Journal of Sustainable Development Studies
ISSN 2201-4268
Volume 9, Number 2, 2016, 267-289

Impacts of Electrical Hazards on Nigerian Construction Industries with a View to Provide Safety Measures- Case Study of Kaptron Technologies

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Abstract: Electrical hazard remains a global occurrence that plagues construction industries in Nigeria Electricity is one of the most common causes of fires, electric shocks, electrocutions and thermal burns in construction industries. Because electricity is a familiar part of our lives, it is often not treated with enough caution. As a result, an average of one worker is electrocuted on the job every day of every year during construction work. No one can replace a worker or loved one that has died or suffered an irreparable consequence of an electrical accident. Researchers are of the opinion that electrical safety in the construction sector is an indispensable component for economic development of the country. In the light of the above, this paper examines the impacts of electrical hazards on the Nigerian construction industries with a view to provide safety measures using Kaaptron technologies as case study. The amount of current the body can withstand, the time it takes a body to be electrocuted when in contact with electricity and risk analyses were issues considered in this study. This study also used a participatory appraisal technique whereby, the electrical engineers and technicians were made to identify the types and magnitude of electrical hazards they encounter in their daily lives. The overall study shows that tasks performed under wet conditions could draw current as high as 480mA and that a body of 500Ω resistance has just 0.2s to be electrocuted when in contact with a 120v supply. The risk analysis revealed that 6 out of 10 construction devices were not safe to work on. Safety measures to eliminate injuries or deaths at construction sites were proffered.

Keywords: Electrical hazard, construction, safety, electric current, voltage.

INTRODUCTION

Our world is filled with overhead power lines, extension cords, electronic equipment, outlets and switches. Our access to electricity has become so common that we tend to take our safety for granted. We forget that one frayed power cord or a puddle of water on the floor can take us right into the electrical danger zone and that it doesn't take a lot of electricity to kill. In fact, the amount of current needed to light an ordinary 60-watt light bulb is 5times what can kill a person. Thus, all electrical equipment in construction sites is potentially deadly. An electrical hazard is therefore a dangerous condition where a worker makes electrical contact with energized equipment or a conductor. Electrical Safety in the workplace is the most important job of an electrical worker. No matter how much training one has received or how much employers try to safeguard their workers, Electrical Safety is ultimately the responsibility of the electrical worker. The human factors associated with electrical accidents can be immeasurable. No one can replace a worker or loved one that has died or suffered the irreparable consequences of an electrical accident. Most accidents can be prevented by taking simple measures or adopting proper working procedures. If we work carefully and take appropriate safety measures, there will definitely be fewer work injury cases, and our sites will become a safe and secure place to work in.

Figure 1.0: A photograph showing an electrical worker rectifying fault on a high tension wire

Defective or misused electrical equipment is a major cause of electrical hazards [2]. Whenever you work with power tools or on electrical circuits, there is a risk of electrical hazards, especially electrical shock. Anyone in the construction sector can be exposed to these hazards. Workers are exposed to more hazards because jobsites can be cluttered with tools and materials, fast-paced, and open to weather. Risk is also higher at work because many jobs involve electric power tools. Electrical trade workers must pay special attention to electrical hazards because they work on electrical circuits. Coming in contact with an electrical voltage can cause current to flow through the body, resulting in electrical shock and burns [3]. Serious injury or even death may occur. As a source of energy, electricity is used without much thought about the hazards it can cause. Because electricity is a familiar part of our lives, it is often not treated with enough caution. As a result, an average of one worker is electrocuted on the job every day of every year. Electrocution is the second leading cause of work-related deaths among other causes in the construction industries in Nigeria. According to the electrical safety authority in Nigeria, there were 120 electrocutions in Nigeria from 2000 through 2012 and that the most common cause of occupational electrocution is using improper procedures [5].

In electrical installations, the black wires and the red wires are at 220 volts. The white wires are at 0 volts because they are connected to ground. The connection to ground is often through a conducting ground rod driven into the earth [10]. If you come in contact with an energized black wire and you are also in contact with the neutral white wire, current will pass through your body. You will receive an electrical shock. If you are in contact with a live wire or any live component of an energized electrical device and also in contact with any grounded object you will receive a shock. Wet clothing, high humidity and perspiration also increase your chances of being shocked. Of course, there is always a chance of shock, even in dry conditions. Whenever two wires are at different voltages, current will pass between them if they are connected. The body can connect the wires if it touches both of them at the same time thereby allowing current to pass through You can even receive a shock when you are not in contact with an electrical ground. Contact with both live wires of a 240-volt cable will deliver a shock. (This type of shock can occur because one live wire may be at +120 volts while the other is at –120 volts during an alternating current cycle—a difference of 240 volts.) [9] You can also receive a shock from electrical components that are not grounded properly. Even contact with another person who is receiving an electrical shock may cause you to be shocked.

Figure 1.1: A photograph showing an electrocution due to contact with live wires

Another common cause of electrical hazard in construction companies is arcing fault. An arcing fault is the unintended flow of current through a medium not intended to carry the current [6]. That just means that the electricity is flowing through something it should not be; in most cases that result in injury, the medium was the air. The air becomes like a piece of copper, conducting the electricity; only with the air, you can see the massive discharge of the electrons from the discharging element. The most common causes of an arcing fault are equipment failure, human error (improper placement of tools or improper use of equipment), or the conduction of electricity due to foreign particles in the air (usually metal shavings).

Wearing personal protective equipment is necessary in reducing injury from electrical arc flash accidents, but it is no substitute for proper safety training, among other best practices in arc safety. Every day, electrical arc flash accidents injure or kill, but wearing proper personal protective equipment (PPE) minimizes accident frequency and severity. PPE alone, however, is no substitute for thorough safety training, consistently following lockout/tag out procedures, keeping electrical equipment well-maintained, and applying engineering controls.

Burns are not the only risk. A high-amperage arc produces an explosive pressure wave blast that can cause severe fall related injuries.

Figure 1.2: A photograph showing an explosion when rectifying a fault.

Studies of patients at Lagos University Teaching hospital (LUTH) burn section found that the majority of patients reporting with electrical burns were injured while working [5]. Cases of electrical burns compiled by American Burn Association reported in 2015 showed that 74% of electrical burns with known injury circumstances from 2010-2014 were work-related [4]. Data published by the Nigerian Institute of Statistics indicate that 480 workers suffered fatal injuries due to contact with electrical current from 2009-2013, which would represent 64% of the 748 injuries recorded. According to the Nigeria Consumer Product Safety Commission, an estimated 60,000 construction site fires of electrical origin occurred between 2011 and 2014, claiming 950 lives and injuring 2,400 people [5]. The Federal Ministry of Labor and Productivity Inspectorate Division (FMLPID) conducted a study of workplace electrocutions which revealed that 73 % of the workers had a high school education, 30% had less than one year of experience on the job to which they were assigned at the time of the fatal accident while 47% of the victims had some type of safety training, according to their employers [2]. Data gathered by Nigerian bureau of statistics show that 97% of all electricians have been shocked or injured on the job, the total costs per electrical incident exceeded $15 million, Approximately 30,000 workers receive electrical shock yearly and that total costs per electrical incident exceeded $4 million for severe burns.

LEADING INDUSTRIES AND OCCUPATIONS IN WHICH ELECTRICAL FATALITIES OCCUR FROM 2013-2014.

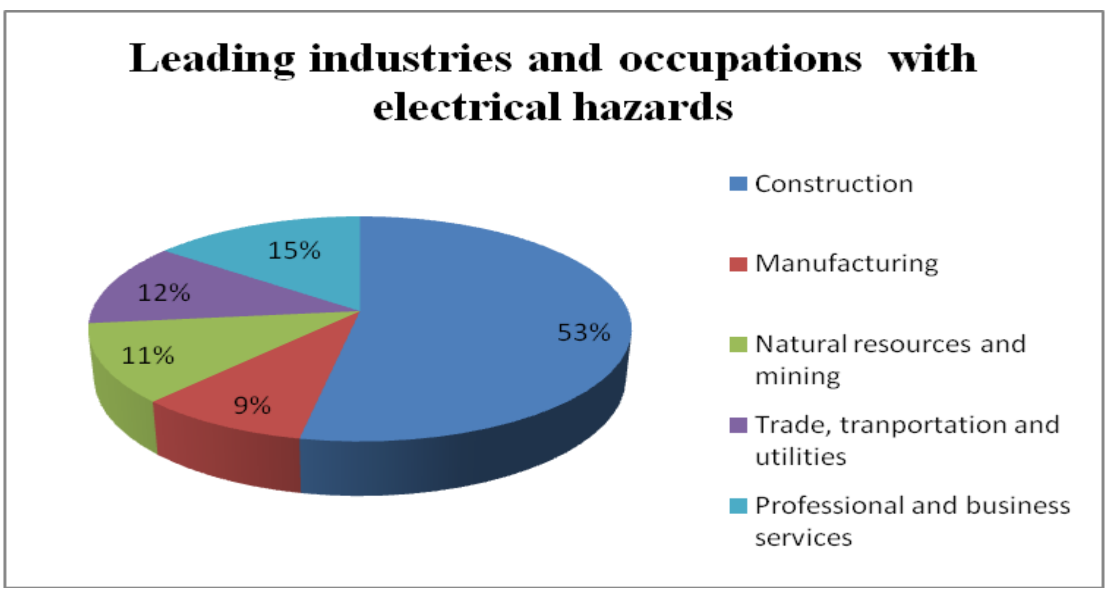


Figure 1.3: Leading industries and occupations with electrical hazards

CURRENT AND ITS EFFECT ON THE HUMAN BODY

Table 1.0: Based on the research of Professor Dalziel of the University of California, Berkeley, the effect of 50 Hz (cycles per second) of alternating current on the human body [7]

AMOUNT OF CURRENT FLOW	EFFECTS ON THE BODY
1 milliamp (mA) or less	no sensation—not felt
3 mA or more	painful shock
5 mA or more	local muscle contractions
30 mA or more	breathing difficult—can cause unconsciousness
50–100 mA	possible heart ventricular fibrillation (, rapid, uncoordinated contractions of the ventricles of the heart resulting in the loss of synchronization between the heartbeat and the pulse beat)
100–200 mA	certain heart ventricular fibrillation
200 mA or more	severe burns and muscular contractions—heart more apt to stop than fibrillate
Over a few amps	irreversible body damage

This condition is more likely to occur at voltages above 600 volts AC. For example, if a person contacted 10,000 volts, I = 10,000/1,000 = 10 amps. This amount of current would create a great amount of body heat. Since the body consists of over 60 percent water, the water would turn to steam at a ratio of approximately 1 to 1,500. This would cause severe burns or exploding of body parts. Accidents involving mobile vertical scaffolding or cranes booming up into power lines can cause these types of injuries or fatalities.

The route that the current takes through the body affects the degree of injury. If the current passes through the chest cavity (e.g., left hand to right hand), the person is more likely to receive severe injury or electrocution; however, there have been cases where an arm or leg was burned severely when the extremity came in contact with the voltage and the current flowed through a portion of the body without going through the chest area of the body. In these cases the person received a severe injury but was not electrocuted.

Figure 1.4: Harzard spotting during an electrical work

DANGERS OF ELECTRICAL SHOCK

The severity of injury from electrical shock depends on the amount of electrical current and the length of time the current passes through the body. For example, 0.1A of electricity going through the body for just 2 seconds is enough to cause death. The amount of internal current a person can withstand and still be able to control the muscles of the arm and hand is less than 10 mA. Currents above 10 mA can paralyze or “freeze” muscles. When this “freezing” happens, a person is no longer able to release a tool, wire or other object. In fact, the electrified object may be held even more tightly, resulting in longer exposure to the shocking current. For this reason, hand-held tools that give a shock can be very dangerous. If you can't let go of the tool, current continues through your body for a longer time, which can lead to respiratory paralysis. You stop breathing for a period of time. People have stopped breathing when shocked with currents from voltages as low as 49 volts. Usually, it takes about 30 mA of current to cause respiratory paralysis.

Currents greater than 75 mA cause ventricular fibrillation (very rapid, ineffective heartbeat). This condition will cause death within a few minutes unless a special device called a defibrillator is used to save the victim. Heart paralysis occurs at 4 amps, which means the heart does not pump at all. Tissue is burned with currents greater than 5 amps [8].

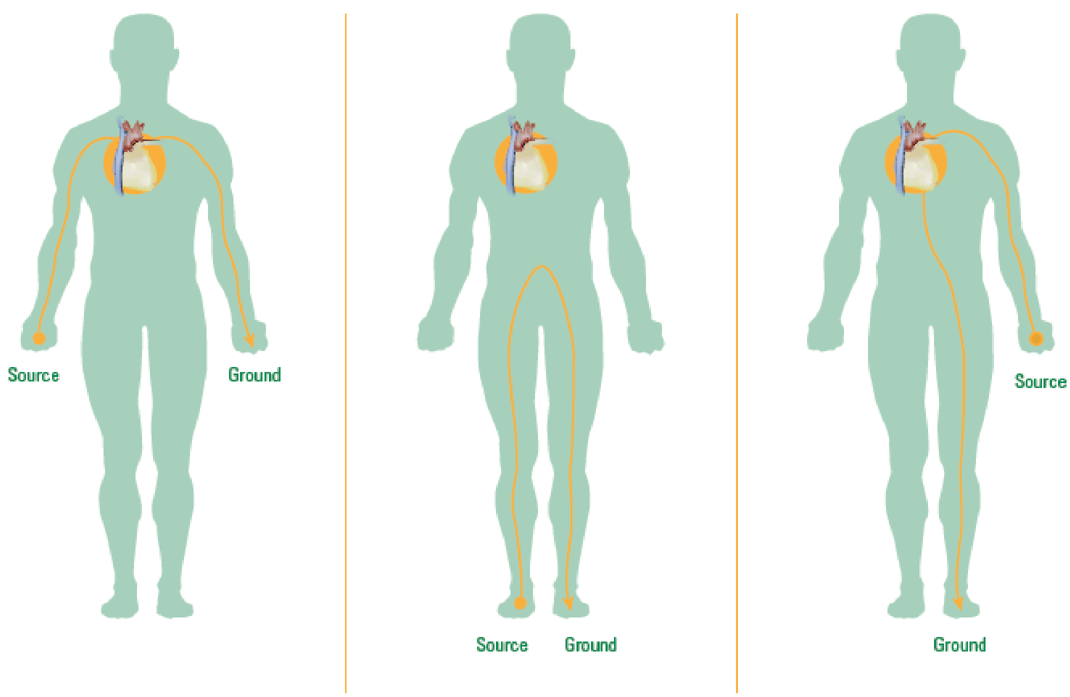
Greater voltages produce greater currents. There is greater danger from higher voltages. Resistance hinders current. The lower the resistance, the greater the current will be. Dry skin may have a resistance of 100,000 ohms or more. Wet skin may have a resistance of only 1,000 ohms. Wet working conditions or broken skin will drastically reduce resistance.

The low resistance of wet skin allows current to pass into the body more easily and give a greater shock. When more force is applied to the contact point or when the contact area is larger, the resistance is lower, causing stronger shocks [7].

ELECTRIC CURRENT PATHWAYS THROUGH THE BODY

The path of the electrical current through the body affects the severity of the shock. Currents through the heart or nervous system are most dangerous. If you contact a live wire with your head, your nervous system will be damaged [1]. Contacting a live electrical part with one hand while you are grounded at the other side of your body- will cause electrical current to pass across your chest, possibly injuring your heart and lungs. There are three basic pathways electric current travels through the body; *1)* Touch Potential (hand/hand path) *2)* Step Potential (foot/foot path) *3)* Touch/Step Potential (hand/foot path).

- In a touch potential contact, current travels from one hand through the heart and out through the other hand. Because the heart and lungs are in the path of current, ventricular fibrillation, and difficulty in breathing, unconsciousness, or death may occur.
- In a step potential contact, current travels from one foot through the legs, and out of the other foot. The heart is not in the direct path of current but the leg muscles may contract, causing the victim to collapse or be momentarily paralyzed.
- In a touch/step potential contact, current travels from one hand, through the heart, down the leg, and out of the foot. The heart and lungs are in the direct path of current so ventricular fibrillation, difficulty in breathing, collapse, unconsciousness, or death may occur.



AIM AND OBJECTIVES

The aim of this paper is to conduct research into electrical hazards, impacts and provide safety measures for Nigerian construction industries using Kaaptron technologies as a case study.

To achieve the overall aim of the study, specific objectives are defined as listed below:

- To determine the amount of current and likely effects on workers in designated areas during construction work.
- To determine the duration it will take to cause electrocution at given body resistances.
- To perform risk analysis matrix at job locations.
- To identify the types and magnitude of electrical hazards workers encounter daily on their jobs through cases of real life deaths obtained from the electrical engineers and technicians on site at the time of the incidents.
- To provide safety measures that would eliminate injuries and deaths.

METHODOLOGY

The body resistances of workers at specific areas of the construction site were obtained. They were grouped into four main sections namely: dry skins, normal skins, wet skins and perspirations. Their respective likely current flow when in contact with voltage source were calculated and compared with the international standard. The time it takes for a human body to be electrocuted when varieties of current pass through were also calculated. Risk analysis matrix was then conducted at job locations to ascertain areas with high risks and areas with no risk at all.

$I=\frac{V}{R}$-- Ohm's law.

$I=I_0 Sinewt$-- Ohm's law

$R= R_0 (1+ \alpha t)$ -- Ohm's law

Where I is the instantaneous current in ampere

V is the instantaneous voltage in volts

R is body resistance in Ohms

For Risk analysis,

Probability of being harmed= P_h

Degree of harm received= D_r

Risk= $P_h \times D_r$--

1- 4---------------------- Proceed with task- Ideal safe work situation

5- 11 ---------------------- Proceed with caution

12- 19 ------------------------ Reassess the plan

20-25 --------------------------- make a new plan- not safe

RESULTS

Cases of electrical hazards recorded in the industry were obtained and outlined below

CASE 1

An electrical technician was helping a company service agent test the voltage-regulating unit during a construction work. While the electrical technician went to get the equipment service manual, the service representative opened the panel cover of the voltage regulator's control cabinet in preparation to trace the low-voltage wiring in question (the wiring was not color-coded). The service representative climbed onto a nearby cabinet in order to view the wires. The technician returned and began working inside the control cabinet, near exposed, energized electrical conductors. The technician tugged at the low-voltage wires while the service representative tried to identify them from above. Suddenly, the representative heard the victim making a gurgling sound and looked down to see the victim shaking as though he were being shocked. He was pronounced dead almost 2 hours later as a result of his contact with an energized electrical conductor.

PRECAUTIONS:

- Make sure all employees know the importance of de-energizing (shutting off) electrical systems before performing repairs.
- Equip voltage-regulating equipment with color-coded wiring.

CASE 2

A maintenance man rode 15 feet above the floor on a motorized lift to work on a 240-volt light fixture. He did not turn off the power supply to the lights. He removed the line fuse from the black wire, which he thought was the "hot" wire. But, because of a mistake in installation, it turned out that the white wire was the "hot" wire, not the black one. The black wire was neutral. He began to strip the white wire using a wire stripper in his right hand. Electricity passed from the "hot" white wire to the stripper, then into his hand and through his body, and then to ground through his left index finger. A co-worker heard a noise and saw the victim lying face-up on the lift. He was pronounced dead at the scene.

PRECAUTIONS:

- If you work on an electrical circuit, test to make sure that the circuit is de-energized (shut off)!
- Never attempt to handle any wires or conductors until you are absolutely positive that their electrical supply has been shut off.
- Be sure to lock out and tag out circuits so they cannot be re-energized.
- Always assume a conductor is dangerous.

CASE 3

A male service technician arrived at a customer's house to perform pre-winter maintenance on an oil furnace. The customer then left the house and returned 90 minutes later. She noticed the service truck was still in the driveway. After 2 more hours, the customer entered the crawl space with a flashlight to look for the technician but could not see him. She then called the owner of the company, who came to the house. He searched the crawl space and found the technician on his stomach, leaning on his elbows in front of the furnace. The assistant county coroner was called and pronounced the technician dead at the scene. The victim had electrical burns on his scalp and right elbow. After the incident, an electrician inspected the site. A toggle switch that supposedly controlled electrical power to the furnace was in the "off" position. The electrician described the wiring as "haphazard and confusing." Two weeks later, the county electrical inspector performed another inspection. He discovered that incorrect wiring of the toggle switch allowed power to flow to the furnace even when the switch was in the "off" position.

PRECAUTIONS

- The victim should have tested the circuit to make sure it was de-energized.

- Employers should provide workers with appropriate equipment and training. Using safety equipment should be a requirement of the job. In this case, a simple circuit tester may have saved the victim's life.

CASE 4

Five technicians were performing preventive maintenance on the electrical system of a rig maintenance facility. One of the technicians was assigned to clean the lower compartment of an electrical cabinet using cleaning fluid in an aerosol can. But, he began to clean the upper compartment as well. The upper compartment was filled with live circuitry. When the cleaning spray contacted the live circuitry, a conductive path for the current was created. The current passed through the stream of fluid, into the technician's arm, and across his chest. The current caused a loud explosion. Co-workers found the victim with his clothes on fire. He died 24 hours later of burns.

PRECAUTIONS

- Before doing any electrical work, de-energize all circuits and equipment; perform lock-out/tag-out, and test circuits and equipment to make sure they are de-energized.
- The company should have trained the workers to perform their jobs safely.
- Proper personal protective equipment (PPE) should always be used.
- Never use aerosol spray cans around high-voltage equipment.

Table 2.10: Amount of current likely to flow through workers body under specific skin conditions

	Dry skin(mA)	Normal conditions (mA)	Hot environment &Perspirations (mA)	Wet conditions (mA)
Hand to hand	0.12 (100k Ω)	120 (1000Ω)	240 (500 Ω)	480 (250 Ω)
Hand to leg	1.09 (110k Ω)	109 (1100 Ω)	218 (550 Ω)	436 (275 Ω)
Leg to leg	0.12 (100k Ω)	120 (1000Ω)	240 (500 Ω)	480 (250 Ω)
Head to chest	1.09 (110k Ω)	109 (1100 Ω)	218 (550 Ω)	436 (275 Ω)
Chest to leg	1.09 (110k Ω)	109 (1100 Ω)	218 (550 Ω)	436 (275 Ω)

Table 2.10 has shown that perspirations and wet conditions reduce the resistance of a body thereby increasing the amount of current that will flow through such body. It is therefore important to guard the body against contact with high voltage under such conditions. The workers whose body resistances were taken were advised to follow precautions during work to avoid terrible accidents.

Table 2.20: Electrocution time when in contact with high voltage

Body resistances (Ω)	Current flowing through the body (mA)	Electrocution time (s)
1000	120	0.8
500	240	0.2
1200	100	1.4
2400	50	2.0
2000	60	5.0
3000	40	7.0
857	140	0.6
750	160	0.5
667	180	0.4
600	200	0.3
545	220	0.25

It is evident from table 2.20 that electrocution and possibly death can occur within 0.2 seconds when any of such bodies considered make contact with high voltage. This information is therefore necessary to serve as precautionary measures when dealing with live conductors.

Table 2.30: Risk analysis done on site during work operations

	Average p_d	Average D_r	Average RISK	COMMENT
Fittings, appliances, fixtures	2	1	2	Proceed with the task
Electric motor	3	5	15	Reassess the plan
Welding machine	4	4	16	Reassess the plan
Hot conductor	4	5	20	Not safe to perform the work
Transformer (11kv)	2	2	4	Proceed with the task
High voltage system	4	5	20	Not safe to perform the work
Underground lines	4.8	5	24	Not safe to perform the work
Wiring	5	5	25	Not safe to perform the work
Lift shafts	4	5	20	Not safe to perform the work
Generators	2	2	4	Proceed with the task
Lighting	1	1	1	Proceed with the task
Switch boards	4	5	20	Not safe to perform the work

Table 2.30 shows that employees working on electric motor, welding machine, hot conductors, high voltage system, underground lines, wirings, lift shafts and switch boards are at high risk of getting electrocuted. The concerned workers are hereby advised to adhere strictly to safety measures.

SAFETY MEASURES/RECOMMENDATIONS

Stage 1—Recognizing Hazards

The first step toward protecting yourself is recognizing the many hazards you face on the job. To do this, you must know which situations can place you in danger.

Likely hazards on the job:

- Inadequate wiring is dangerous.
- Exposed electrical parts are dangerous.
- Overhead power lines are dangerous.
- Wires with bad insulation can give you a shock.
- Electrical systems and tools that are not grounded or double-insulated are dangerous
- Overloaded circuits are dangerous.
- Damaged power tools and equipment are electrical hazards.
- Using the wrong personal protective equipment (PPE) is dangerous.
- Using the wrong tool is dangerous.
- Some on-site chemicals are harmful.
- Defective ladders and scaffolding are dangerous.
- Ladders that conduct electricity are dangerous.

- Electrical hazards can be made worse if the worker, location or equipment is wet.

Stage 2—Evaluating Hazards

After you recognize a hazard, your next step is to evaluate your risk from the hazard Conditions showing a hazard:

- Obviously, exposed wires should be recognized as a hazard. If the exposed wires are 15 feet off the ground, your risk is low. However, if you are going to be working on a roof near those same wires, your risk is high. The risk of shock is greater if you will be carrying metal conduit that could touch the exposed wires.
- Improper grounding and a damaged tool greatly increase your risk.
- Wet conditions combined with other hazards also increase your risk.
- If there are clues that electrical hazards exist. For example, if a ground fault circuit interrupter (GFCI) keeps tripping (disconnect automatically) while you are using a power tool, there is a problem. Don't keep resetting the GFCI and continuing to work. You must evaluate the clue and decide what action should be taken to control the hazard.
- Short—a low-resistance path between a live wire and the ground or between wires at different voltages (called a fault if the current is unintended).
- Tripped circuit breakers and blown fuses show that too much current is flowing in a circuit.
- An electrical tool, appliance, wire or connection that feels warm may indicate too much current in the circuit or equipment.
- An extension cord that feels warm may indicate too much current for the wire size of the cord. You must decide when action needs to be taken.
- A cable, fuse box or junction box that feels warm may indicate too much current in the circuits.

- A burning odor may indicate overheated insulation.
- Worn, frayed or damaged insulation around any wire or other conductors is an electrical hazard because the conductors could be exposed. Contact with an exposed wire could cause a shock.
- Damaged insulation could cause a short, leading to arcing or a fire. Inspect all insulation for scrapes and breaks.

Stage 3—Controlling Hazards: Safe Work Environment

In order to control hazards, you must first create a safe work environment, and then work in a safe manner. Generally, it is best to remove the hazards altogether and create an environment that is truly safe. But you never know when materials or equipment might fail. Prepare yourself for the unexpected by using safe work practices. Use as many safeguards as possible. If one fails, another may protect you from injury or death. A safe work environment is created by controlling contact with electrical voltages and the currents they can cause.

Electrical currents need to be controlled so they do not pass through the body. In addition to preventing shocks, a safe work environment reduces the chance of fires, burns and falls. You need to guard against contact with electrical voltages and control electrical currents in order to create a safe work environment. Make your environment safer by doing the following:

- Treat all conductors even "de-energized" ones as if they are energized until they are locked out and tagged.
- Lock out and tag out circuits and machines. Lockout involves applying a physical lock to the power source(s) of circuits and equipment after they have

been shut off and de-energized. The source is then tagged out with an easy-to-read tag that alerts other workers in the area that a lock has been applied.

- Prevent overloaded wiring by using the right size and type of wire.
- Prevent exposure to live electrical parts by isolating them.
- Prevent exposure to live wires and parts by using insulation.
- Prevent shocking currents from electrical systems and tools by grounding them.
- Prevent too much current in circuits by using over current protection devices.

CONCLUSION

The amount of current the body can withstand, the time it takes a body to be electrocuted when in contact with electricity and risk analyses as discussed in this paper are pertinent issues needed to avert electrical hazards in construction companies. It has also been shown that high voltages are no respecters of persons. Construction industries working with hot conductors must be able to protect their employees both electrical workers and others. Those working under wet conditions must follow the necessary precautions and most importantly have stand by medical team in case of injury.

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