Grounding

A. Grounding

1. A ground is a direct electrical connection to the earth, a connection to a particular point in an electrical or electronic circuit, or an indirect connection that operates as the result of capacitance between wireless equipment and the earth or a large mass of conductive material. For the purpose of this discussion, a ground is a direct electrical connection to the earth.

2. Purpose of Grounding

   a. Equipment is grounded to prevent damage in the event of an internal short and to prevent injury to personnel. Ground lines normally do not have current flowing through them. The subject of grounding may be divided into two main parts: grounding of energized equipment to protect personnel from electrical faults and grounding of a de-energized bus to protect maintenance personnel in the event the bus becomes re-energized.

3. Grounding Line

   a. Most electrical equipment housings and transmission towers are grounded. If an energized conductor should come into contact with the housing (or tower) the housing would become energized. For example, an ungrounded toaster with a broken heating element which touches the side of the toaster has 120 volts potential on its metal surfaces. As long as the toaster remains insulated from ground (e.g., on plastic legs), no path exists for a short circuit to ground. However, if a person touched the metal surface of the toaster, the current would flow through the path of least resistance to ground. In this example, a lethal 120 milliamps would flow through the body.

   b. A ground wire attached to the toaster body provides a direct path to ground. This is essentially a short circuit to ground and will either blow a fuse or trip a circuit breaker on high current. However, even if it remained energized, the owner is protected because current will still take the path of least resistance (the grounding wire). Protection only exists as long as the grounding wire remains properly connected to both the toaster and ground.

c. Equipment used in the distribution system (such as high tension towers) is also grounded. Ground wire for this equipment operates in the same fashion as for the toaster. The main reasons for grounding an industrial power distribution system are:

1) reduce operating and maintenance expense
2) keep transient over-voltages at a minimum
3) improve lightning protection
4) better system and equipment overcurrent protection
5) limit displacement of the neutral for greater safety
6) readily locate and isolate circuits accidently grounded
7) improve service reliability

d. Failure to provide proper grounding for electrical equipment (e.g., using a two-prong adapter on a three prong cord) may be considered the primary cause of many accidents or death of personnel. No system is complete unless adequate grounding connections have been made. This is particularly important as high voltages are not necessary to cause death from electric shock. Many deaths are recorded annually from shock received from the common 115-120 volt circuits. These deaths could and should have been avoided by proper grounding connections.

4. Grounding for Maintenance

   a. After a piece of equipment has been completely disconnected from all power, one additional step provides protection from electrical shock. If terminals normally energized (now de-energized for maintenance of the equipment) are grounded, chance of accidental shock is minimized. This is done by connecting portable cables to a suitable ground (e.g. metal rods or plates buried in the ground). Resistance to ground will be low, therefore, no dangerous voltage will develop on the grounding cable or anything connected to it. In the event that the equipment or bus should become energized (e.g., the power supply breaker inadvertently closed), maintenance personnel are protected from electrical shock. This type of grounding is usually used when working on high voltage equipment.

B. Effects of Electrical Shock

1. Electrical Shock and the Body

   a. Current kills (electrocution). Voltage is important because it determines the amount of current that will flow through a given body resistance. Resistance of the body to current flow is shown in Table 1. If 120 volts are applied across a body whose skin plus internal resistance equals 1200 ohms, current of one tenth ampere (100 milliamps) would flow through the body. If skin contact is maintained while current flows through the skin, skin resistance gradually decreases.

Table of Resistance	
Item	Resistance Value
External Body	
Dry Skin	100,000 to 600,000 ohms
Wet Skin	1000 ohms
Internal Body	
Hand-to-Foot	400 to 600 ohms
Ear-to-Ear	About 100 ohms

2. Table 2 shows the approximate effects that various currents have upon the body.

Effects of 60 Hz Current on an Average Human	
Current Value	Effect
Safe	
≤ 1 ma	Causes no sensation (not felt)
1 to 8 ma	Sensation of shock (not painful) Individual can let go at will
Unsafe	
8 to 15 ma	*Painful shock, Individual can still let go at will
15 to 20 ma	*Painful shock. Individual cannot let go
20 to 50 ma	*Very painful. Severe muscular contractions. Breathing difficult

100 to 200 ma	*VENTRICULAR FIBRILLATION. (A heart condition which results in death if not corrected)
≥ 200 ma	*Severe burns. Severe muscular contractions

a. The individual is the best safeguard. Whenever work is done on electrical equipment, it should be treated as if it were energized. The proper safety equipment must be used.

2. Safe Distance

a. Sufficient clearance between a person and an energized conductor must be maintained for safety purposes. The amount of clearance depends upon voltage involved and work being done. Minimum safe distances for personnel to energized electrical equipment are contained in the Occupational Safety and Health Manual, Electrical Work Practices (SFT-OSH-0114). When work must be done near an energized conductor, a barrier may be used between work areas and conductor. This avoids consequences caused by momentary forgetfulness.

3. Electrical Safety Considerations

a. Anytime a person works on or near electrical equipment three hazards exist. First, there is danger of current passing through a person's body. Second, body burns from an intense electrical arc. And third, the body can be injured from flying debris (solid and molten) from explosive effects of a melting conductor due to a short circuit. Each of these dangers can be minimized by using caution, protective clothing, and instruments to verify the status of the equipment (energized or de-energized).

b. Each utility has its own rules and procedures for working on electrical equipment. The following is a general list of safety rules to follow.

1) Use common sense

2) Remove all loose articles of clothing

3) Remove all extraneous metal (e.g., rings, watches, necklaces)

4) Use protective clothing (e.g., face shield, hard hat, fire resistant coat, and rubber gloves with or without leather)

5) Use rubber mats or an insulated stool, when appropriate.

6) De-energize as much equipment in the surrounding area as possible and practical

7) All equipment should be dry

8) Treat all electrical equipment as if it were energized

9) Use insulated tools whenever possible

c. Understand that not all rules will always apply. The procedures used working outdoors in the switchyard will be different than those used working between panels in the control room.

B. Electrical Fires

1. In case of electrical fire, the following steps should be taken:

a. De-energize the circuit. This will extinguish many electrical fires

b. Report the fire to the appropriate plant authority

c. Call the fire department

d. Control or extinguish the fire, using the correct type of fire extinguisher

2. Extinguishing Agents

a. The two best extinguishing agents for electrical fires are carbon dioxide (CO_2) and Halon.

b. Carbon dioxide deprives the fire of oxygen (smothers it) and can cool the fire if released close to burning material. If a portable CO_2 extinguisher is used, the discharge should be directed to the base of the flame for best results. Since CO_2 is heavier than air, CO_2 will displace oxygen in the room from the ground up. When large amounts of CO_2 are released in an enclosed space, the atmosphere may not have enough oxygen and the room should be evacuated by personnel.

c. Halon is another commonly used electrical fire extinguishing agent. Halon neither smothers nor chemically reacts with the fire.

d. It breaks into small chemical units called ions. These ions migrate towards the hottest part of the fire and rob heat from the flame. The cooler fire can no longer burn fuel (insulation in this case) and the fire goes out. Therefore, halon acts as a cooling agent without cooling surrounding components (as CO_2). This is very beneficial in an electronic system because a rapid cooling effect can permanently damage the semiconductor devices.

e. Water and foam agents should only be used on electrical fires with extreme caution. Regular tap water is an excellent conductor of electricity. If water is used, personnel should attempt to stand on a dry area to prevent electrocution. The use of carbon tetrachloride (CCI_4) should not be used because poisonous byproducts such as carbon monoxide may be formed.

3. Cable Fires

    a. Perhaps the hardest fire to fight is a fire in a concealed space. It is hard to get the extinguishing agent on the fire. In cable fires, inner layers of insulation or insulation covered by a protective covering are burning. The only positive method of preventing the fire from running the length of the cable is to cut the cable and separate the two ends. This procedure can severely limit operation and monitoring of plant systems and should only be done when authorized by appropriate personnel.

C. In Summary

1. It has been shown that current is the killing factor of electrocution. Current in excess of 100 miliamps is enough to place the heart into ventricular fibrillation and current in excess of 200 milliamps can cause severe burning of body tissue. The best protection one has against electric shock is self-checking. By using common sense, and eight other general rules for electrical safety, one can safely work on or near energized equipment.
2. A common result of an electrical short or overload is an electrical fire. When a fire is discovered, four basic steps need to be followed. Circumstances dictate the order in which they are performed. Upon discovery of a fire, the proper plant authority should be contacted. This ensures help will arrive in the event the operator becomes overcome by smoke. The fire department should also be informed. The first step in combating the electrical fire is to deenergize it. By doing this, the source of the original fire (electric current) is removed. In many cases this will put out the fire. If an extinguishing agent is required to control and put out the fire, the best agents to use are carbon dioxide or halon. If neither of these are available, water may be used only as a last resort, and then only with extreme caution. The threat of electrification becomes very great when fighting an electrical fire with water.

PRACTICE:

1 Why is electrical equipment grounded?

2. At what current level does ventricual fibrillation occur in humans?

3. What is an electrical ground?