Safety First – The Splendiferous Cliché against Electrical Hazard: Discourse on the distaff side

FADARE[1], Suraju Adebayo and ADETONA[2], Zacchaeus A.
Electrical Engineering Department
Federal Polytechnic, Ilaro
Ogun State, Nigeria.
[1]asfadare@yahoo.co.uk, [2]zachadetona@gmail.com
Phone: Fadare: 08167718894; Adetona: 08157562049

ABSTRACT
The mind of an engineer should be fraught with the cliché - 'Safety First' - as he or she involves in all engineering activities, evolving from idea conception to implementation or final production. This paper does not contest the fact that electrical hazard can affect anybody that his or her body forms part of an electrical circuit. However, according to research, women have higher electrical body resistance than men and this fact has prompted the writing of this paper. The paper's aim is to create a splendid emphatic awareness for the electrical safety related-work practises policy makers and regulators, the entire female colleagues, students and electrical appliance users to the safety of their lives while working or using or passing by or standing by electrical appliances. The discourse is an in-depth tutorial on electric hazard with emphasis on the female gender.

1 INTRODUCTION

Electricity is a utilitarian co-worker but it can change to a hazard in a trice, in a manner that cannot be easily fathomed until it is experienced (Cadick, Cappelli-Schellpfeffer, & Neitzel, 2006). In fact, electricity has become indispensable in our daily life that we tend to overlook the hazards it poses and fail to treat it with the respect it deserves (OSHA[1], 2005). Electric hazards are often present in all our work areas, hence, both electrical and non-electrical workers are often exposed to the hazards (EFCOG[2], 2006). Therefore, the important engineering cliché- 'Safety First'- should not be underestimated when dealing with electricity.

Electric hazard can be classified into three types – electric shock, electric arc and electric arc blast (Cadick, Cappelli-Schellpfeffer, & Neitzel, 2006). The most common hazard out of the three hazards mentioned is the electric shock. It is related to the electrical body resistance of the victims. The body resistance of female is larger than that of their male counterpart (Fish, Geddes, & Babbs, 2003). Hence, in accordance to the Joule's law, the same amount of current can cause larger hazardous effects in women than men.

In 2007, at the fiftieth anniversary of Independent Electrical Contractor (IEC) in USA, Bruce Bowman presented a table that compares effect of electric current on man and woman

[1] OSHA (the Occupational Safety and Health Administration) is a part of the US Department of Labor that establishes, issues, and enforces national workplace safety regulations
[2] EFCOG stands for Energy Facility Contractors Group

which also shows the fact that women have greater tendency to experience electric shock than men (Bowman, 2007). Consequently, there should be a specific awareness to the female folk about the electric hazard so that both female electrical and non-electrical workers will ensure their own safety when relating with electricity in any form. Furthermore, policy makers, electrical workers association, insurance companies and other organisations that attach importance to electrical hazard safety should espouse the idea of establishing electrical safety procedure and law protecting the female against the menace of electrical hazard. This issue can be achieved by first educating the people about the specific effects of electricity on female which is the utmost objective of this paper.

2 ELECTRICAL HAZARD

Several works consulted categorise electric hazard into three. For instance, Cadick, Cappelli-Schellpfeffer, & Neitzel categorised electric hazard to electric shock, electric arc and electric arc blast (Cadick, Cappelli-Schellpfeffer, & Neitzel, 2006) and Dennis K. Neitzel affirmed this categorisation in his work- *Establishing Electrical Safety Program* (Neitzel, 2006). Bruce Bowman classified electric hazard to electric shock, arc flash and blast, and fire ignition (Bowman, 2007). Inside the study guide provided by EFCOG Electrical Safety Improvement Project, electric hazard was categorised into electrical shock, electrical burn and blast (EFCOG, 2006). Studying the section 2 of Nigeria Electricity Health and Safety Standards Manual, electrical hazard is divided into electric shock, flash and blast.

However, they all agree that electric shock to be the first category while discrepancy exists in the second and third category. For clarity purpose, these terms used for the categorisations will be described. Electric shock can be defined as electrical accident that occur when the victim's body make contact with an electrical circuit and connects two points of the circuit with different electrical potential together thereby allow current to pass through the body (Kuphaldt, 2006; EFCOG, 2006). It takes a very low value of current that passes through the victim's body to cause death or permanent physical damage of human body (Neitzel, 2006). According to EFCOG and supported by other texts on electrical safety, before electrical shock could occur, a combination or any of these three conditions must happen (Neitzel, 2006; Cadick, Cappelli-Schellpfeffer, & Neitzel, 2006; Kuphaldt, 2006):

- The victim's body provides electrical connection between two conductors in the circuit.
- The victim's body provides a path between ungrounded electrical live conductor and ground.
- The victim's body provides electrical path between the ground and a conducting material that is having an electrical connection with an ungrounded electrical circuit.

When any of the above conditions is established, electric current is made to pass through the victim's body causing damages to his/her tissues and muscles, especially the heart muscles. This can result in a total or partial paralysis or death of the victim. Electric shock does the most damage to the chest cavity or brain. Fatal ventricular fibrillation of the

heart (stopping of rhythmic pumping action) can result from the flow of current as little as several milliamperes (mA). Nearly instantaneous fatalities can result from either direct paralysis of the respiratory system, failure of the rhythmic pumping action of the heart, or immediate heart stoppage. Other injuries that can occur include severe injuries, such as deep internal burns, even if the current does not pass through vital organs or nerve centers.

Once electrical shock occurs, electrical energy as determined by Joule's Law will be converted to other forms of energy such as heat which may cause severe damage or malfunction of the body (Cadick, Cappelli-Schellpfeffer, & Neitzel, 2006).

The law is as follows,

$$E = I^2Rt \quad (1)$$

where E= Energy in Joules (J)

I= Current in Amperes (A)

R= Resistance of the current path through the body in ohms ($\boldsymbol{\Omega}$)

t = Time of current flow in seconds (s).

Therefore, severity of the electric hazard relies on the amount of current, the body resistance of the victim and the period the current flows through the victim (Merck Sharp & Dohme, 2009; Kuphaldt, 2006; Cadick, Cappelli-Schellpfeffer, & Neitzel, 2006; EFCOG, 2006). The damage to the body of the person is due to energy *E*, dissipated in form of heat in the body. Thus, female victim will receive more damage as indicated in eqn. (1) due to higher body resistance since higher *R* means higher *E* in the equation.

3 ELECTRICAL HAZARD ON THE DISTAFF SIDE

Electric hazard to the female victim is more pronounced than to the male counterpart. Some previous works have been able to establish this scientifically. Bruce Bowman pointed out the discrepancy in the effect of electric hazard between man and woman through the table adapted from the work of Ray A. Jones in his text –Electrical Safety in the Workplace. For clarity, the table is reproduced as shown in Table 1 (Bowman, 2007).

Fish, Geddes, & Babbs, (2003) also expatiated on this issue by throwing more light on the physiological theory of electrical hazard. He affirmed that resistance goes up with length and down with diameter. Since men tend to have thicker arms and legs (more muscle), they usually have lower resistance. An implication of this is that the lethal current for men is higher than that for women (Fish, Geddes, & Babbs, 2003). Hence, women have higher resistance than men.

Furthermore, within the body, the tissues with the greatest resistance are bone and fat - nerves and muscle have the least resistance. That said, the majority of the body's resistance is in the skin - the dead, dry cells of the epidermis (the skin's outer layer) are very poor

conductors (Fish, Geddes, & Babbs, 2003). Generally, women have more fat in their bodies than men. Therefore, fat women have higher resistance than others.

Another point to be considered is the skin. Women that bleach their body are reducing or removing the thickness of their outer skin and lowering their outer-skin resistance simultaneously. Body resistance (measured in ohms/cm^2) is provided primarily by the skin. Therefore, these women are making their body a conductor of electricity (Merck Sharp & Dohme, 2009).

Kuphaldt also contributed to the fact that men and women have different experience on electric shock hazard. The current that can cause hazard in women is lesser than that of men (Kuphaldt, 2006). The approximate values of these hazardous current values in the table were derived through tests. However animals were used carryout the fibrillation test because of its dangerous nature to human being (Kuphaldt, 2006) and probably, that is the reason for having the value to be equal for both men and women). This is summarized in Table 2.

As seen on Table 2, a d.c. current of 1mA will have a slight sensation in men while the current to produce equivalent results in women is 0.6mA. At a frequency of 60Hz, the values are 0.4mA and 0.3 mA for men and women respectively. As the current increases different feelings ensued in a victim ranging from real perception of the flow of current to severe damage to the body of the victim and possible heart fibrillation. For instance at 76/51mA d.c. or 16/10 5mA at 60Hz respectively for men and women, the victim is unable to break his/her contact with the live electrical conductor. This is categorized as "Painful, unable to let go of wires" on the table.

When the current is increased up to 500mA d.c. or 100mA a.c. for up to 3 seconds contact, the victim suffers from severe heart fibrillation, that is, failure of the rhythmic pumping action of the heart occurs. In all, the level of current that causes a specific damage to the victim's body is significantly lower in female than in male victims. It should be noted that some livestock were used to test for the last item on the table where possible heart

Table 1: Comparison of Effects of Electric Current on Man's and Woman's Body (Bowman, 2007)

Electric Hazard Effect	**Man**	Woman
Perception Threshold	1mA	0.7mA
Painful Shock	9mA	6mA
Current Let-Go Level	10mA	10mA
Ventricular Fibrillation	100mA for 3 Seconds Exposure 200mA for 1 Seconds Exposure	100mA for 3 Seconds Exposure 200mA for 1 Seconds Exposure

Heart Failure	500mA	500mA
Organ Burn and Cell Breakdown	1500mA	1500mA

fibrillation after 3 seconds was reported to occur at the same level of current both in male and female victims.

Table 2: Bodily Effect of Current on Men and Women (Kuphaldt, 2006)

BODILY EFFECT		DIRECT CURRENT (DC)	60 Hz AC	10 KHz AC
Slight sensation felt at hand(s)	Men	1.0 mA	0.4 mA	7 mA
	Women	0.6 mA	0.3 mA	5 mA
Threshold of perception	Men	5.2 mA	1.1 mA	12 mA
	Women	3.5 mA	0.7 mA	8 mA
Painful, but voluntary muscle control maintained	Men	62 mA	9 mA	55 mA
	Women	41 mA	6 mA	37 mA
Painful, unable to let go of wires	Men	76 mA	16 mA	75 mA
	Women	51 mA	10.5 mA	50 mA
Severe pain, difficulty in breathing	Men	90 mA	23 mA	94 mA
	Women	60 mA	15 mA	63 mA
Possible heart fibrillation after 3 seconds	Men	500 mA	100 mA	
	Women	500 mA	100 mA	

4 SAFETY OF WOMEN UTMOST CONSIDERATION

Several occupational safety and health investigations have documented a lot of fatalities arising from unawareness of electrocution hazard by the victims (NERC[3], 2008). It has really been shown that women are more vulnerable to electric shock and arc than men. Female social and biological characteristics are great factors that increase the electrical hazard vulnerability of women. Therefore, these factors must also be put into consideration when meeting the safety procedure for protecting them against all form of electrical hazards earlier mentioned in section 2. Safety procedure plies the guidelines for safely working around the electrical hazards (NERC, 2008; EFCOG, 2006). Safety is the only thing that is of personal concern in electrical power system (Cadick, Cappelli-Schellpfeffer, & Neitzel, 2006). Therefore, personal social and biological attributes of women should be taken into cognisance while preparing safety procedure for electrical work that will involve them.

Women should also know that that safety is personal matter because it is a matter of life and death (Cadick, Cappelli-Schellpfeffer, & Neitzel, 2006). They should think of their safety always while working in an electrical hazardous environment. They should not allow any issue to distract their attention. They should insist on getting the electrical work procedure and strictly obey it to the letter. Apart from the safety work procedure, before commencement of any work, they should request for job briefing and update from their supervisor or the team leader so as to know purview of the work area and limit the level of the exposure to electric hazard. In addition, women as well as men alike should not work alone on a live electric circuit. If one must work with energized circuits or equipment over 50 volts peak, make sure that at least one other person can see you and hear you.

Electrical safety is for everyone because even contact with the standard 220 volt electrical circuits, which we constantly use, can be lethal under certain conditions. In addition to other general safety rules the following safety precautions should be observed by the female folk:

i. Be familiar with the work to be performed and the safety procedures involved.
ii. Avoid wearing jewelleries while handling or working on live electrical circuits or equipment.
iii. Shun the practice of bleaching your skin. It increases the risk of electric shock.
iv. Any questions about work safety should be brought to the attention of your immediate supervisor or instructor. If problems arise that cannot be solved at this level, you should contact your supervisor or Safety Officer.
v. When appropriate, use special female safety equipment and wears such as shoes, gloves, etc.
vi. Be aware of the amount of current in a circuit you are working on to determine the right safety equipment to be used.

[3] The Nigerian Electricity Regulatory Commission (NERC) is by Section 32 (1) (a) of the Electric Power Sector Reform (EPSR) Act, 2005 mandated to create, promote and preserve efficient industry and market structures and to ensure the optimal utilization of resources for the provision of electricity services.

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