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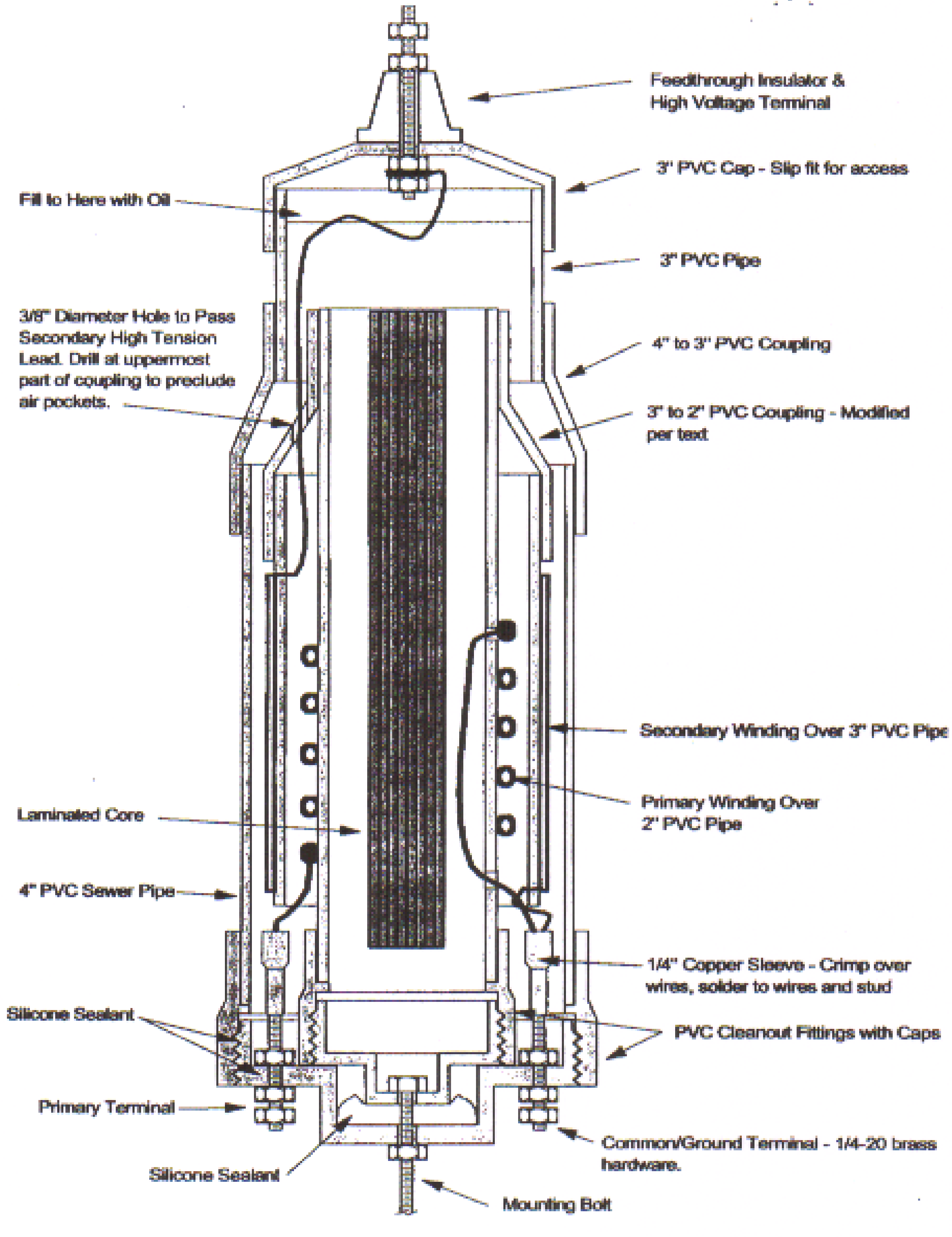


Figure 3 - Impulse Transf
Assembly (Note, vertical :
shortened.)

ELECTRICAL PRINCIPLES, TERMINOLOGY & SAFETY

The use of electricity is so common place that most people assume that it will always be available on demand. To fully realize the dependence upon electricity, survey the ways electricity is being used each day in the home and on the farm and ranch. Electricity is doing more to increase work efficiency and promote enjoyable living than any other single factor. The use of electricity has grown to the extent that an increasing portion of the home or business budget is used in paying for this source of energy.

1. Definition of Electricity

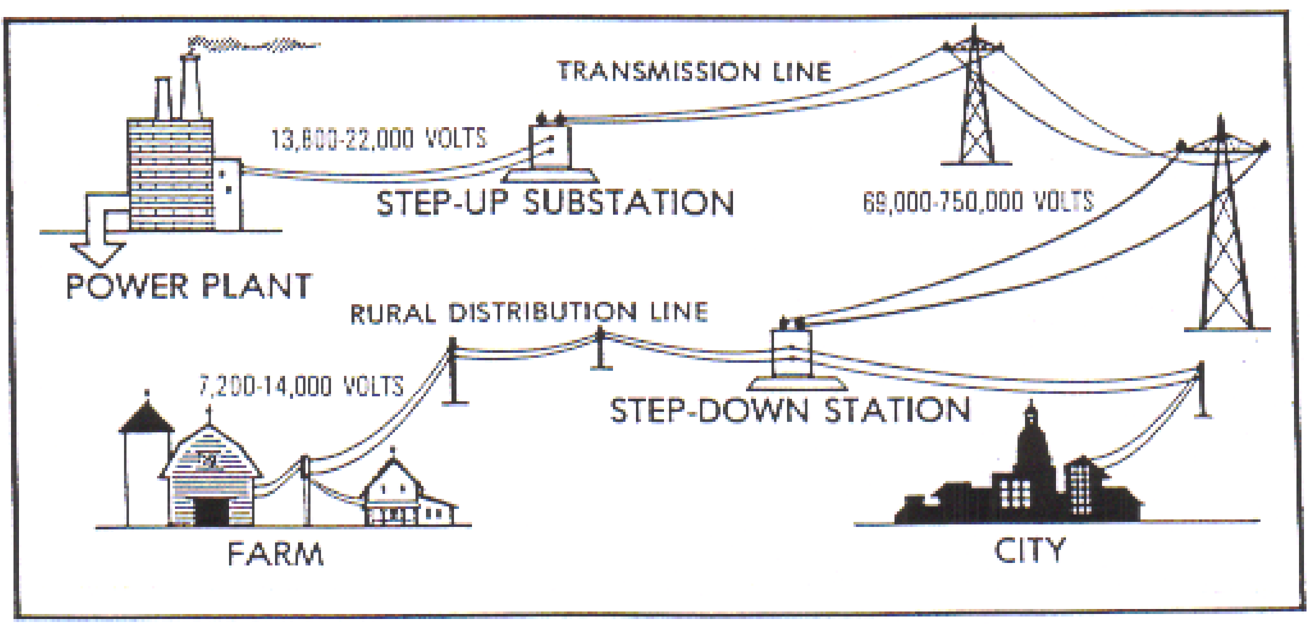
Electricity can be defined in several ways. The layman defines electricity as a source of energy that can be converted to light, heat, or power. Electrical engineers define electricity as a movement of electrons caused by electrical pressure or voltage. The amount of energy produced depends on the number of electrons in motion.

2. The Manufacture and Distribution of Electricity

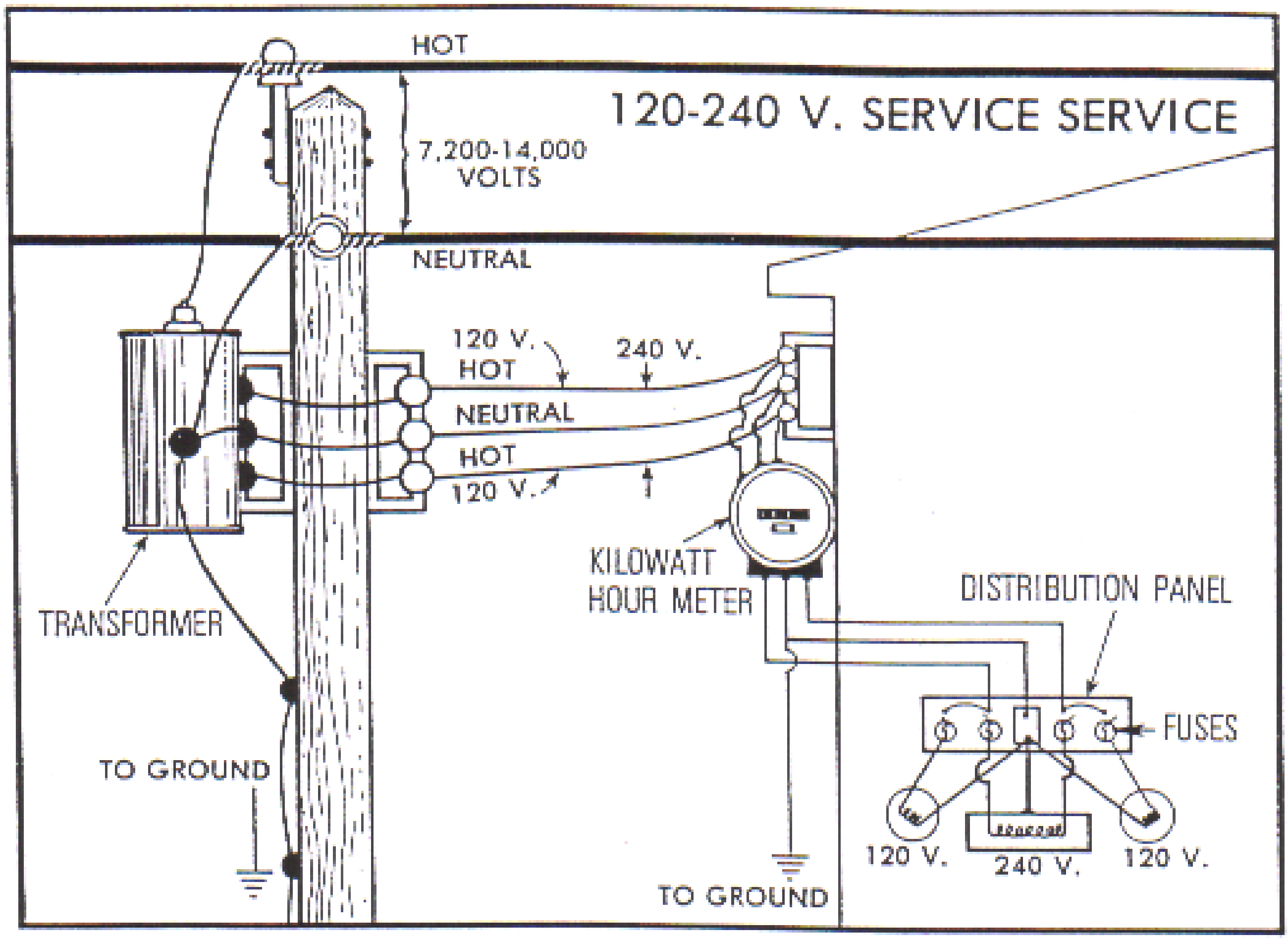
Electricity is produced from generators that are run by water, steam, or internal combustion engines. If water is used as a source of power to turn generators, it is referred to as hydroelectric generation. There are a number of this type located in areas where huge dams have been built across large streams.

Steam is used as a source of power for generating much of today's electricity. Water is heated to a high temperature, and the steam pressure is used to turn turbines which generate electricity. These are referred to as thermal-powered generators. Fuels used to heat the water are coal, natural gas, and/or fuel oil.

Generators at the power plant generate from 13,800 to 22,000 volts of electricity. From the power plant, electricity is carried to a step-up substation which, through the use of transformers, increases the voltage from 69,000 to 750,000 volts. This increase in voltage is necessary for the efficient transmission of electricity over long distances. From the step-up substation, the electricity is carried on transmission lines to a step-down substation which reduces the voltage to 7,200 to 14,000 volts for distribution to rural and city areas.



Transformers at the business or residence reduce the voltage to 120 or 240 volts to the meter of the customer.



3. **Common Electrical Terms**

In order to work safely and efficiently with electricity and have the ability to converse on the subject, the following terms should be understood:

Ampere (Amp) - A measurement in units of the rate of flow of electrical current. This may be compared with the rate of flow of water in gallons per minute.

Example: A 60-watt incandescent lamp on a 120V circuit would pull 1/2 ampere of electricity (60 divided by 120 = .5 or 1/2). (Formula: Amperes = Watts divided by Volts

Volt (V) - A unit of measure of electrical pressure. A given electrical pressure (V) causes a given amount of electrical current (Amps) to flow through a load of given resistance. Voltage may be compared with water pressure in pounds per square inch in a water system. Common service voltages are 120 volts for lighting and small appliance circuits and 240 volts for heating, air conditioning, and large equipment circuits.

Watt (W) - A unit of measure of electrical power. When applied to electrical equipment, it is the rate that electrical energy is transformed into some other form of energy such as light. Watts may be compared to the work done by water in washing a car. (Formula: Volts x Amps = Watts)

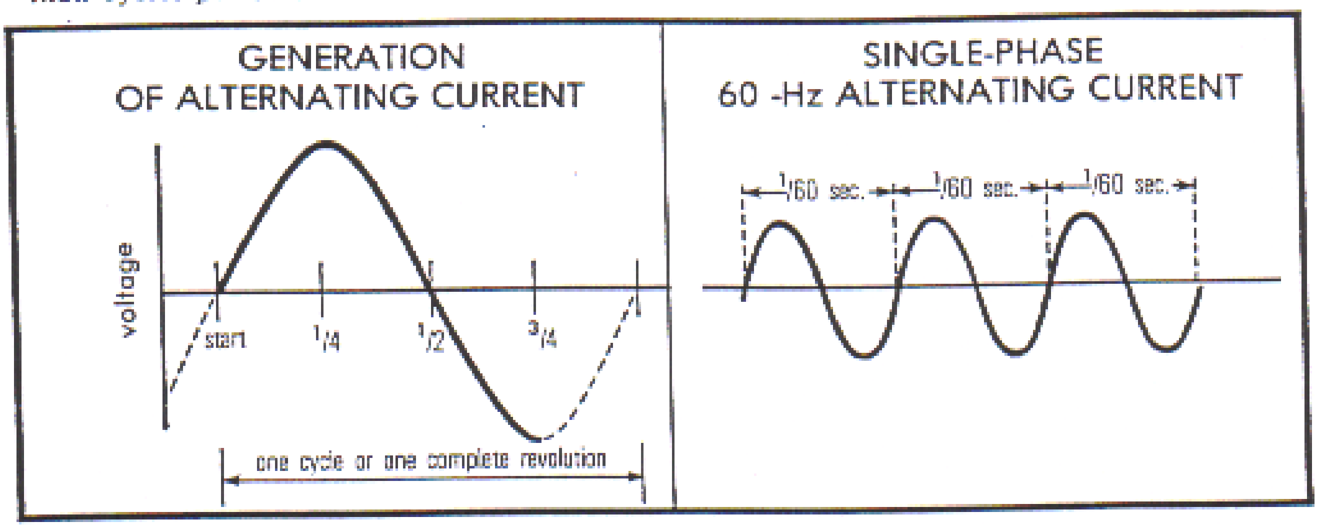
Kilowatt (KW) - A unit of measurement used in computing electrical energy used. Kilowatts are determined by dividing the number of watts by 1000 (1 KW = 1000 W).

Kilowatt Hour (KWH) - A measure of electricity in terms of power in kilowatts and time in hours. A KWH is 1000 watts used for one hour.

Alternating Current (A.C.) - Electrical current that alternates or changes direction several times per second. The direction current moves depends on the direction the voltage forces it.

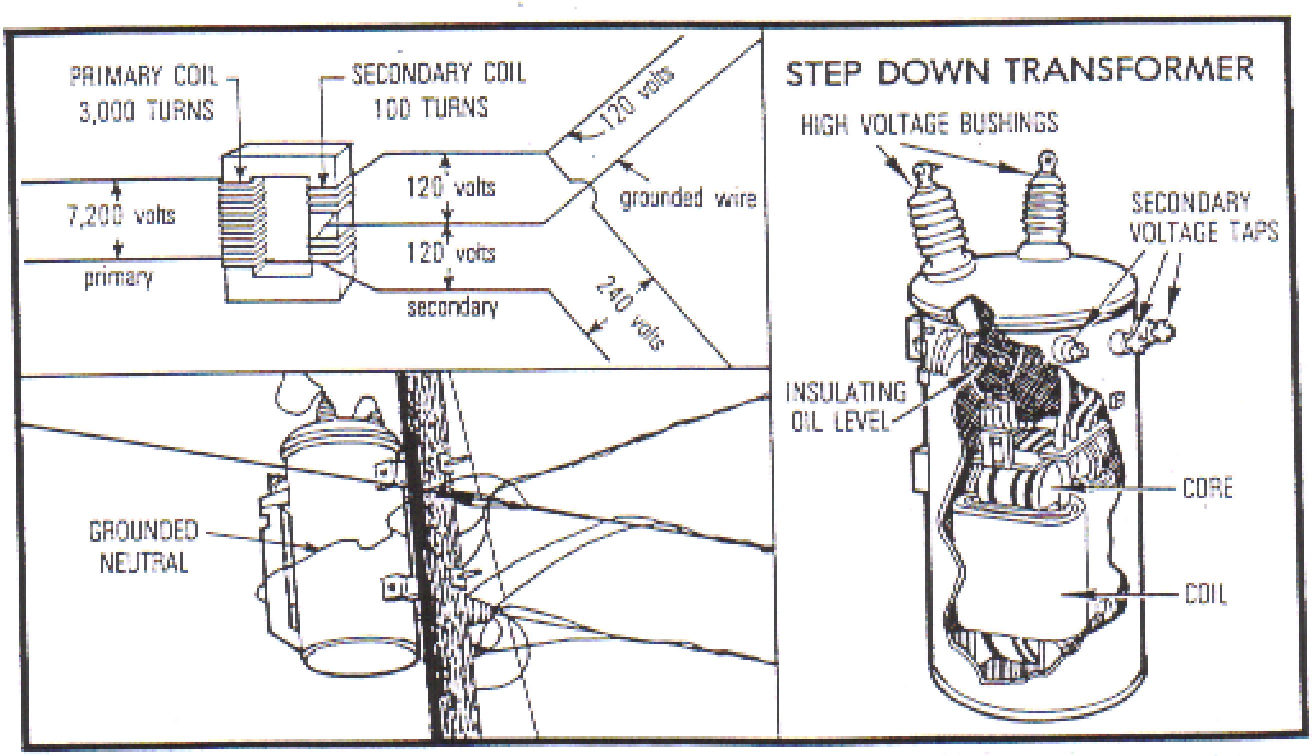
Cycle - The flow of electricity in one direction, the reverse flow of electricity in the other direction, and the start of the flow back in the other direction.

The cycles per second are regulated by the power supplier and are usually 60. Most electric clocks are built to operate on 60 cycles. More or less cycles would cause the clocks to gain or lose time. The present practice is to use the term Hertz (Hz) rather than cycles per second.



Direct Current (D.C.) - Electrical current flowing in one direction. Example: electrical circuit in automobiles and tractors.

Transformer - A device used to increase or decrease voltage.



Single Phase - The most common type of electrical service or power available to consumers. One transformer is used between the distribution line and the meter. Usually three wires, two "hot" and one neutral, are installed to provide 120V and 240V single-phase service. Single-phase service may also be supplied with three-phase service.

Three-Phase - This type of service is designed especially for large electrical loads. It is a more expensive installation due to three wires and three transformers. The important advantage of three-phase power is that the total electrical load is divided among the three phases; consequently, the wire and transformers can be smaller. Other advantages exist in the design of three-phase motors.

Short Circuit - A direct connection (before current flows through an appliance) between two "hot" wires, between a "hot" and neutral wire, or between a "hot" wire and ground.

Voltage Drop - A reduction of current between the power supply and the load. Due to resistance, there will be a loss of voltage any time electricity flows through a conductor (wire). Factors that influence voltage drop are size of wire, length of wire, and the number of amps flowing. A drop in voltage may cause a loss of heat, light, or power output of a motor. It could cause motor burn-out unless the motor is properly protected (time-delay fuse).

Fuse - A device used to protect circuits from an overload of current.

Circuit Breaker - A device used to protect circuits from an overload of current. May be manually reset.

Time-Delay Fuse - A fuse with the ability to carry an overload of current for a short duration without disengaging the contacts or melting the fuse link.

Horsepower (hp) - A unit of mechanical power equal to 746 watts of electrical power (assuming 74.6% electric motor efficiency). One hp and above motors are rated at 1000 watts per hp; motors below one hp are rated at 1200 watts per hp.

Conductor - The wire used to carry electricity (copper or aluminum). Copper and aluminum should not be spliced together due to their incompatibility resulting in deterioration and oxidation.

Insulator - A material which will not conduct electricity and is usually made of glass, bakelite, porcelain, rubber, or thermo-plastic.

"Hot" Wire - A current-carrying conductor under electrical pressure and connected to a fuse or circuit breaker at the distribution panel. (Color Code: usually black or red)

Neutral Wire - A current-carrying conductor not under electrical pressure and connected to the neutral bar at the distribution panel. (Color Code: usually white)

Grounding - The connection of the neutral part of the electrical system to the earth to reduce the possibility of damage from lightning and the connection of electrical equipment housings to the earth to minimize the danger from electrical shock. (Color Code: can be green or bare wire)

Underwriters' Laboratory (U.L.) - A national organization which tests all types of wiring materials and electrical devices to insure that they meet minimum standards for safety and quality.

National Electric Code (N.E.C.) - Regulations approved by the National Board of Fire Underwriters primarily for safety in electrical wiring installations. All wiring should meet the requirements of the national as well as the local code.

4. Computing Electrical Energy Use and Cost

If an estimate of cost for electricity used is desired, the name plate data on appliances and equipment and an estimate of operating time may be used. The following formulas should be used for determining watts, amps, volts, watt-hours, kilowatt-hours, and cost.

$$\text{WATTS} = \text{VOLTS} \times \text{AMPERES}$$

$$\text{AMPERES} = \frac{\text{WATTS}}{\text{VOLTS}}$$

$$\text{VOLTS} = \frac{\text{WATTS}}{\text{AMPERES}}$$

$$\text{WATTS} \times \text{HOURS OF OPERATION} = \text{WATT HOURS}$$

$$\text{KILOWATT-HOURS} = \frac{\text{WATT-HOURS}}{1000}$$

$$\text{COST} = \text{KWH} \times \text{LOCAL RATE PER KWH}$$

EXAMPLE COST PROBLEM:

LOCAL RATE PER KWH USED - 8 CENTS
NAME PLATE DATA - 120 VOLTS, 5 AMPS
MONTHLY HOURS OF OPERATION - 10

(1) $(W = V \times A)$ $\quad W = 120 \times 5$ $\quad W = 600$

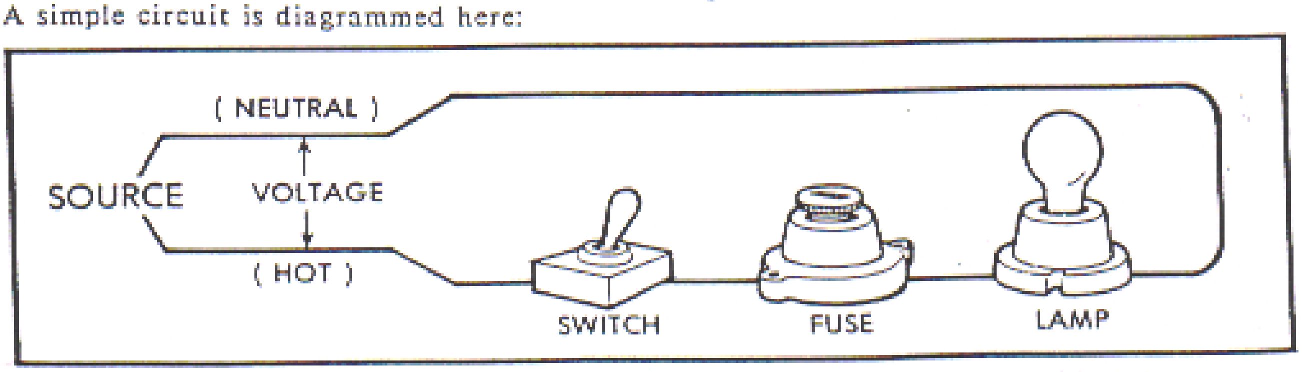
(2) $(\text{WATT-HOURS} = W \times \text{HOURS})$ $\quad \text{WATT-HOURS} = 600 \times 10$ $\quad \text{WATT-HOURS} = 6000$

(3) $(\text{KWH} = \frac{\text{WATT-HOURS}}{1000})$ $\quad \text{KWH} = \frac{6000}{1000}$ $\quad \text{KWH} = 6$

(4) $(\text{COST} = \text{KWH} \times \text{RATE})$ $\quad \text{COST} = 6 \times 8$ $\quad \text{COST} = 48$ CENTS

5. Electrical Circuits

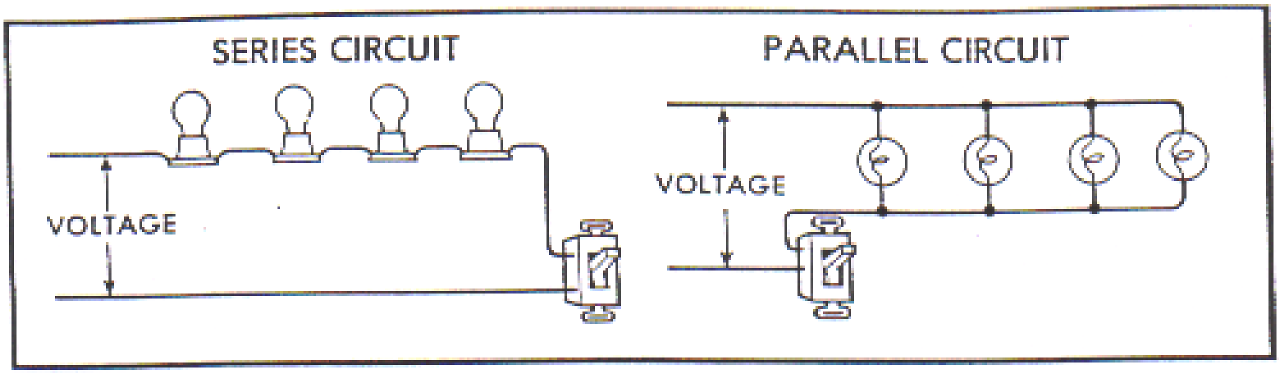
An electrical circuit is a completed path through which electricity flows. Insulated conductors (wires) provide the path for the flow of electricity. A water system and an electrical circuit are similar in many respects. Water flows through pipes and is measured in gallons per minute, and electricity flows through conductors and is measured in amperes. A simple circuit is diagrammed here:



A circuit includes a "hot" wire (red or black) carrying current from the source through a switch, circuit protector (fuse or circuit breaker), and an appliance. The neutral wire (white) conducts the current from the appliance to the source (ground).

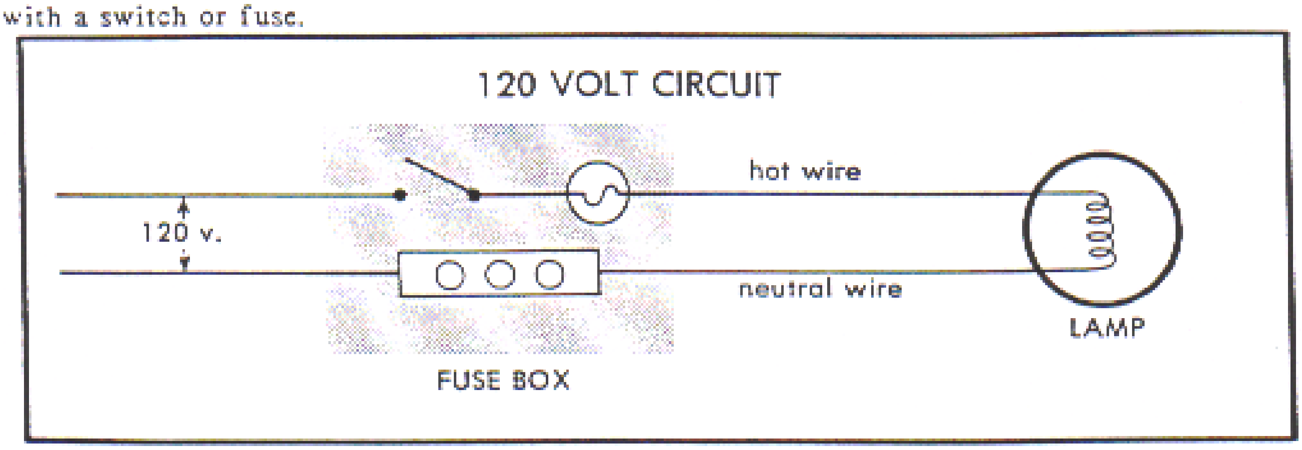
There are two methods for connecting devices in a circuit--series and parallel. In a series circuit all the current must flow through each device in the circuit. Removing or opening any one of the devices in the series circuit will stop the flow of current. In parallel circuits the load (lights or appliances) are connected between the two wires of the circuit providing an independent path for the flow of current, and removing a lamp has no effect on the other lamps in the circuit.

Switches, fuses, and circuit breakers are always connected in series. In most cases, except for some Christmas tree lights, appliances and lights are connected in parallel.

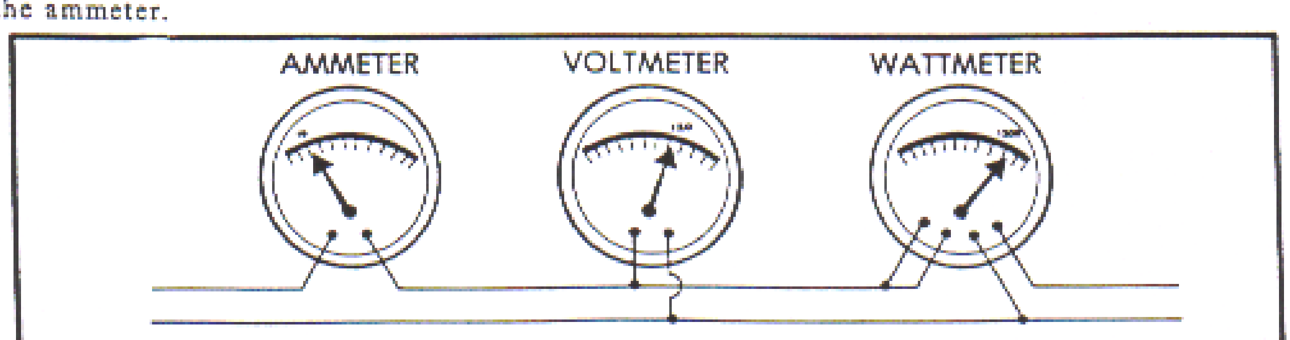


6. **120 Volt and 240 Volt Circuits**

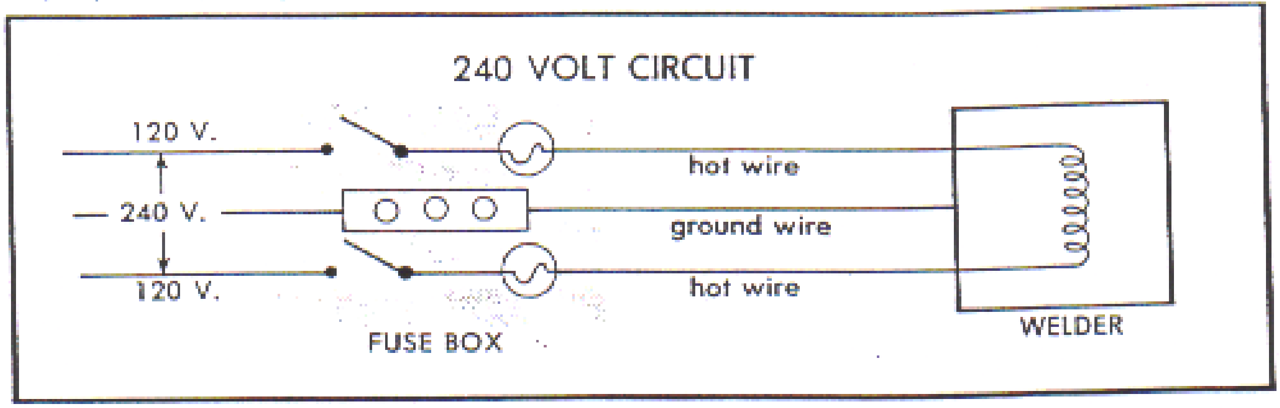
The 120V circuit has one "hot" and one neutral wire with the switch and circuit protector in the hot line. The neutral wire from the appliance is connected to the neutral bar in the fuse or breaker box. For safety, the neutral wire should never be broken or interrupted with a switch or fuse.



The voltage in a 120V circuit is measured with a voltmeter with one lead on the hot terminal and the other lead on the neutral bar. The number of amperes flowing may be measured with a clamp-on ammeter by encircling the hot or neutral wire with the jaws of the ammeter.



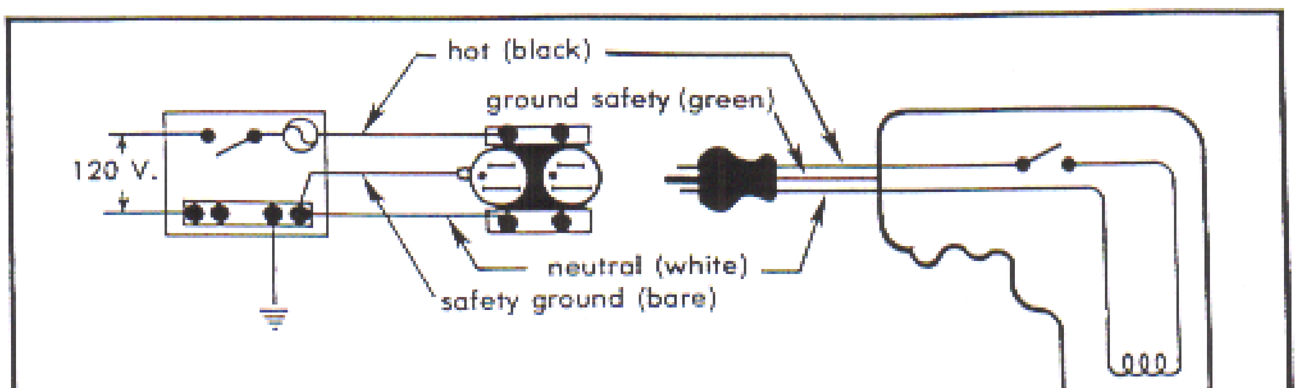
The 240V circuit has two hot wires and one safety-ground wire. Switches and fuses are installed in the hot lines. The two hot wires are necessary for the operation of 240V welders and motors. The safety-ground wire, connected to the metal frame of the equipment or motor and to the neutral bar, does not carry current unless a "short" develops in the motor or welder. If a short should occur, one of the circuit protectors will burn-out or open, thus opening the circuit.



The voltage on a 240V circuit is measured by fastening a lead on the voltmeter to each of the hot wires. Voltage between either hot terminal and the neutral bar will be one-half of the voltage between the two hot wires. The number of amperes flowing can be measured by clamping an ammeter around either of the hot wires.

7. **Safety Grounding Electrical Equipment**

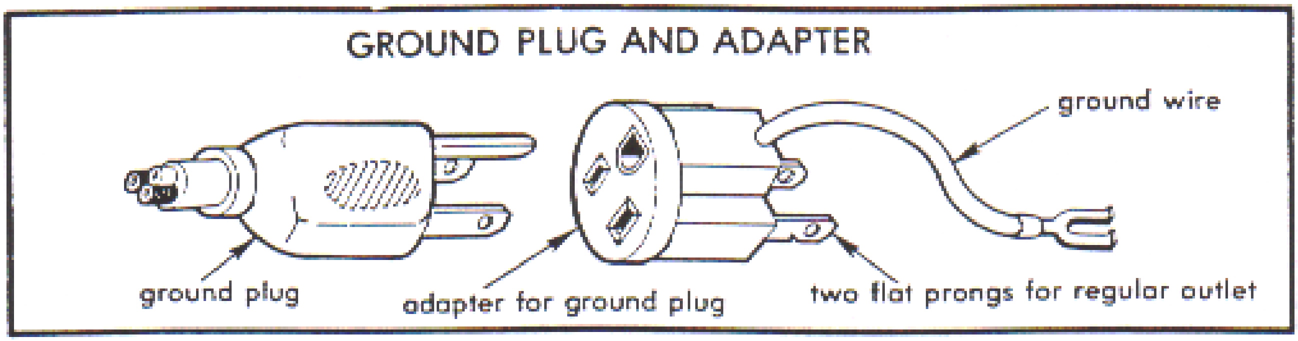
Refer back to the 240V circuit and note the ground wire from the metal frame to the neutral bar. The following illustration shows proper safety grounding when operating a drill in a 120V circuit. The safety-ground wire may be bare, but a three-wire romex is recommended. Safety-ground wire in three-wire romex is usually green in color. A current-carrying neutral wire should never be used for a safety-ground. Likewise, a safety-ground wire should never be used as a current-carrying hot or neutral wire.



SAFE-3-WIRE-GROUNDED

If short occurs, fuse will blow and open the circuit.

Using grounded receptacles and a safety-ground on all circuits will allow the safety-grounding of appliances when they are plugged into the outlet. An adapter must be used to properly ground appliances connected to receptacles not safety-grounded. If an adapter is used, the green pigtail wire must be connected to a known ground to give protection from electrical shock should a short occur.



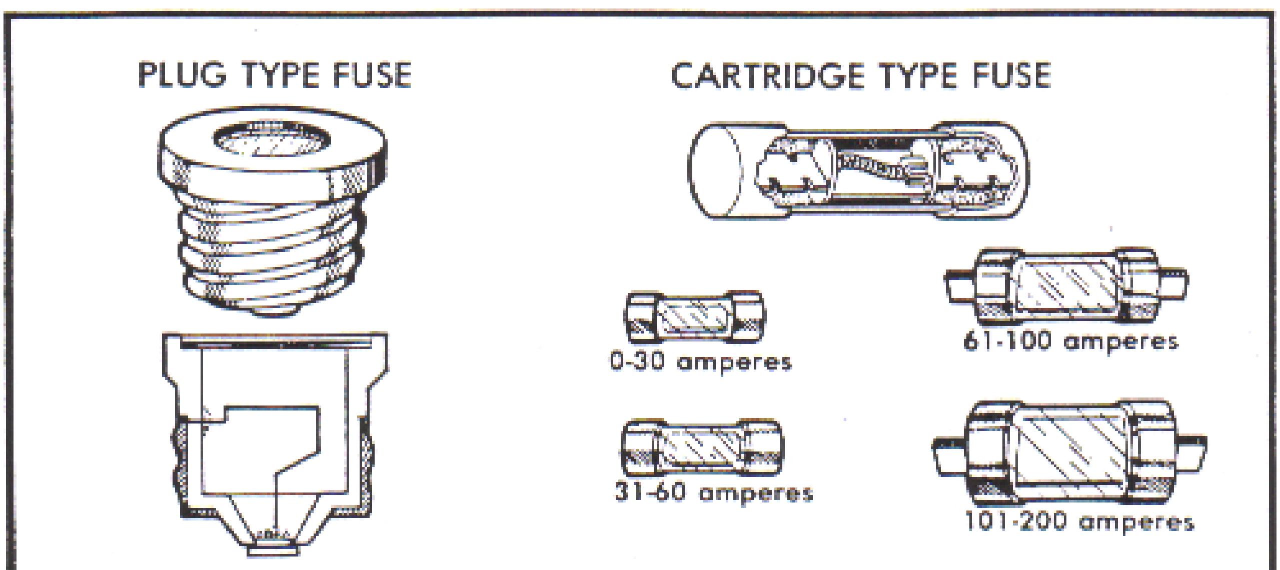
A test lamp can be used to check a circuit completed between a "hot" wire and a neutral wire. Use the test lamp to check appliances for shorts. With the appliance plugged into an outlet, touch the appliance frame with one lead of the test lamp while the other lead of the test lamp is grounded to a water or gas line. If the test light does not burn, reverse the appliance plug and check with the test lamp again. If the light burns, a short exists. (Hot wire is touching the frame of the appliance.) Unplug the appliance and repair or discard it.

8. **Electrical Circuit Protection**

Electrical circuits should be protected from an overload of amperes. Too many amperes flowing through an unprotected circuit will generate heat, which will deteriorate or melt the insulation and possibly cause a fire. The number of amperes that a given conductor can carry safely depends upon the kind and size of wire, type of insulation, length of run in feet, and type of installation. Charts are available in reference texts giving allowable current-carrying capabilities of various conductors.

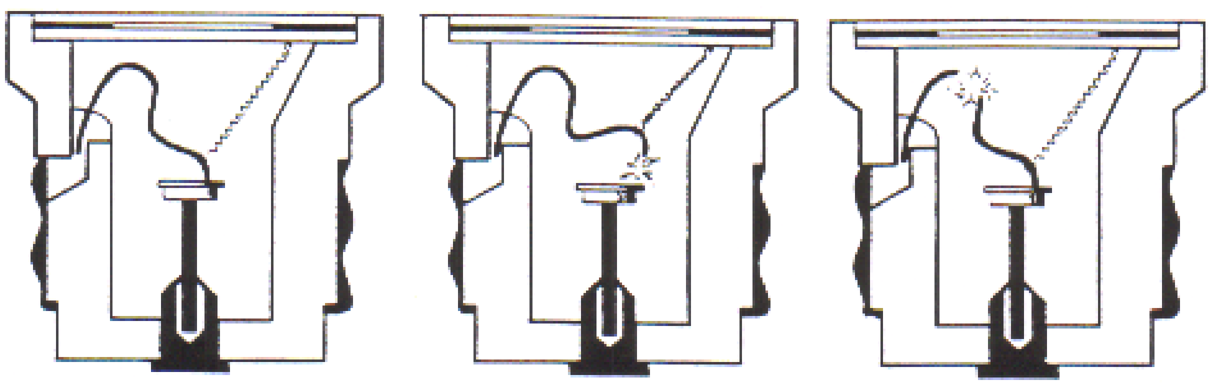
The four types of circuit protection are common fuses, fusetrons (time-delay), fustats (two-part time-delay), and circuit breakers. Fuses are of two basic types, plug and cartridge.

Common fuses contain a link made from a low melting alloy which is designed to carry current up to the rating of the fuse. Current higher than the amperage rating causes the link to heat above its melting point. When the fuse "blows", the link melts and opens the circuit.



Fusetrons (time-delay fuses) are made to carry a temporary overload, such as the overload caused by the starting of an electric motor. The fuse, however, still provides protection for the circuit, and a short circuit will melt the fuse link. If a common fuse is used, the fuse link will melt every time an electric motor starts. The use of a larger ampere common fuse will prevent the "blow" resulting from the temporary overload, but will not provide protection for the motor or the circuit.

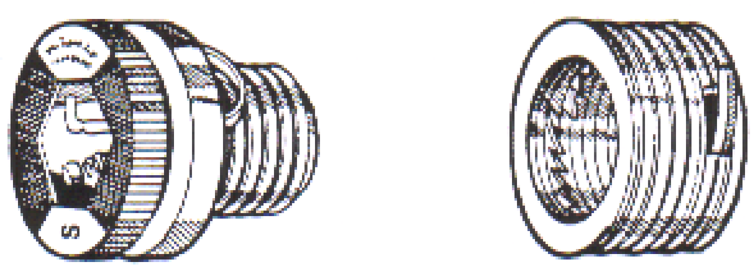
OPERATING PRINCIPLE OF DELAYED ACTION FUSE



TIME DELAY CONTINUED OVERLOAD SHORT CIRCIUT

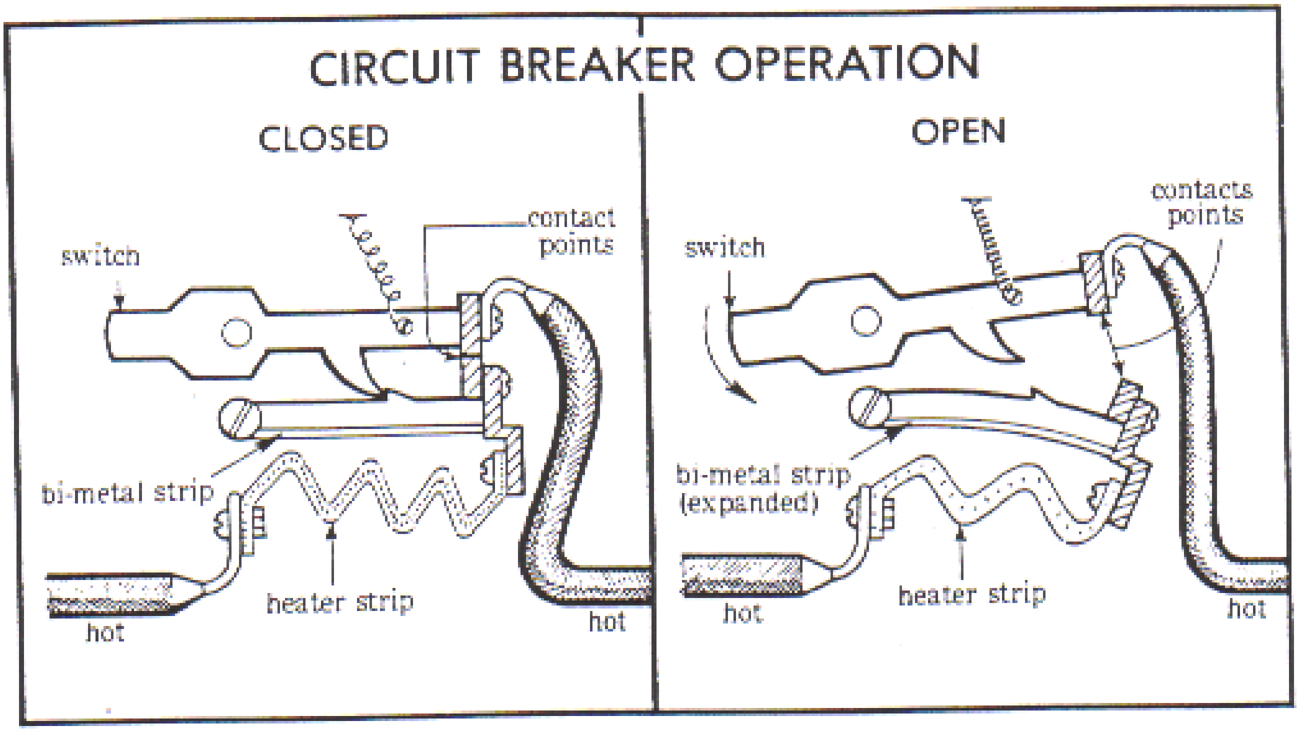
Fustats, nontamperable fuses of the time-delay type, have a different size base and require a special adapter that is screwed into the standard fuse socket. After the adapter is installed, it cannot be removed. For example, the installation of a 15-ampere adapter allows only the use of 15-ampere or smaller fuses.

FUSTATS



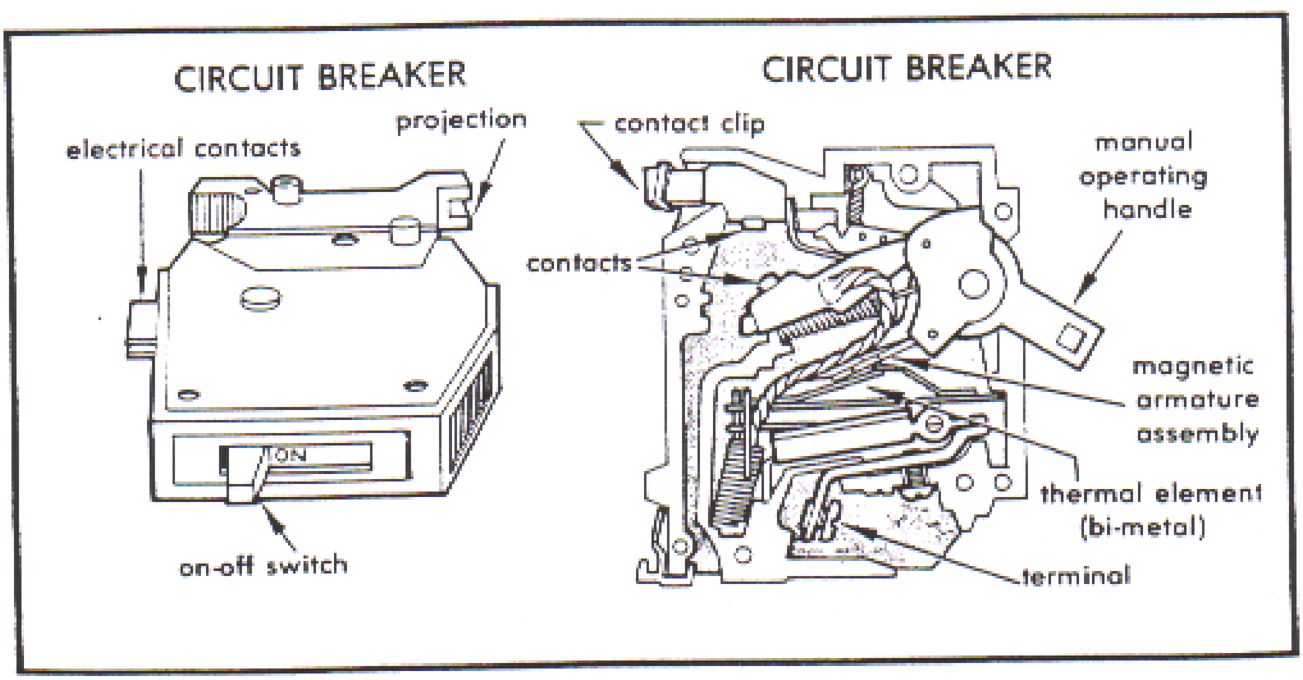
FUSE ADAPTER

Circuit breakers eliminate the replacement of fuses and are commonly used even though a circuit breaker box costs more than a fuse box. Circuit breakers are of two types, thermal and magnetic. The thermal breaker has two contacts held together by a bi-metal latch. An overload of current causes the bi-metal strip to become heated, the latch releases, and the points spring open. After the bi-metal strip cools; the switch is reset; and service is restored.



The magnetic breaker has contacts that are held together by a latch which is released by the action of an electromagnet. The amount of current flowing through the circuit will determine the size of the electromagnet. This type of breaker is reset by moving the toggle switch to the "on" position.

The following diagram shows the parts of a circuit breaker.



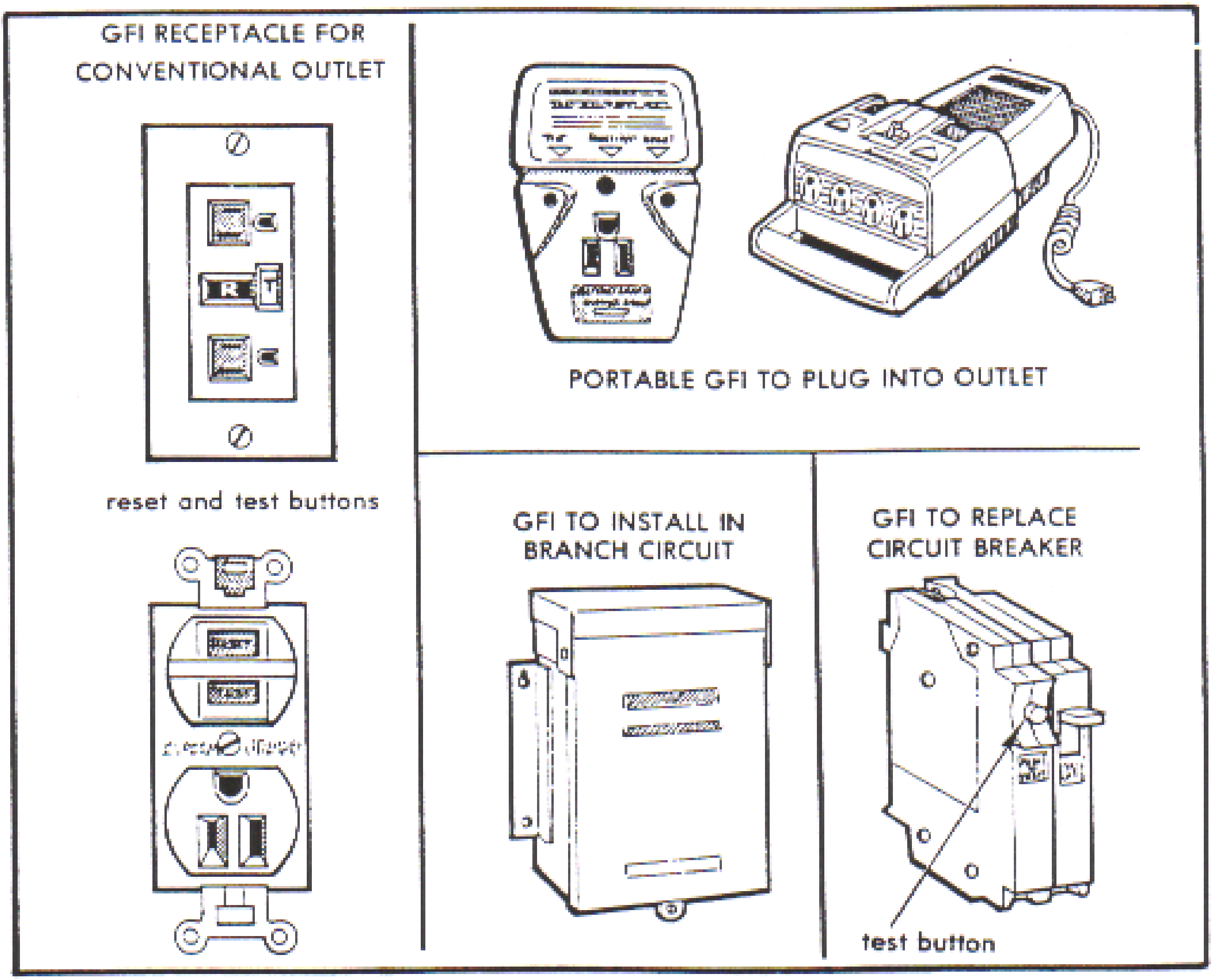
9. **No Fault Grounding**

Fuses and circuit breakers are safety devices which limit current (amperage) in a circuit. Their main function is to protect equipment and wiring from overload. Ground fault circuit interrupters (GFI) are designed to protect humans, equipment, and/or electrical systems from injury or damage if electricity flows in an unintended path (a short).

A GFI is a very sensitive device that functions by comparing the current moving in the "hot" wire with that in the neutral wire. If these two currents are not equal, a fault exists, and current is "leaking" out of the circuit. If the difference in current between the two wires is 5/1000 of an ampere or greater, the GFI will open the circuit, shutting off the power and eliminating any shock hazard.

The National Electrical Code requires GFI's for all 120V, single phase, 15 and 20 amp receptacles installed outdoors, in bathrooms, and in garages for residential buildings. A GFI is required at construction sites and some other applications. After correcting the circuit fault, the GFI may be reset for further use.

A variety of GFI equipment is made for 120 and 240 volt circuits.



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