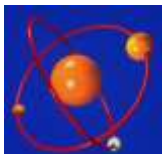

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Word for the day: **Electrical Protection Components - Part Two**

Poets, artists and many "non-technical" people have always advised the mankind to pursue what the heart feels and not what the mind says. Feeling of heart has always overridden the logics of mind. By doing or enjoying something that we love most, our heart will miss a beat, for sure. But if same heart misses more beats, it needs medical attention. And, one of the culprit causing this is ELECTRICITY. Malfunctioning of heart is one of the most instant effects of electric shock, apart from other bodily injuries. This week let us explore how electricity affects our body and understand its seriousness, by heart!!!

A common phrase makes frequent appearance in electrical field: "***It is the current, not the voltage that kills***" While there is an element of truth to this statement, we can understand more about the electric shock and its effects on human body. If voltage presented no danger, there would not have been a board that read:

"DANGER – HIGH VOLTAGE !!"

It is the electric current that burns tissues, freezes muscles and disturbs heart beat. However, electric current doesn't just occur on its own. The voltage is responsible for creating current which flow thru body and damages the organs. To understand how electricity affects our body, we may have to re-visit Ohm's Law:

The current flow thru any conductor is directly proportional to magnitude of potential difference (voltage) impressed across the conductor and inversely proportional to resistance offered by the conductor. This can be mathematically represented as $I\ (amperes)\frac{V\ (or\ E\ in\ volts)}{R\ (resistance, in\ Ohms)}$, which when written other way mean V (or E) = I x R

$$\boldsymbol{Current = \frac{Voltage}{Resistance}}$$

The amount of current thru body is, therefore, directly proportional to voltage applied and inversely proportional to body's resistance. The amount of resistance body offers varies from person to person and which parts get touched and also the surrounding weather conditions. Therefore, for a given resistance, if the voltage applied is more, the magnitude of current flowing will also be more, indicating more injury to the body.

The resistance offered by body changes depending on where the contact is being made. The contact can be between hand to hand or hand to foot or hand to chest or foot to foot. Also, a wet hand – due to sweat, for example – offers less resistance compared to a dry hand. Interestingly, body size, amount of fat in the body also alter the resistance. Remember also that blood, being a mixture of many minerals, is a good conductor of electricity.

So how much current is generally harmful for the body? Amount of current that can be considered be hazardous is listed in following table along with its impact. From the table, it is quite evident that AC voltage is more harmful than DC voltage.

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All currents are in milli Amperes (One milli Ampere = 1/1000th of an ampere = 0.001 Ampere)

NOTE: Most of the readings were obtained from quite a few practical experiences and tests done on various animals. It is quite possible that the geographical location can also affect these current limits for a body. But, this table can serve as a good starting point to incorporate necessary safety and precautions.

Current Limit, DC		Current Limit, AC 50 / 60 Hz		Current Limit, AC 10000 Hz		Effect on the body
Men	Women	Men	Women	Men	Women	
1.0	0.6	0.4	0.3	7	5	Slight sensation, like a shivering felt in hands
5.2	3.5	1.1	0.7	12	8	Can feel the shock, but does not have any direct effect
62	41	9	6	55	37	Painful, but the body can be immediately retracted from source to avoid further injuries
76	51	16	10.5	75	50	Muscles contract and the body cannot let go of the conductor
90	60	23	15	94	63	Severe pain with extreme difficulty in breathing and burn may occur
500		100				Possible heart fibrillation with severe burns. May result in death also

On average, a dry human body has a resistance value of 100,000 Ohms (1 MΩ). With this resistance, let us calculate how much voltage is necessary to produce a current of 20 milli amperes, which is sufficient to cause muscle contraction. The resistance is measured between two hands holding two probes of a multi-meter tightly.

Due to lesser muscles and fat content in their body, women suffer same electric injuries at LESSER current than men.

V = I x R

V = 20 mA x 100,000 Ω

V = 20,000 volts or 20 kV

Consider the second scenario whether the hands are wet and resistance measures only 1000 (1 KΩ) Ohms. Under such condition, the voltage required to produce same current will be much less

V = I x R

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V = 20 mA x 1000

V = 20 volts

Therefore, depending on body resistance under different circumstances, even low voltage system which we all "assume" to be safe can prove fatal.

With several electrical and medical research it has been found that 17 milli amperes of current is sufficient to cause **FIBRILLATION** of heart, which when exposed for longer duration, will result in death. Heart beat is a systematic contraction and expansion (called RHYTHM) of various muscles. Fibrillation is an effect when heart stops beating in rhythm. The contraction and expansion happen randomly at different rate, sometimes reaching 200 pulses per minute. Immediate medical attention and **DEFIBRILLATION** is necessary to restore the heart beat.

Remember also that the body resistance DECREASES with increased duration of exposure to the electricity. So, it is extremely essential to disconnect the power source or isolate the person as soon as possible, without creating panic. The body resistance value is also influenced by what conductor we are holding and HOW we are holding it. Research in this area have obtained certain approximate values for different conditions, as shown in the list below:

- Wire touched by a single finger – 40,000 (40 kΩ)to 1000000 (1 MΩ) ohms when dry and 4000 (4kΩ) to 15000 (15kΩ) ohms when wet
- Wire totally held by hand – 15,000 (15kΩ) to 50,000 (50kΩ) ohms when dry and 3000 (3kΩ) to 5000 (5kΩ) ohms when wet
- Non-insulated cutting (or any metal) plier by hand – 5000 (5kΩ) to 10,000 (10kΩ) ohms when dry and 1000 (1kΩ) to 3000 (3kΩ) ohms when wet
- Metal contact with palm (instead of fingers) – 3000 (3kΩ) to 8000 (8kΩ) when dry and 1000 (1kΩ) to 2000 (2kΩ) ohms when wet
- 1 ½" metal pipe firmly held by ONE hand – 1000 (1kΩ) to 3000 (3kΩ) ohms when dry and 500 to 1500 (1.5kΩ) ohms when wet
- 1 ½" metal pipe firmly held by BOTH hands – 500 to 1500 (1.5kΩ) ohms when dry and 250 to 750 ohms when wet
- Hand immersed in conductive liquid – 200 to 500 ohms
- Foot immersed in conductive liquid – 100 to 300 ohms

It is interesting to note that resistance value when holding pipe by two hands is exactly half the value, when held by one hand. This agrees with the

Resistance in parallel:

According to Ohm's law, when more than one resistance elements are connected in parallel, the net resistance value reduces.

It can be depicted by following formula:

$$\frac{1}{Rtotal} = \frac{1}{R1} + \frac{1}{R2} + \dots \frac{1}{Rn}$$

Resistance in series:

When more than one resistance elements are connected in series, the net resistance value increases.

It can be depicted by following formula:

$$Rtotal = R1 + R2 + \cdots Rn$$

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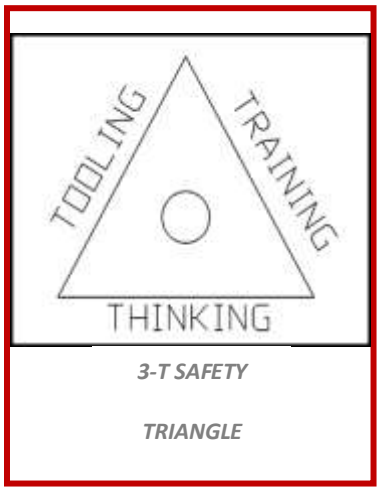
principle of RESISTANCE IN PARALLEL. When two hands are holding the conduct, it will DOUBLE the contact area and reduces the resistance.

From practical work point of view, it is not possible to always shut down power before working. Sometimes, we may be troubleshooting the working of a machine or checking the trip conditions of a breaker or just measuring the voltage in a conductor. 30 or less volts is considered to be safe limit for not suffering any electrical shocks. But having said that, it is important to take all precautions before attempting to work on "live" circuit. It is quite common to have mix of different voltage levels in an electrical panel. Following is a small list of precautions to prevent electrical hazards

- Before attempting to go near any "live" circuit, ensure your hands and legs are dry
- Remove all metal items on your body including rings and other jewelries. Avoid keeping too many items like tester, mobile phones in your pockets. They may accidentally touch some "live" terminal
- Do not stand on loose points from where your chances of toppling or slipping are high. Due to such instability, the person may not be able to balance himself and will fall on high voltage conductors. This will be specially important when working outdoors
- As much as possible use only one hand while working – Keep other hand away
- Do not work alone – Have one or more personnel either assisting you or just watching your activity. A stitch in time saves nine!!
- Communicate to everyone around you, including non-technical personnel, that you are working on some part of electrical system and nobody should turn on any equipment without confirming
- Wear necessary protective elements – Eye-glasses, Gloves, Rubber boots – to prevent any untoward incident. The resistance of all these add to protect body from electric shocks



3-T SAFETY TRIANGLE

- Personnel, specifically attending "live" electrical work must use proper TOOLING and should have undergone necessary & proper TRAINING. They should be THINKING about what they are doing instead of getting distracted by other mental pressures - With a perfect balance of three T's, virtually zero electrical accidents can be achieved
- Never use wrong tools for adjusting something - Use right tools and right measuring instruments – Sometimes when tightening a nut-bolt assembly that is "invisible," you could get a feeling of "tightening" but it might not have happened – Pay close attention under such circumstances
- Avoid using left hand as much as possible, since the current flow path is close to heart
- When working on electronic equipments, independent of its size, wear antistatic wrist wrap. This will not only help prevent small shocks to your body but will equally prevent electrostatic charge from our body damaging the electronic components

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- Even if the main circuit breaker is disconnected, the conductor(s) of load side on which you will work, must be temporarily connected to ground using a piece of wire – This is an usual practice in high-tension transmission systems

- Wherever you are walking, especially on rainy days, be cautious. Look "above" and "below" for any loose cables fallen from a pole. Never be ***curious*** to play with electrical wires without confirming voltage levels

From the prevention stand point, few points are listed that you can follow to avoid (possibly eliminate) all electricity related hazards

- Create a "grounding-check audit" schedule and make it part of preventive maintenance activity. The frequency of audit can be determined based on complexity of electrical system in your set-up. It is essential to ground the BODY and NEUTRAL, separately. If neutral is left ungrounded, "floating" voltage from other sources may pass thru this and create electric shock

    - There is no limit for number of "pits" that can be created for grounding. Based on the location and convenience, it is better to have as many "pits" as possible to ensure 100% grounding under all circumstances. This will be extremely helpful if set-up is new and possibility of adding more machines exist in future

> As a thumb rule, the distance between two "pits" should be equal to or greater than the depth of "pit."

- Discharge capacitors before attempting to work on them or connected device. Measuring with a multi-meter itself is a good method of discharging capacitor

    - Avoid discharging capacitor using a short piece of wire. The sudden discharge will exert lot of pressure on dielectric material which will eventually reduce capacitor's life. Using resistors of suitable rating is recommended

- ***DO NOT CONNECT GROUNDING WIRES OF EQUIPMENTS IN SERIES***, just to save few meter of cable. This is called daisy chaining and will increase the magnitude of ground current. You might get electric shock from grounding line without knowing where it originated – The best practice is to run a continuous strip of conductor bar (Aluminum, GI or Copper) around the set-up and INDIVIDUALLY hook-up grounding to this bar

    - And, never "twist" some wire piece for grounding purpose. The grounding wire must be firmly tightened at both ends to increase conductivity and reduce ground related faults

> Being so important, we will publish a separate newsletter on PRINCIPLES OF GROUNDING very soon

- Sometimes, when you use a "tester" on a conductor, its light will feebly turn on, indicating some "floating" voltage somewhere. With multiple electrical equipments connected, it is pretty difficult to explain this phenomenon. But it clearly points to some grounding fault somewhere. Perform a grounding-check audit

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- The floating voltage which "appears" on tester could be an indication of some "internal leakage" somewhere. Poorly insulated windings or motor, windings of transformers are two examples that can cause "internal leakage"

- Never force loose cables into sockets / receptacles to "save" time. And, never force more than acceptable cable into a socket. All electrical wiring must be done with patience and in proper manner. Short-cut & Short-term methods will lead to accidents

- Never run cables across ways where there is movement of people or vehicles – If that be necessary, guide the cable thru strong pipe and provide sufficient ramp for vehicle to pass over smoothly (or if permissible, use armored cables)

- Cables should never be allowed to suspend by itself or be used as support ropes for holding something else – Always provide sufficient support for cables and they should be free of all "mechanical" weights

- Each cable has "minimum bending radius" limit – Do not force them beyond it. This will be especially applicable to armored cables, which if bent beyond limit will develop severe mechanical stress resulting in insulation failure

- In humid and wet locations provide sufficient protection for electrical items from moisture – Distribute plenty of "silica gel" packets inside panels to absorb moisture and replace them from time to time

- Install necessary grade – DRY POWDER TYPE – fire extinguishers near important electrical panels and also across the plant

- The electrical panels / distribution systems should have sufficient clearance all around, with good ventilation (natural or forced)

As much as possible eliminate power from the equipment on which you will perform some electrical work. The number of equipments / machines to be isolated depends on location of electrical work. For performing some work on main incoming panel, obviously the incoming HT-LT distribution system itself must be isolated. On the other hand, Based on the level of power isolation possible, it can be classified into three states

1. **ZERO ENERGY STATE (ZES)**
   When all the power to an equipment or a system is completely eliminated or isolated and any component can be safely touched, removed and worked upon, it is said to be in zero energy state. This state also includes other "power" sources like pressurized air in a receiver, pressurized hydraulic fluid, heavy weight suspending from certain height and inflammable products. All of these must be isolated before concluding that the equipment or system is in total zero energy state.

   Specifically from electrical perspective, if the equipment or system is connected to multiple power sources, all of them must be isolated. For example, a machine can have main incoming power for electrical components and "conditioned" power from UPS for electronic components. Both of them must be isolated for attaining zero energy state. If capacitors are installed, they must also be fully discharged for achieving zero energy state.

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Although zero energy state eliminates risk in handling components, it does not compromise on safety requirements necessary for accomplishing the desired task.

2. **INTERMEDIATE ENERGY STATE (IES)**
When certain power exists in an equipment or a system, even after partial isolation, it is said to be in intermediate energy stage. An air-receiver could be storing pressurized air while the electrical power alone is isolated. Similarly, when it is "interfaced" to other machines or computer for exchange of certain signals, voltage could exist on those wires which cannot be isolated for various reasons.

From electrical perspective, if some work is being carried out on control system with specific isolation, main incoming power could still be on feeding other components on the machine.

Equal precaution and care should be taken while working on equipments placed in intermediate energy state.

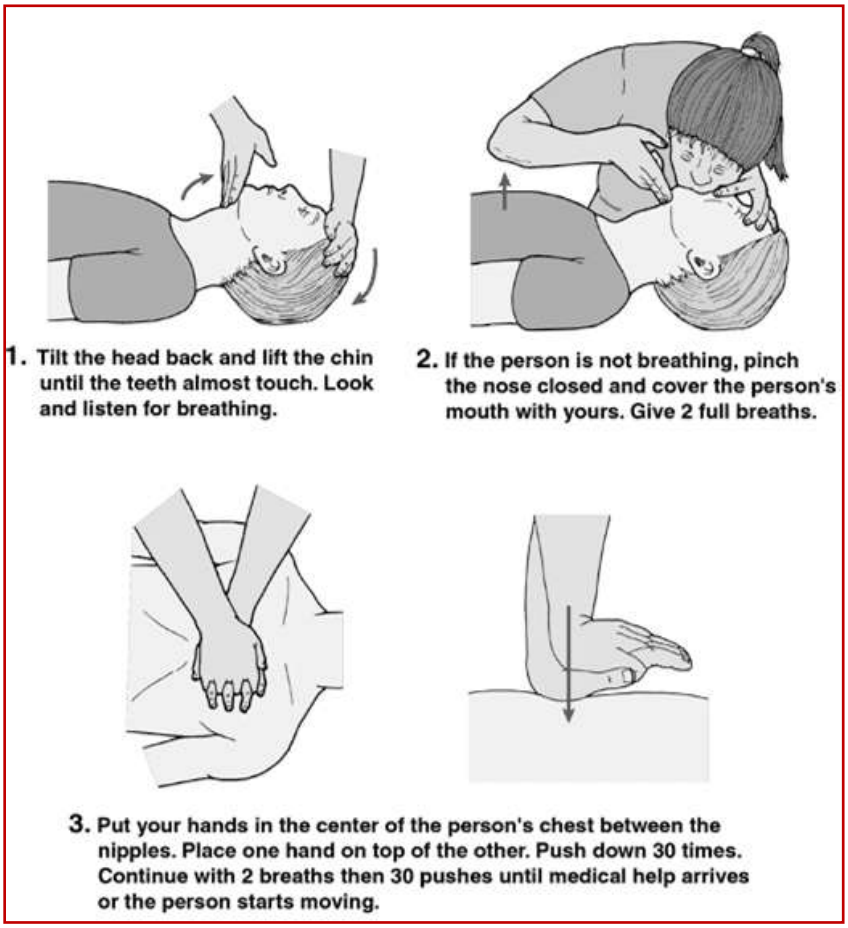
3. **COMPLETE OR FULL ENERGY STATE (CES or FES)**
When all the necessary power is available to an equipment or a system and can be fully functional, it is said to be in complete or full energy state. This is the normal state of equipments, when they are operational.

CPR – Cardio Pulmonary Resuscitation – One of the oldest known and best methods of restoring heart beat when it gets "fibrillated." (Besides, CPR is also administered on persons suffering heart attack due to other reasons – mental stress, high BP, drowning, sudden mental or physical shock etc.,) CPR may not guarantee complete restoration but will definitely help keep the heart functioning to some extent, at least till primary medical assistance is provided.

The adjacent picture shows three most elementary steps of CPR.

CPR training must be made compulsory for people involved in working with machines and equipments. Of course, there is no harm in providing CPR training to all the personnel in any set-up. It will be helpful under any circumstances.

Apart from typical first-aid kit that is fixed at various locations, it is also essential – especially for maintenance personnel – to be familiar with



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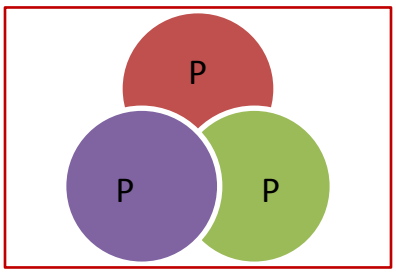
using doctor's stethoscope and thermometer. These two devices are very effective in checking body condition when any such incidents occur and are very easy to use.

Special note on shock from AC versus DC From the current limit table somewhere in this newsletter, it is quite evident that less magnitude of alternating current causes same damage compared to direct current. Alternating current, as the name implies, fluctuates between a positive and negative value repeatedly over a period of time, compared to direct current which flows in one direction. To understand why this happens, just recall how we break a piece of small metal rod.

The metal rod is usually held in hand (or fixed in vice) and repeatedly bent up & down (hit both sides) which breaks it faster than just bending in one direction or hitting with hammer. Also, observe that after repeated bending, the metal would become little soft and very hot, especially in the broken region. Exactly similar will be the effect of alternating current on muscles and tissues. It causes repeated contraction and expansion causes accelerated rupture and more damage.

Follow 3-P principle for saving a life that otherwise can be lost.



Avoid P – PANIC – Do not panic and create a commotion or confusion., while witnessing and attending the victim.

Have P – PATIENCE – Nothing happens by magic. Have patience and recollect all actions that you must do to save life. Nobody should try to prove "super-hero" actions under such circumstances.

Practice P – PREVENTION – Once the situation is under control and the victim is out of danger, perform a thorough, in-depth analysis of what all led to the incident. Take all steps to prevent the same incident from occurring. If necessary, use statistical tools like *RCA, PDCA, 5W-1H, Cause-Effect Diagram, Spider Diagram* to arrive at specific solutions.

After spending some time reading the contents and "by-hearting" them for a safe tomorrow, activate your brain's electrical impulse to solve the Techuzzle on this subject !!

Happy Solving!!!

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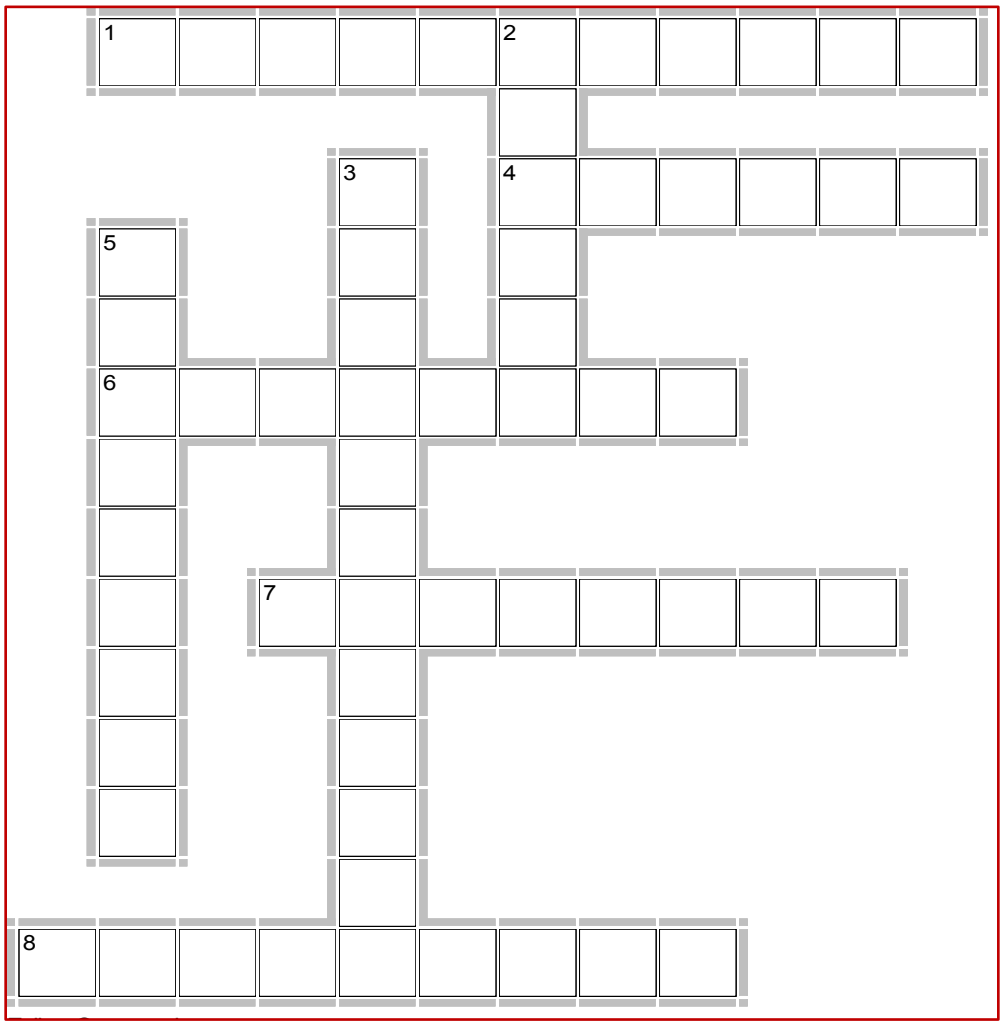

Across

1. What is the opposite of resistance?
4. Insulating hand gloves are usually made from this material
6. Salt and which other material are commonly used in pit?
7. Voltage you "see" on tester, but usually cannot be measured
8. Another word for earthing?

Down

2. What does C stand for in CPR?
3. Lost of rhythmic beat of heart
5. Does body resistance increase or decrease with prolonged contact with electricity