such accidents can be prevented by wearing insulating rubber gloves instead.

The numbness experienced during an electric shock from a low-voltage live wire while wearing cotton gloves can be weaker than when using bare hands. The electric shock is reduced when grasping a live and a grounded wire.

Human body currents					
100 V	200 V	240 V	400 V	3300 V	6600 V
200 mA	400 mA	480 mA	800 mA	6.6 A	13.2 A

Table 1: Current through the Human Body as a Function of Voltage.

Simultaneously by hand with a wet cotton glove. This is because a cotton glove made moist by perspiration has a lower electrical resistance. The reduction of an electric shock by a wet cotton glove would reduce the electric current within the hand. When a constant current of a few milliamperes flows in the hand, the electric shock reduction effect appears occasionally when using wet cotton gloves. We can say that the electric shock reduction effect when using wet cotton gloves does not appear when the electric current flows between a hand and a foot.

Current through the Human Body in an Electric Shock

The internal impedance of the living human body is 500 Ω, whereas skin impedance varies with the contact voltage. On the other hand, the average internal body impedance of a cadaver is 1,000 Ω. Voltages of 100, 200, 240, 400 (415), 3,300, and 6,600 V for less than distribution lines with insulated cables are used for the electrical installation. Electric-shock accidents can occur when cutting or replacing a live wire carrying such voltages. Assuming a human body impedance of 500 Ω, the resulting body currents are as shown in Table 1.

Table 1 lists the currents that would traverse a body under the above conditions, assuming a body impedance of 500 Ω. Perspiration lowers the skin impedance to almost zero in summer. Ventricular fibrillation can occur with a probability of more than 50% when a current of 200 mA lasts for 2 s. In summer, a 100 V shock is most probably fatal.

Preventive Measures

When in contact with a charged component of an electrical installation, severe body reactions can be avoided by preventing current flow. This is an important consideration, given that insulating safeguards are not always properly applied. Electrical installations are sometimes handled using bare hands, without wearing insulating gloves. Using cotton gloves is already safer than bare hands but electrocutions can occur nonetheless. Cotton gloves thus provide incomplete protection.

Cutting a live wire using a metallic tool (e.g., nippers) while wearing cotton gloves can lead to fatal accidents. It is therefore essential to use insulated tools, such as ceramic cable cutters, even when wearing cotton gloves.

Wearing fully covering insulating clothing in the summer strongly reduces the likelihood of electrocutions. It is common to wear light clothing (short sleeves and T-shirts) in summer, but this presents a significant risk of accident when handling electrical installations for maintenance or replacement.

When cleaning high-voltage equipment (e.g., transformers) using waste cloth, appropriate tests must be performed with an electroscope by a safety supervisor or a specialist in electrical and electronic engineering before cleaning can commence. Fatal accidents can occur during the cleaning of high-voltage equipment. Voltage checks of the equipment and an insulator are therefore important.

During a thunderstorm, it is habitual to interrupt work on a construction site and for workers to retreat to the safety of a metallic enclosure (e.g., a car) or a house.

When opening the cover of a pendant switch in a crane, care must be taken to avoid touching any charged component using bare hands. Likewise, electrical devices should not be replaced using bare hands but by wearing cotton gloves or insulating rubber gloves.

Conclusion

Insulating rubber gloves are not occasionally used by workers, and even cotton or leather gloves are not always used. Most fatal electrocution accidents occur when appropriate insulating rubber gloves are not used or insulating safeguards are not applied. When such precautions are not taken, it is a matter of chance whether accidents can be fatal.

The likelihood of fatal electrocution accidents from voltage-distribution lines is less in Japan than in the U.S.A. owing to the use of insulated cables everywhere in Japan. The numbness experienced during an electric shock when using cotton gloves can be weaker than when using bare hands, when a live wire and a grounded wire are grasped simultaneously. Insulated tools, such as ceramic cable cutters, must be used by workers when cutting a live wire. Handling electrical equipment while wearing light sleeveless clothing should be avoided in the summer. These precautions will help to prevent electrocution accidents and are important from the view point of biomedical systems and emerging technologies.