A HOMEOWNERS HANDBOOK

By Everett H. Rawlings

ELECTRICAL

Electricity in the home plays a critical role in our lives. From activating our alarm clock in the morning to all aspects of our lives for the rest of the day; providing refrigeration for our food, household lighting and powering most of our appliances, tools and devices. Our very existence is dependent on the safe and convenient availability of electricity.

Most electrical codes are based on the "Model Code" - the National Electrical Code (NEC.) The NEC is published by the National Fire Protection Association based in Quincy, MA. The NFPA has acted as sponsor of the National Electric Code since 1911. Most electrical codes in local jurisdictions are based on the NEC which is the nationally recognized standards of electrical practices. It is updated and revised generally (since World War II) every three years after extensive and thorough review to include new standards or products. Local and regional jurisdictions adopt the NEC by reference and then modify and amend it to suit the local conditions.

Electric power is produced by electrical generators (coal, gas, oil or biomass fueled, nuclear, solar or hydroelectric.) This power is produced as alternating current (AC) at 60 Hertz and about 15,000 to 20,000 volts. Alternating current flows through a circuit in one direction and then alternates to flow in the other direction; this constitutes as a cycle. The number of cycles per second is the frequency, which is measured in Hertz (Hz.) A frequency of 60 Hz has been accepted as a standard throughout most of the United States while 50 Hz is generally used internationally.

Transformers may step-up the voltage at the generating plant from 120,000 to 500,000 or so volts for transmission over long distances. This high voltage is first reduced at substations to 130,000 or so volts and then to about 13,000 volts in most residential neighborhoods today. Transformers are either located on poles where overhead electrical service is present, or in steel boxes on the ground where underground electrical service is provided which further reduce the voltage to 120/240 single phase for most residential applications. Single phase service consists of three wires entering the building providing 120/240 volt service. Three phase service is more commonly found in commercial buildings and consists of four wires entering the building. In rural areas and older neighborhoods the utility company provides power to the home through overhead conductors. In urban areas and newer neighborhoods the power comes to the house or building underground. In very old installations there may only be only two conductors serving the building providing 120 volt service. If you can adopt a 1920's lifestyle you should be very happy with this inadequate arrangement.

Volts:

Electrical pressure is measured in volts in a similar way that water pressure is measured in pounds per square inch (PSI.) Most small appliances and general lighting circuits throughout the home operate on 120 volts. Larger appliances, air conditioning units, water heaters, clothes dryers and ovens require 240 volt power. Voltage is not governed by wire size. For instance a relatively small 14 American Wire Gage (AWG) wire used for general lighting circuits throughout a home carries the same 600 volt rating as a large 2/0 AWG entrance cable bringing the power into the home.

Amperage:

Electrons flowing through a wire or conductor are measured in terms of amperage. The greater the rate of flow the higher the amperage will be. In order to raise the rate of flow of electrons, the wire size must be increased. Thus a smaller conductor will have a lower amperage rating. About the smallest wire size used in general lighting circuits in a home is 14 AWG (American Wire Gauge) rated at 15 amps. A modern house will have at least 100 amp, 120/240 volt service. Larger more complex homes will have 200-300 amp service and very large homes may have 600 or more amps service. Homes built prior to the 1930's or so may only have 30 amp, 120 volt two wire service. Through the 1950's many smaller homes were built with 60 amp, three wire 120/240 volt service, especially those with few major electrical appliances.

Watts:

Wattage is the product of volts times amperes or W = VA. Watts are used to rate electric power in terms of total energy consumed. One watt used for one hour equals one watt hour; one thousand watt hours equals on kilowatt hour. Payment for electric power is based on kilowatt hours, thus when one thousand watts are used for one hour, one kilowatt hour of electric power has been used. The electric meter records the amount of wattage used in the home and the utility provider charges accordingly. The meter belongs to the power company.

Main Service Panel:

Once electricity is carried beyond the meter and enters the home it is distributed to receptacles, general lighting circuits, switches and appliances throughout the home. Older homes built prior to the 1960's will likely contain main panels containing fuses, while newer homes will most likely have main panels with circuit breakers. Fuses are perfectly safe and acceptable, although breakers are more convenient. The purpose of these overcurrent devices is to keep the current in a wire at a safe level, and if overloaded will "blow" or "trip" and break/open the circuit. Main panels may be mounted outside the home near the meter but more commonly are located inside the home on a wall in the garage, kitchen, utility room or a hallway. The main service disconnect breaker controls the maximum amperage and shuts off all the power to the home. It may be located in a service disconnect panel near the meter and/or very commonly are located inside the main panel. The maximum amperage that the main breaker can carry is marked on the breaker. In modern electrical installations the main panel receives three incoming current carrying conductors and routes smaller cables to secondary sub panels, major appliances and general lighting circuits, receptacles and appliance circuits throughout the home. Two large "hot" wires from the meter are attached to two lugs usually at the top of the main panel and attached to metal strips called buss bars and pass it along to secondary breakers. These two large wires carry 120 volts to each buss bar and sub panels and heavy appliances then pick up 120 volts from each buss bar providing 240 volt service. The third entrance cable is the neutral and is attached to another buss bar called the neutral and all electric circuits are connected to this bar by way of the neutral conductors in the various circuits. Older terminology referred to voltage as 110 or 220 volts. That terminology sort of went out with high button shoes, but is still in common usage. The power company attempts to deliver electric service to homes and businesses at 120 or 240 volts but fluctuations occur throughout the day depending on demand on the grid. Minor voltage changes (plus or minus 10%) will not generally be noticeable or harmful.

Federal Pacific Service Panels:

Federal Pacific Electric Stab-Lok main disconnect panels and breakers were manufactured by Federal Pacific Electric (FPE) from the 1950's until about mid 1980. Some FPE circuit breakers when tested under proper protocol have been shown to fail to trip at their rated amperage. Breakers that do not trip are a fire and safety hazard. In published reports of independent research and in Consumers Product Safety Commission (CPSC) sponsored tests a significant portion of circuit breakers manufactured by FPE failed to trip properly under overload or short circuit conditions. In some cases these breakers failed to trip 60% of the time. There is a substantial amount of data and information available that indicates a serious problem exists.

The author's position is that the presence of a Federal Pacific Electric panel in a home is a safety hazard. The breakers in these panels are of questionable operating reliability. A visual inspection of the panel and the breakers generally will not reveal any defects. Even random testing by tripping each breaker will not likely reveal any problems.

For further information go to WWW.Federal Pacific Electric FPE Stab-Lok Panel Circuit Breaker Hazard.

Aluminum wiring:

According to the Consumers Product Safety Commission (CPSC) more than 1,500,000 homes were built between 1965 and 1973 using aluminum wiring for the lower branch circuits that may create fire hazard conditions. Many other homes were remodeled or added-on during this same period and possibly beyond 1973 because of electrical wiring still available in hardware stores or electrical supply outlets. Many home fires have been related to the use of aluminum wiring. Because aluminum expands and contracts at a greater rate than copper or brass the wire connections could become loose. Heat is generated at loose connections and in some cases fires have resulted. The CPSC research has shown that houses with old technology aluminum wire manufactured before 1972 are 55 times more likely to have one or more connections reach fire hazard conditions than is a home wired with copper wire. The hazard occurs at connections at the outlets, switches and ceiling light fixtures because of dissimilar metals. Improper connections can create electrical resistance and overheating which can cause fires. Connections at these locations have been reported to fail without any previous indications of problems. **Where aluminum wire is present a qualified electrician should review this potentially dangerous system and make necessary repairs.**

Electrical Circuits:

An electrical circuit is a complete loop. Electrical circuits carry power from the Main Service Panel, throughout the house and back to the main service panel. Several receptacles and switches or appliances may be connected to a single circuit. A microwave oven generally uses a lot of wattage and therefore will likely be on its own circuit. Also, dishwashers, garbage disposers and refrigerators are usually wired in modern homes with their own individual circuits. Current travels through the hot wires and returns on neutral wires. Hot wires are black or red (or any color except green) and neutral wires are white or gray. For safety most circuits include a bare copper or green insulated grounding wire. The ground wire conducts current in the event of a short circuit or overload and helps reduce the chance of a severe electrical shock. The ground wire travels back to the main service panel which is connected to a ground wire to a metal water pipe and a driven ground rod into the earth buried outside - usually below and near the meter.

Ground Fault Circuit Interrupter:

GFCI (Ground Fault Circuit Interrupter) receptacles are a wonderful electrical safety device. They protect against an electrical shock. The device senses an imbalance (any loss of current) in the flow of current if there is a ground fault (a short) and immediately (in a fraction of a second) shuts off the electricity at the receptacle. GFCI receptacles and/or circuit breakers have been required by the National Electrical Code (NEC) in specific locations since 1973.

Most local regulations follow the NEC and these jurisdictions having authority have adopted the NEC proposals over time. The author recommends upgrading by installing GFCI protected receptacles in all locations required by present standards. This includes locations in outdoor receptacles (since 1973,) bathrooms (since 1975,) garage wall outlets (since 1978,) kitchen locations within six feet of the sink (since 1987,) and more recently all receptacles serving the kitchen countertop, bar sink locations, unfinished basements and crawl spaces (since 1990.) They are also commonly utilized for equipment such as sump pumps, whirlpools, spas and pool equipment.

GFCI's have two basic forms for residential applications: receptacles with test/reset buttons and electrical panel circuit breakers and either form is effective in protecting appropriate outlets and fixtures. Most receptacle type breakers can be installed so that they protect other electrical outlets further downstream in the branch circuit. The Consumers Product Safety Commission (WWW.cpsc.gov) recommends you consider upgrading unprotected receptacles in areas where GFCI protection is presently required. **A qualified electrician should do the work.**

It is recommended A GFCI be used wherever operating electrically powered garden equipment (mower, hedge trimmers, edger etc.) Homeowners can obtain similar protection by using GFCI's with electrical tools, (drills, saws, sanders, etc,) for do-it-yourself work in and around the house. Portable GFCI units are available in situations where there are no built in GFCI protected receptacles. The portable GFCI needs no special knowledge to install. Just plug the portable GFCI into a wall receptacle and then plug the electric power tool into the GFCI.

Arc Fault Circuit Interrupter:

Arc Fault Circuit Interrupters (AFCI) are circuit breakers installed in new or existing main panels in the home. Arc faults can occur anywhere in the home. AFCI breakers have been required by the National Electrical Code (NEC) since 2008. Your town or city or local jurisdiction may not have adopted this requirement. A nail from a picture hanger can puncture wiring in hidden areas of the wall, an improperly installed switch or wall outlet or ones with loose connections, damaged table lamp cords or extension cords can cause an arc fault causing a house fire. Arc faults are small sputtering electrical sparks that can reach very high temperatures, igniting wood, carpet and other nearby combustibles. Regular circuit breakers will not likely detect a problem. An AFCI breaker protects your home from a house fire. When the AFCI breaker detects an arc fault of large enough magnitude, it will trip the breaker.

Presently, AFCI breakers are only required for circuits serving bedrooms. Bedrooms are typically the farthest away from the main panel. Many house fires are associated with electrical problems. The AFCI may prevent many of these house fires. If your home is not equipped with AFCI's - consider upgrading. **A qualified electrician should do the work.**

Ceiling Paddle Fans:

Ceiling paddle fans offer several special hazards around the home. Properly installed fans can reduce energy costs by circulating air and improving comfort. Unprofessional installations can lead to serious electrical shock hazards or safety hazards due to an improperly installed fan coming loose and falling.

An ungrounded ceiling fan is not connected to the electrical ground system. Modern residential electrical systems are wired with three conductors. There is a hot wire carrying the current, a neutral wire and a ground wire. Properly wired fans will have all three color coded wires connected to the appropriate factory installed fan wires. If the ground wire is loose or not connected a potential electrical shock hazard exists. An ungrounded fan rarely causes a serious shock or fire, but they increase the chance. **This condition should be corrected by a qualified electrician.**

Another serious problem that can occur with an improperly installed ceiling fan is one that happens when an improper ceiling electrical junction box is used. Specially engineered and designed fan mounting junction boxes should be used for this purpose. Standard electrical boxes are not to be used to support a ceiling fan. A listed fan junction box can be used to support a fan up to 35 pounds. Fans over 35 pounds require independent support. Unprofessional installations can cause a ceiling fan to come loose and become a revolving projectile.

Ungrounded Electrical Outlets:

Every electrical system must be grounded so that a short circuit, frayed wire, faulty appliance, or a voltage surge caused by a lighting strike, the electricity will be harmlessly discharged into the earth, rather than into the house system or a person. The grounding system is primarily designed with electrical safety in mind.

System grounding (earthing) is achieved by connecting the neutral wires from all the electrical circuits to a metal strip (neutral buss bar) in the main service panel, which in turn is generally connected by a heavy duty wire to a rod driven into the earth or a cold water pipe which goes into the earth. In most cases both means are used so that the building plumbing system within the home also is grounded and thus also provides a ground for metal fixtures such as faucets, sinks and bathtubs.

From the early 1920's to about the mid 1950's homes were wired with two single conductors and a ceramic tube was then used at the framing penetrations such as floor joists or ceiling rafters and a ceramic knob was used when the wires changed direction and also for keeping the wires spaced away from direct contact with the joists or rafters. Knob and tube wiring was exposed "in free air" and ran along the sides of the framing members. Knob and tube wiring may still be used if in service, but most local jurisdictions require that it be removed when the electrical system is remodeled. The insulation on the wiring was a rubberized cloth called "loom" and the splices were wrapped with electrical tape. Over time the insulation becomes brittle and deteriorated and may be missing in spots. The original spices were made by removing a portion of the insulation and wrapping the spliced wire around the original wire and soldering it in place and then wrapping the splice with cloth electrical tape. Any splices or modifications to the original wiring are not permitted. In older homes knob and tube wiring is often found in obscure portions of the attic or basement but may in fact be disabled and abandoned - just not entirely removed. **Knob and tube wiring is an ungrounded and an ungroundable system and is therefore more hazardous than a grounded system.**

The National Electric Code (NEC) in 2002 addressed the issue of knob and tube wiring, "Concealed Knob and Tube Wiring, Uses Not Permitted."

"Concealed knob and tube wiring is designed for use in hollow spaces of walls, ceilings, and attics and utilizes the free air in such spaces for heat dissipation. Weatherization of hollow spaces *by blown-in, foamed-in, or rolled insulation prevents the dissipation of heat into the free air space. This will result in higher conductor temperature, which could cause insulation breakdown and possible ignition of the insulation."*

Thus weatherized homes should not have active knob and tube wiring in use and therefore modern homes should not have any knob and tube wiring.

Prior to the early1960's our homes were provided with two prong ungrounded outlets including those homes wired with knob and tube conductors. Modifications to ungrounded outlets can be made by installing three prong outlets and attaching a piece of copper wire to the grounding connection on the three prong outlet and attaching the other end to a cold water pipe.

A modern home will have all grounded three prong receptacles with GFCI protection in appropriate locations.

Reversed Polarity:

Modern electrical receptacles in a home have three slots. The smaller slot is for hot, the larger slot is for neutral and the lower "U" shaped slot is for ground. Reverse polarity occurs when the hot terminal is hooked up to the neutral and the neutral terminal is hooked up to the hot and thus the wires are reversed. It can be a hazardous condition when the hot side of the electrical system is connected to certain types of lamps or equipment. Home repair persons and even professional electricians sometimes make the mistake of hooking the black (hot) wire to the silver terminal on a receptacle and the white (neutral) wire to the brass terminal.

Any downstream receptacles in the circuit will be affected.

