Chapter 1 - Safety

1.1 Introduction

1.1.1 Objective

The objective of this book is the study of the

1. magnetic effect
2. of an inductor
3. created by a coil of wire.

To accomplish that goal will involve an understanding of *electrical* circuit elements in association with the non-linear *magnetic* energy in a *mechanical* device.

1.1.2 Magnetic Machines

Matter consists of three components - mass (m), charge (q), and magnetic pole strength (p). Space configuration and time makes the combination into unique items related by energy and power. Electrical engineering covers two-thirds of physics since it is the study of electromagnetic phenomenon consisting of charge and magnetics. Most electrical engineering addresses the electric side, which includes circuits, electronics, and computers. A few classes look at the mathematical side, which includes communications and electromagnetic theory. Electric machinery covers the magnetic side in an interface to mechanical systems.

Electric machinery looks at numerous configurations of magnetic devices. The common element of all these devices is a coil of wire, called an inductor.

1. loop antenna – a simple coil
2. electro-magnet – a coil with power applied
3. transformer – a stationary primary field coil with ac inducing ac to a stationary secondary.
4. dc machine– a stationary field coil with dc and a rotating coil with dc
5. synchronous machine – a stationary coil with ac and a rotating field coil with dc
6. induction machine – a stationary field coil with ac inducing ac to the rotating secondary
7. relay – a coil which moves a mechanical lever that operates a switch

A machine can be either a motor or generator. A generator has mechanical power applied to the shaft and electric power is delivered from the coil. As a motor, electric power is applied to the coil terminals and mechanical power is delivered from the shaft.

Conversion between forms is observed in the Durham energy relationships, where E is energy and V is volume. These relationships as well as much of the physical system theory in the second chapter is developed from papers by the author.

Node electromagnetic energy $$E = \frac{pq}{t}$$

Field electromagnetic energy $$E = \frac{(pq)(bds)}{Vt} = \frac{(pq)(bd)}{At}$$

In determining the characteristics of power systems, only three things are practically measured: voltage (V), current (I), & time (t). From these time shift (power factor), apparent power (S), and impedance (Z) are calculated. This gives the complete performance description of the system.

1.2 Safety Reference

Numerous projects will be built and investigated. Of necessity, this will involve working on energized circuits to perform the tests. Electrical power is inherently dangerous above a very low threshold. Where practical, tests and research will be conducted below the threshold. It is incumbent that safe practices be used.

The first chapter is devoted to electrical safety. Four standards impact the area of safety associated with electrical energy.

> *National Electrical Code* is published by the National Fire Protection Association (NFPA) as NFPA 70. The standard is the first reference for most electrical installations.
>
> *National Electrical Safety Code* is published by the Institute of Electrical and Electronics Engineers (IEEE) as IEEE C1. It is the standard for overhead and burial of power and communications systems.
>
> *Standard for Electrical Safety Requirements for Employee Workplaces* is published by the National Fire Protection Association as NFPA 70E. It is the standard for personnel protection equipment.
>
> *OSHA 1910 Workplace Safety Regulations* is published by the Occupational Safety and Health Administration (OSHA) of the Federal government. It is an extensive compilation of regulations that are enforced by an agency of the US government.

This chapter will address all levels of electrical safety, not just those involved in the laboratory. These are based on many years of practice in association with the applicable standards. Rather than a discussion, the points will be enumerated for quick reference and ease of learning.

1.3 Safety Key Points

1. ***Think.*** Electrical safety does not cost, it pays. Safety begins with top management and a philosophy. Safety is for you. If it is dangerous, dirty, or demeaning, hire a professional.

2. ***Terms.*** Terminology is crucial to safety. Voltage (Volt, V) corresponds to pressure. Current (Amp, I) is the flow rate. Impedance (Ohm, Z) including resistance is opposition to flow. It is a ratio of voltage and current. Power (Watt, S) is the energy during a period of time. It is the product of voltage and current.

   Ohm's Law $Z = V/I$

   Power $S = VI^*$

3. ***Body Design.*** The Creator designed the body to operate by electrical and chemical action. Electrical signals can be measured from the brain (EEG), heart (EKG), and muscles (EMG). These signals are very small compared to power levels.

4. ***Body Resistance.*** The external body resistance varies from 15,000 to 40,000 Ohms depending on health, age, sex, physical conditions, attitude, environment, and cleanliness. The internal body resistance is 500 Ohms for each limb and 100 Ohms for the torso. The skin provides the major resistance. If the skin breaks down, the resistance is lowered to the internal value. The power capacity is only about one-quarter watt.

5. ***Body Burns.*** When the body encounters a shock, it reacts as if it were a burn. A blister develops to protect the area. The saline water lowers the resistance to about 1000 ohms. This is detrimental, since more fatal current flows.

6. ***Response Levels.*** Current kills, not voltage. Current greater than 10 milliamps (10/1000) through the heart or brain can have very deleterious effects.

7. ***Threshold.*** A threshold voltage of at least 40 volts is necessary to overcome cell insulation and cause a fatality. Only qualified individuals should work on energized circuits above 50 volts. The current in a 7.5 watt, 120 volt lamp can be fatal. The only difference between 120 and 20,000 volts is an open casket or a closed.

8. ***Retraction Response.*** One common fallacy is the electricity 'knocked' someone. The muscles involuntarily contract when exposed to a shock. The reaction may assist gravity to contribute to a fall. Touch metal

enclosures with the back of the hand to determine if the metal is energized. The muscles will contract away and prevent serious problems.

9. ***Contraction Response.*** Another common fallacy is the electricity 'grabbed' someone. If the hand is grasping for a metal object, the muscle contraction may cause a death-grip.
10. ***Arc.*** The arcing distance of electricity in dry air is about 15,000 volts per inch. It is difficult to grab a conductor at 2400 volts or higher since the arc will cause the body to withdraw. For this reason, many electricians exposed to very high voltage survive although burned extensively.
11. ***Approach Distance.*** When working around energized lines, stay outside the minimum approach distance. For circuits less than 1000 volts, simply avoid contact. The minimum approach distance for up to 15,000 volts is 2 ft-2 in.
12. ***Compassion.*** First aid response is critical. Never touch someone who is still in contact with an energized circuit. Two injuries are not helpful. De-energize the circuit or use a dry non-conducting object to move the victim.
13. ***Assistance.*** CPR is critical for survival from electrical shock. Paralysis of nerves restricts breathing, requiring resuscitation. Ventricular fibrillation of the heart requires heart massage. Brain cells die within four minutes. Pray, holler for help, and get with the program. CPR only helps the other guy, it does you no good.
14. ***Arcs.*** Electrical hazards come from shock, arcs and blasts, as well as radiation. A shock requires contact. The other hazards come from proximity. An arc between metal can have temperatures as high as 35,000F. That is 4 times the temperature of the sun. A blast is the result of pressure build-up associated with an arc.
15. ***Burns.*** Electrical burns are two types. One is cooking of flesh by the energy. These are deep and slow healing. The other is a flash burn from spraying molten metal at 6000 degrees. These are surface and often facial.
16. ***Radiation.*** Radiation occurs from being around an electrical energy system. Voltage causes an electric field, while current causes a magnetic field. High frequency also causes thermal cooking. At some level, all these can cause serious health effects.
17. ***Clothing.*** Proper tightly woven natural fabrics, such as 100% cotton or wool, are preferred for protection from electrical and other burns. Flame retardant synthetic (such as Nomex or Kermel) is acceptable but less comfortable and adaptable. Avoid wearing acetate, polyester, rayon, or nylon materials since they melt.
18. ***Conductive Attire.*** Rings, watches, necklaces, and large metal belt buckles must be removed or rendered non-conductive before working around any electrical circuits.
19. ***Protective Gear.*** Protective equipment includes eye and face, hearing, respiratory, head, foot, clothing, electrical isolation, and fall protection. Avoid metal hard hats and metal nails in boots.
20. ***Procedures.*** Plan electrical work. Conduct a briefing to discuss the work with everyone on the site. As a minimum identify hazards, procedures, precautions, energy control, and protective equipment. Use lock-out and tag-out procedures.
21. ***Awareness.*** In the US, about 90% of the people electrocuted each year involve a circuit of only 120 volts. It is the most common, and it is carelessly taken for granted.
22. ***Ground Wire.*** Metal enclosures containing electrical circuits must be grounded. Certain heating devices are the only exception. Look for the ground wire and connection before touching. Gently touch the metal appliance with the back of the hand before use. Nevertheless, a ground is no guarantee a shock will not occur.
23. ***Double Insulated.*** Use double insulated tools. These have two levels of protection. They are recognized by a two prong plug and a non-metallic housing. If the equipment has a metal enclosure, it should be grounded.
24. ***Cheaters.*** Avoid adapters and cheaters for plugs. If the receptacle does not have a ground terminal, it probably is not grounded. Some brave souls even cut off the ground attachment wire. In any case, a cheater is simply trying to cheat the grim reaper. It is not worth it.
25. ***Cords.*** Inspect all cords for frayed, broken, or damaged insulation before use. Portable cords, attachment plugs, receptacles, and portable electric tools were involved in 320 case of 910 electrical injuries in one year.
26. ***Lighting.*** Provide adequate lighting for the task. Trouble lights are widow-makers. During use, the holder is often crawling or in solid contact with steel, concrete, or other excellent electrical conductors. Use a double-winding transformer to reduce the voltage from 120 volts to 6 or 12 volts.

27. ***GFCI.*** Ground fault circuit interrupters are designed to trip when the leakage current exceeds 7 milliamps. These should be installed in bathrooms, in garages, outdoors within reach of grade level, in spaces below grade, within six feet of a kitchen sink or wet bar, and in boathouses.
28. ***Arc Fault.*** Arcing is short duration overload, so it will not trap thermal breakers. Arc fault circuit interrupters are required in bedrooms and sleeping areas.
29. ***Reclosing.*** After a fuse blows or a breaker trips, exercise extra caution when reclosing the switch. Gently touch the metal enclosure with the back of your hand before making full contact. Stand to the side of the panel before energizing. A fault could cause the enclosure to rupture.
30. ***Connection Sequence.*** Jumpers and fuses should be applied in a proper sequence to reduce possible hazards. When removing, extract the source side first, then the de-energized. When replacing, install the de-energized side first, then the source.
31. ***Step and Touch.*** Step and touch potential can be fatal. If a power line comes in contact with the ground, a fence, or any metal surface, avoid contact with all metal in the area. Jump away from the location with kangaroo hops. Be careful to remain upright.
32. ***Vehicle.*** Similarly, if a vehicle comes in contact with an energized line, jump from the vehicle. Avoid contact with any part of the vehicle and the earth at the same time.
33. ***Overhead.*** Overhead lines present a potential hazard when handling pipe and antennas, operating cranes and booms, or moving large items. Material handling should be kept at least 10 feet from energized lines. The distance increases 4 inches for each 10,000 volts greater than 50 kV. Look up and live.
34. ***Buried.*** Identify all buried cable before digging. Most cables have a marker tape above the conductors. High voltage cables are covered by metal conduit or by colored concrete.
35. ***Ladders.*** Avoid metal ladders around electrical systems. The distance between the wall and the base of non-conductive extension ladders should be one-fourth the length.
36. ***Fire Prevention.*** Fires can be prevented with proper protection. Use appropriate circuit protection for any cords, motors, or lights.
37. ***Fire Extinguishers.*** Use only appropriate fire extinguishers on electrical fires. Avoid spraying water or extinguishers that are water based. Avoid high pressure extinguishers if it can spread the burning material. Devices with a Class C rating are the only approved extinguishers for electrical use.

Electricity is exciting, but do not touch the juice.
Electricity is clean fun, but do not get a charge out of it.
Electricity can light up your life, but do not let it light you up.

1.4 Current Effect

Above a threshold of about 40 volts, very small levels of current have tremendous impact on the human body. The table below provides a guideline into the effect on a 150 pound man.

The human body responds to a variety of very low level electrical signals that can be measured. These include heart with electrocardiogram (EKG), brain with electroencephalogram (EEG), and muscles with electromyogram (EMG).

Notice that at low levels, the external current is interfering with and overriding the current signals within the body. At higher levels, the external current is providing heating effects.

CURRENT RANGE AND EFFECT ON A 150 POUND MAN

Current **60 Hz**	**Physiological** **Phenomenon**	**Feeling or** **Lethal Incidence**
< 1 ma	none	imperceptible
1 ma	perception threshold	
1 - 3 ma		mild sensation
3 - 10 ma		painful sensation
10 ma	paralysis threshold of arms	cannot release hand grip may progress to higher current
30 ma	respiratory paralysis	stoppage of breathing frequently fatal
75 ma	fibrillation threshold, 0.5%	heart action not coordinated probably fatal
250 ma	fibrillation threshold, 99.5% > 5 second exposure	
4 A	heart paralysis threshold no fibrillation	heart stops for duration may restart on interruption usually not fatal from heart dysfunction
> 5 A	tissue burning	not fatal unless vital organs burned

Dalziel, C.F., and Lee, W.R., “Reevaluation of Lethal Electric Currents”, *IEEE Transactions on Industry and General Applications*, Vol. IGA-4, pp. 467-476, Sept/Oct. 1968; discussion pp. 676-677, Nov/Dec, 1968

The table is correlated to a young man who is in excellent condition. The values are reduced about one-half for women and children.

A personal experience illustrates the differences. We had a freezer which developed a problem. My wife noted a small tingling when she touched the freezer. Being the electrical engineer that knew about this sort of thing, I carefully touched the handle with the back of my hand – nothing. I explained eloquently that it must have been static. Sometime later, she mentioned that she felt the tingle. I cavalierly checked with the back of my hand – nothing. An equally flippant explanation was proffered. A few days later she exclaimed matter of factly that one of the kids was shocked by the freezer. From the tone of voice, I appropriately responded, “Yes, Ma’am, I will fix it.” On further investigation, I found a pinched wire to the indicator light and repaired it. She reported no more shocks. The point is not everyone responds to the same level of shock.

Because of the relatively low levels of current required for serious shock, the *National Electrical Code* requires ground fault circuit interrupter receptacles be installed in potentially wet environments. These are designed to trip above a current of 5 milliamps.

Electrical shock is a very serious issue. Any reported problems should be investigated immediately.

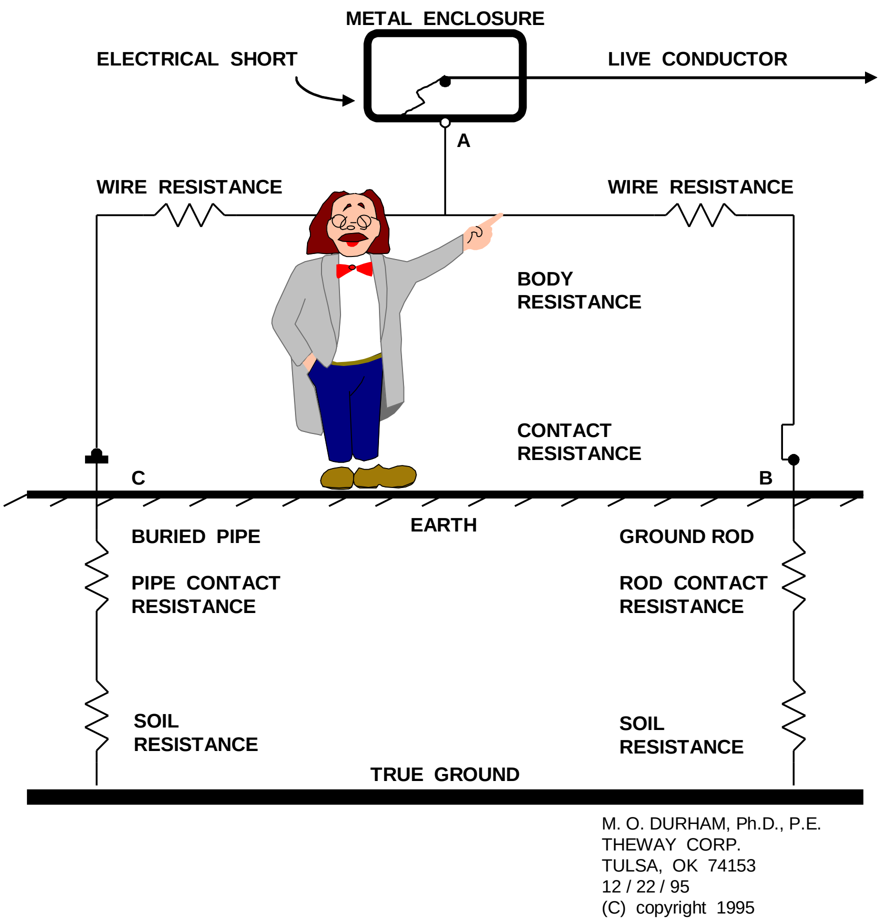
1.5 Ground Paths

A common assumption is that metal equipment that is grounded is safe to touch. The basis for the idea is that all ground operates at an equipotential. This is analogous to the flat earth society. There is difference in connection resistance, soil resistance, and path resistance. This can easily be observed by testing the ground path resistance with an instrument.

The figure illustrates the differences in ground path resistance.

Always check enclosures with the back of the hand before grabbing. If there is an energized surface, the muscles will contract and draw the hand away from the energy.

Ground Paths



1.6 Lockout / Tagout

One of the guidelines that must be addressed in any energy related safety discussion is lockout/tagout. A lockout/tagout program is a matter of law as well as safety. It is dictated by the Occupational Safety and Health Administration (OSHA). The structure and implementation is a matter for each organization. A general guideline is provided.

The procedure directs control of energy storage devices that may contribute energy even when the equipment is not operating. As a result, the equipment is locked in the de-energized position. A tag is attached to the control point to identify work is being performed on the equipment.

Energy sources include pressure, springs, and mass not in its lowest position. Electrical energy comes from the supply as well as stored energy in capacitors.

These guidelines should be followed religiously to prevent oversight in performing the service activities. The plan requires notification, shutdown, isolation, tagging, control, and verification. These procedures are incorporated in the training checklist. A summary of the necessary steps can be included on the tag.

1.7 Step and Touch Potential

1.7.1 Introduction

When a fault occurs on a power line, there is an impedance between the line and the source. The impedance may be another line or it may be the earth. If the impedance is large, the entire voltage that existed on the line prior to the fault is now impressed on the electrode contacting the impedance. If the impedance is low, such as a metal tower or conduit, less voltage will be impressed. The hazard depends on the available fault current. If there is not a continuous metal path back to the source, all of the fault current will be flowing in the earth.

1.7.2 Voltage Gradient

The dissipation of voltage from an energized grounded electrode is called the ground potential gradient. Voltage drops associated with the dissipation create a ground potential in the earth. The potential is very high near the ground electrode, but it typically drops off exponentially with distance from the energized point.

1.7.3 Step and Touch

Step potential is the difference in voltage between two points at different distances from the energized electrode. When a person or animal walks across the energized ground, he places an alternate path for the current. The impedance between the feet is in parallel with the earth. Therefore, a voltage develops between the feet and current flows through the body. Very small currents can place a person at risk during a fault simply by his standing near the grounding point.

Touch potential is the difference in voltage between an energized object and some distance away. An alternate path is provided through the body to the earth. If the object is grounded at a location remote from where it is touched, the potential could be nearly the full voltage across the object. This occurs when a crane or metal pipe touches an energized line and a person touches the metal. Since the path of the current through the body may be through vital organs, touch potential can be fatal.

1.7.4 Ground Potential Gradient Protection

Fault currents and ground potential distribution is determined by an engineering analysis. The hazard depends on the level of current, the soil resistivity, and the resistance of the body. Since all these vary with different conditions, general guidelines should be used to reduce the risk from gradients. Three techniques are using equipotential zones, insulating equipment, and restricted work areas.

Equipotential zones restrict the potential difference between points within the area. The zone is created by a metal mat connected to the grounded object. In some installations, a grounding grid can also be used. Notice a potential now exists between the equipotential zone and outside objects. Touching objects both within and outside the area creates a hazard. Bonding metal objects in the work area can contribute to the equipotential zone. However, bonding objects outside the area will create a hazardous potential between the object and its surroundings.

Insulating equipment, such as rubber gloves, isolate the person from energized objects. Gloves protect from touch potential with the hands. They provide no protection from step potential or touch potential with other parts of the body. The insulating equipment is rated for the highest voltage that can be impressed on the grounded object, not the rated system voltage.

Restricted work areas are used to protect people not involved with operations being performed. Personnel on the ground in the vicinity should be kept at a distance where step voltage is insufficient to cause hazard. A worker should not handle grounded conductors (neutral) or equipment likely to become energized unless he is in an equipotential zone or is using insulated equipment.

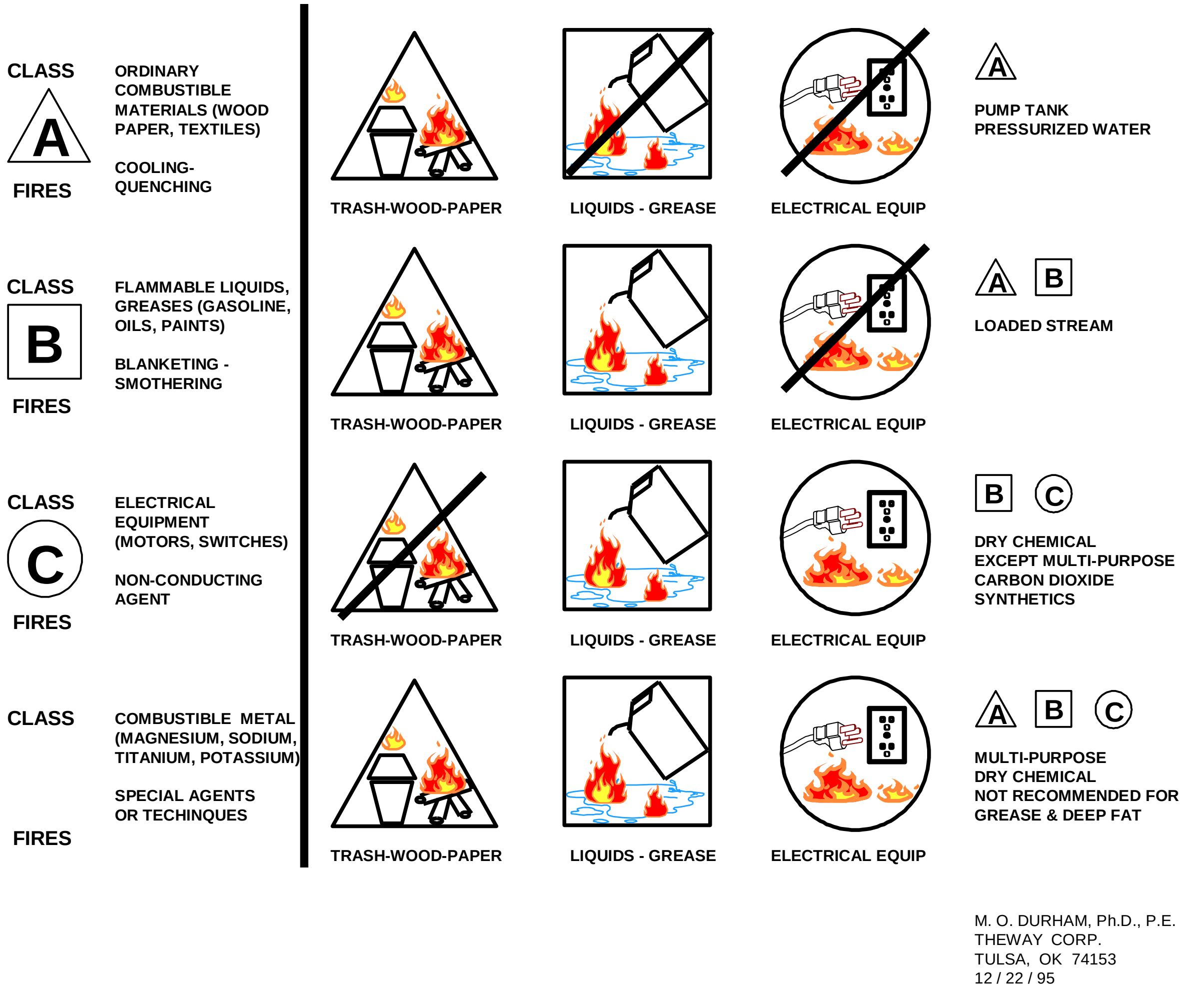
1.8 Fire Protection

An unfortunate result of electrical equipment failure or other incident may be a fire. Different extinguishers are required for various fuel and ignitions. Most fire extinguishers should not be used on electrical fires, since the stream may be conductive.

The graphic illustrates the appropriate extinguisher application.

In use, the stream from the extinguisher should be aimed at the base of the fire in a sweeping motion. Be very careful to prevent burns and smoke inhalation.

FIRE EXTINGUISHERS



1.9 Electrical Safety Questions

1. Electrical voltage best relates or compares to which of the following?
   (a) pressure or potential (b) flow rate, bbls/min (c) viscosity or API gravity

2. Electrical current best relates or compares to which of the following?
   (a) pressure or potential (b) flow rate, bbls/min (c) viscosity or API gravity

3. Impedance (opposition to current flow) can be defined as voltage and current:
   (a) division (ratio) (b) multiplication (product) (c) sum

4. Power (energy per time) can be defined as voltage and current:
   (a) division (ratio) (b) multiplication (product) (c) sum

5. A voltage tester is used for checking:
   (a) fuses (b) live circuits (c) high voltage over 800 V

6. A continuity tester is used for checking:
   (a) fuses (b) live circuits (c) high voltage over 800 V

7. Which is more likely to be dangerous or fatal?
   (a) high voltage (b) low amperage or current (c) high impedance

T F 8. A 1000 volt circuit is more dangerous than a 120 volt circuit.

T F 9. It is necessary to check an electrical enclosure with a voltmeter to see if it has a short and is electrically hot.

T F 10. During wet weather electrical circuits work the same; therefore, it is no more dangerous to work around them.

T F 11. A grounding wire is necessary for an electrical circuit to work properly.

T F 12. A grounding wire is always necessary for equipment to be safe.

T F 13. If a grounding wire is connected to a box, you can assume the box is safe to touch.

T F 14. If a fuse is blown and you do not have the same size to replace it, you should use the largest fuse available that will fit in the holder.

T F 15. If a fuse puller is not readily available, your fingers should be used to remove cartridge fuses in a control panel, exercising great care.

T F 16. It is accepted practice to use the master disconnect switch for start and stop control of electrical equipment.

T F 17. For safety reasons, the master disconnect switch should be locked-off if work is being done on a pump or motor.

T F 18. A ground fault circuit interrupter will not protect a person from electrical shock when working in a wet area.

T F 19. Energy from electromagnetic circuits only travels on wires so you are safe from its hazards if you do not touch it.

T F 20. Avoid clothing of natural fibers (wool and 100% cotton) if around flashes and sparks.

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DATE EMPLOYEE ID # INSTRUCTOR

1.10 Safety Tips

1. ***Voltage.*** Electrical voltage is closely related to head pressure or potential above a reference point.

2. ***Current.*** Electrical current is flow rate or quantity of material that moves down a line. It depends on pipe (or wire) size and head potential (volts).

3. ***Impedance.*** Ohm's Law describes the ratio of voltage to current as impedance.

4. ***Power.*** Power in any calculation is the product of pressure and flow rate.

5. ***Testers.*** A voltage tester is used to check if a circuit is energized. Most test instruments have insulation rated up to 600 volts. Use on higher than rated voltage is hazardous.

6. ***Continuity.*** A continuity tester is used for testing fuses or checking for open circuits only on de-energized equipment.

7. ***Body Response.*** BEWARE, very small amounts of current can cause death, if voltage is sufficient to overcome circuit impedance. Relatively large voltages without significant current, such as auto ignition systems, may not be lethal. Never try to outguess the hazard.

8. ***Awareness.*** A standard 120-240 volt circuit can kill, therefore it has as much ultimate danger as 1000 volts.

9. ***Quick Tap.*** A quick test to check if metal enclosed equipment may be electrically hot is to lightly tap the enclosure with the back of your hand. Muscle contraction will withdraw your hand if the device has shorted. A voltmeter needs two connections. One is the enclosure. What is the other?

10. ***Wet and Wild.*** Electrical circuits usually work the same during wet weather; however, the impedance of the circuit which an individual may become part of is greatly reduced and much more hazardous. Extra caution should always be used in wet or damp conditions.

11. ***Ground Safety.*** An equipment ground wire is not necessary for an electrical device to operate properly. It is a safety component.

12. ***Double Insulated.*** Certain specialized equipment does not require a ground for safety. Double insulated tools and electrically heated appliances such as toaster/broilers are two examples. If a ground conductor is supplied or required by the manufacturer on any apparatus, use the ground.

13. ***Ground Hazard.*** CAUTION, an attached ground wire may not make a metal enclosure safe if the ground circuit is broken or if ground conductors are carrying current.

14. ***Fuse Replacement.*** Always replace fuses with the proper size for the load. If this is indeterminate, replace fuses with the same size and type.

15. ***Proper Equipment.*** Never allow any part of your body to come in contact with potentially "live" electric circuits. Use the right equipment when performing any electrical work.

16. ***Load Break.*** Use approved control switches, contactors and relays to start and stop any load. The master disconnect is generally not intended for circuit control applications.

17. ***Energy Control.*** Anytime work is being performed on electrically operated equipment, the worker should lock "off" all power controls himself.

18. ***GFCI.*** Ground fault circuit interrupters de-energize electrical circuits when the current in the ground path exceeds 7 milliamps. This effectively protects from serious shock in any conditions.

19. ***Proximity.*** Voltage causes an electric field, while current causes a magnetic field. Both have harmful health effects at certain levels. In addition, arcs and flashes can cause severe burns.

20. ***Natural Clothing.*** Wear only natural fibers and flame retardant synthetics. Avoid acetate, polyester, rayon, and nylon.

1.11 Ten Commandments for Technicians

Humor is one of the best ways to remember. Just for fun, salient safety issues are arranged in the format of the ancient Ten Commandments in old English. Like the original, these are not suggestions, but absolutes.

I. Beware the lightning that lurketh in the undischarged capacitor, lest it cause thee to bounce upon thy buttocks in a most untechnician-like manner.

II. Cause thou the switch that supplieth large quantities of juice to be opened and thusly tagged, that thy days in this earthly veil of tears may be long.

III. Prove to thyself that all circuits that radiateth and upon which thou worketh are grounded and thusly tagged lest they lift thee to perform unpleasant bodily functions.

IV. Tarry not amongst those fools who engageth in intentional shocks for they are surely nonbelievers and are not long for this world.

V. Take care that thou useth the proper method when thou taketh the measure of a high-voltage circuit lest thou incinerate both thyself and thy meter, for verily, though thou hast not muchprofit for thy shop and can easily be replaced, the test meter doth have worth and, as a consequence, bringeth much woe unto thy employer.

VI. Take care that thou tampereth not with safety devices and interlocks, for this incurreth the wrath of thy supervisor and bringeth the fury of the safety inspector upon thy head and shoulders.

VII. Work thou not on energized equipment, for if thou dost, thy fellow workers will surely buy beers for thy widow and console her in other ways.

VIII. Service thou not equipment alone, for electrical cooking is a slow process and thou might sizzle in thine own fat for hours upon a hot circuit before thy maker sees fit to end thy misery.

IX. Trifle thou not with radioactive tubes and substances lest thou commence to glow in the dark like a lightning bug and thy wife have no further use for thee except thy wages.

X. Thou shalt not make unauthorized modifications to equipment, but causeth thou to be recorded all field changes and authorized modification made by thee, lest thy successor tear his hair out and go slowly mad in his attempt to decide what manner of creature hath made a nest in the wiring of such equipment.

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