THE COMPONENTS OF ELECTRICAL SYSTEMS
CHAPTER 1: ELECTRICITY BASICS

Course Overview

We encourage our customers to visit the [FAQs section](#) for further information regarding your educational experience. They have complete step-by-step tutorials that we've designed with YOU in mind!

Please note: Upon completion of the final exam, you will need to advance to the survey page and complete the survey. Once that is done, the course will be marked as "Complete" in our system and credit may be issued.

Course Description

For most, living in a home without electricity, or another power source, is unimaginable. In such a house, all of the appliances that make living more convenient would be useless. This house has no lights at the push of a button or flip of a switch; no refrigerator to keep food and drinks cool; and no radio, television, or computer.

Because so much of the home is affected by electricity, the home inspector must have a basic understanding of electricity. As always, safety is of paramount importance when dealing with this potentially dangerous form of power.

Learning Objectives

After completing this Unit, you should be able to:

- Identify basic electrical concepts and components.
- Recognize how electricity is generated, transmitted, and delivered.
- Describe elements of inspecting the service box or service panel, including electrical protection devices, grounding, and bonding.
- Identify methods of wiring.
- Explain aspects of inspecting electrical fixtures.

Electricity Basics

According to the first law of thermodynamics, energy can neither be created nor destroyed. It can only be changed from one form to another. In order to produce electricity, one must begin with some form of energy—such as heat, kinetic, radiation, or nuclear—and convert it to electricity.

Measuring Electricity

In order to understand the characteristics of electricity, a home inspector should know terms that relate to measuring it. There are four basic quantities of measurement within the electrical industry: current, voltage, resistance, and power.

Current

Current is a measurement of the flow of electrons in a designed path. Current is measured in amperes or, more commonly, amps or amperage. The electrical current that flows through a wire is dependent on the electrical potential (voltage), the diameter of the wire (gauge), and the type of wire used (the resistance to flow). Electrical current can be measured by an amp meter, which utilizes magnetic waves to obtain the reading.

The service amperage rating of any home is limited by the smallest of: the service conductors (service entrance cables), the main disconnect fuse or circuit breaker, or the capacity of the electric panel itself. A home inspector should inspect all three of these components and report any inconsistencies. Each factor will be discussed in greater detail later in the unit.

Voltage

Voltage is the force that propels electricity through a circuit, analogous to the pressure in a water hose. For electricity to traverse a circuit, it requires this pressure or force. Voltage is also referred to as potential or electromotive force. In a water system, potential is evident through a pump or the elevation of the water. Similarly, in electrical circuits, the driving force for current is derived from a battery or electrical generator, just as the potential in a water tank prompts water to flow through pipes at lower elevations.

Resistance to Flow

Resistance serves as the impediment to the flow of electricity within a circuit. The higher the resistance impeding the electric flow, the more heat is produced. Excessive resistance can lead to the generation of enough heat to trigger fires. All materials exhibit resistance, with those possessing low resistance being termed conductors. Conductors facilitate the flow of electricity from power generation points or power plants to homes. On the other hand, materials with high resistance to electrical flow are classified as insulators.

The unit of measurement for resistance is ohms, typically associated with the load upon which the current is acting. Electricians employ formulas to ascertain the appropriate proportions of each of the four quantities when designing circuits.

These formulas are known as the Ohm's Law formulas. Ohm's Law is used to express and calculate the relationship between voltage, resistance, current, and power. In the following formulas, V = Voltage (volts), R = Resistance (ohms), and I = Current (amps).

Basic Formulas for Voltage, Resistance, and Current

1. $V = I \times R$
2. $R = V \div I$
3. $I = V \div R$

Ohm's Law also accounts for the calculation of power. In the following formulas, P = Power (watts), I = Current (amps), and V = Voltage (volts).

Basic Formulas for Power

1. $P = I \times V$
2. $I = P \div V$
3. $V = P \div I$

Since all of these formulas contain three quantities, if two of the three values are known, the third quantity can be calculated.

Power

Power is the quantity of energy that is used or converted to another form of energy, such as heat or light. The rate of power used is measured in watts. Watts are the measurement of the actual amount of electrical force that is available to do work. It is a function of both amperage (quantity) and voltage (pressure). The mathematical formula for calculating wattage is volts × amps. A 15-amp circuit at 120 volts produces 1,800 watts of power (15 × 120 = 1,800). Devices like an electrometer can measure the number of watts in an electrical circuit.

Direct Current and Alternating Current

Electricity comes in two types: direct current (DC) and alternating current (AC).

Direct Current

In direct current electrical circuits, the current flow is constant in one direction from negative to positive potential. A battery delivers direct current.

Alternating Current

Alternating current (AC) is a type of distribution system that allows the current to flow in two directions in cycles. In the first half of the cycle, the current flows in one direction. In the second half of the cycle, the current flow reverses and travels in the opposite direction. As the current flow reverses in the cycle, the polarity of the line also changes from a positive to a negative potential. The rate at which the flow of electricity is reversed is called the frequency. In the United States, 60 cycles per second is the standard. The unit for measuring frequency is hertz.

Alternating current, rather than direct current, is used in houses. One advantage of AC power is its ability to change voltage by using a transformer. A transformer is a device that is capable of changing electrical voltage from one value to another. This allows the power plant to ship the electricity at an extremely high voltage that is efficient for transmission, and then step the voltage down to a safe and practical level for residential use.

Electrical Circuits

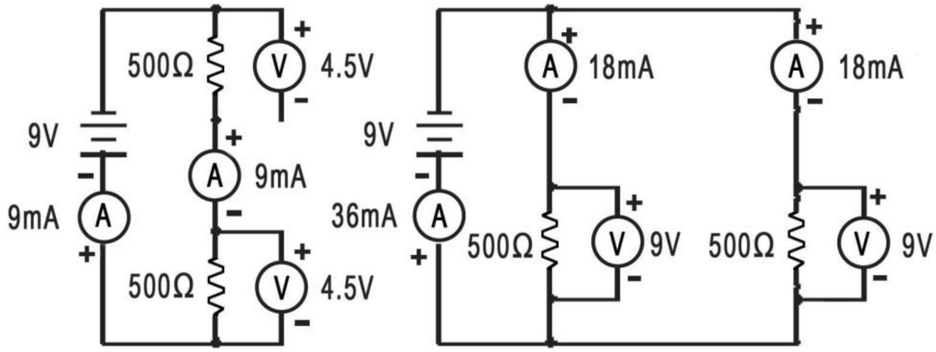
All the electrical quantities of measurement interact within an electrical circuit. An electrical circuit is a closed-loop pathway in which electricity flows continuously. The components in an electrical circuit may be connected together either in series or parallel.

Series Circuit

Components are connected in series if two or more of them are connected end to end. In a series circuit, there is a single path for current through all the components. The electrical current flows through all the loads sequentially. In this case, if one load fails, an open circuit is created, and all the loads will be de-energized as the flow is cut off in the entire circuit.

Parallel Circuit

If two or more circuit components are connected like the rungs on a ladder, they are connected in parallel. A parallel circuit has a different path for current through each component and provides the same voltage across all components. The current flows through all loads simultaneously and the failure of one load does not affect the others.



Complete Circuit

For electricity to operate a household item, like an appliance or a light, a full circuit is essential. This circuit comprises an energy source, an electrical load, and a continuous path from the energy supply to the load, and then back from the load to the supply to close the circuit (or loop). Any disruption in this path, such as an open switch or a severed wire, hinders the flow of electrical current. In such instances, a complete circuit is absent. It's crucial to recognize that the wires facilitating the flow by linking the source and the load are also referred to as circuits.

Electrical Source

The energy source is the place from which the electrical energy is supplied. This can be a storage battery, a power transformer, or a solar panel. Every electrical source has two terminals: one positive and one negative. The negatively charged electrons congregate at the negative terminal. Because all of these electrons have the same negative charge, they repel each other and generate electrical pressure at the negative terminal, which pushes the electric flow. The flow of electricity does not occur by moving specific electrons around the circuit. Rather, electrons are pushed onto an atom of the conductor. This creates an overabundance of negative charge that pushes some electrons to another atom. This continues throughout the wire with atoms pushing electrons off to other atoms around the circuit.

At the same time, the source's positive terminal provides an attractive force for the negative electrons being pushed through the wire. Therefore, the path of electrical current flow is through a conductor. The negatively charged electrons are transported to an electrical load, such as an appliance, via this path. This is the hot leg of the circuit.

Loads

A load is anything used in a building that draws electrical power. The load is where the work happens. A load is an area of electrical resistance where the energy of electricity is converted to another form of energy, such as heat, motion, or light.

Some form of switch is installed in most circuits to allow selective operation of the load. When the switch is in the off position, there is an opening in the flow path of electricity in the circuit. This is an open circuit and does not allow work to be done. When the switch is in the on position, the closed circuit is established, and the load is supplied with electricity. After the work is done, the electrons are transported back to the positive terminal via the neutral leg.

Loads are part of the house's active system. The active system is made up of components that must have electricity to operate. Loads perform functions such as heating and air conditioning, artificial lighting, and water heating.

Active Loads

- Heating and cooling
- Ventilation
- Humidifiers and dehumidifiers
- Lighting
- Water heating
- Appliances
- Computers, copiers, and work-related electronics
- Miscellaneous items such as coffee makers, personal space heaters, and pencil sharpeners

Fixed and Variable Loads

Loads may be categorized as fixed or variable.

Fixed loads are those that are independent of the occupants and vary only minimally over time. Variable loads may be turned up, down, off, or on depending on the number of occupants and the functions they are performing. Heating and air conditioning are fixed loads, although they are not entirely fixed.

Appliances such as the coffee maker are variable loads. Lighting is also a variable load, although, in some buildings, lights are not related to occupancy even though they should be. Lighting comprises the greatest waste in the United States because lights are left on in most commercial buildings even when there are no occupants. Newer technology can reduce this waste through internet-connected timers or dimmers.

Conductors

The path is the conductor, or wire, along which the electricity flows. The flow of electricity through a conductor is often compared to the flow of water through a pipe. Conductors are used to transport electricity to the loads in the home. Certain materials are better conductors of electricity than are others. For example, metal is a much better conductor than wood.

Metal Wire Conductors

Certain metals offer almost no resistance to the flow of electrons and are the preferred materials for making electrical wire. The two most popular choices for residential metal wiring are copper and aluminum. Of these two choices, copper is by far the better conductor, but it is heavier and more expensive.

Copper Wire

Copper is one of the best conductors of electricity and is used widely for wiring in houses. The copper oxide that is produced when copper corrodes is as good a conductor as the copper itself.

In addition to the effects of corrosion, copper has a low coefficient of expansion that reduces the risk of connections loosening over time.

Reportable Deficiencies – Copper Wire

- Loose connections
- Splicing
- Fraying

Aluminum Wire

Aluminum wire was not popularized until 1965, when it was used as a substitute for copper, which was in short supply. By 1979, aluminum was no longer being installed for two reasons. First, aluminum forms a surface coating of aluminum oxide when exposed to air. Aluminum oxide is a very poor conductor of electricity. When electrical connections are made with aluminum wire, aluminum oxide forms at the connection and produces a hot spot that can cause a fire. Many home and apartment fires have been attributed to aluminum wire. The second problem with aluminum wire is that aluminum expands and contracts more than copper due to changes in temperature. Electrical connections that are made at screw terminals are subject to becoming loose with the seasonal changes in temperature. Loose electrical connections lead to overheating and fires.

Because of the problems associated with aluminum wiring, inspectors must take extra precautions when aluminum wiring is discovered in the house circuits. They should open outlet boxes and switch boxes in each room to verify that the devices are designated for use with both aluminum and copper wire. If the switch is designated for use with both types of wire, the outlet or switch has the label CU/ALR.

Another major problem with aluminum wiring is that connections become loose over time. The wire literally backs away from the connectors. This can be seen at junctions. Loose connections can cause overheated cover plates and flickering lights. Overheated cover plates and flickering lights are symptoms of loose connections or overloaded circuits.

More on Aluminum Wire

Whenever circuits have aluminum wire, the connections must be made so that the wire is not exposed to air. This can only be achieved by the use of a splicing device and method called a copalum parallel splice connector. Using a procedure called pigtailing, a short piece of copper conductor is attached to the device terminal screw. Then, the other end of the copper wire is spliced to the aluminum wire using the special copalum parallel splice. The splice consists of an insulated sleeve that has a pasty compound called anti-oxidant on the inside of the sleeve. The two wires are inserted into the anti-oxidant in the sleeve and a compression tool is used to squeeze the splice with such force that the two wires inside the sleeve are welded together to make a solid splice. The inspector should note in the report if this has not been done to aluminum wire connections.

Reportable Deficiencies – Aluminum Wiring

- Overheated aluminum wiring
- Loose connections
- Missing anti-oxidant grease
- Improper devices designated
- Improper splices

Copper and Aluminum Wire Sizes

The wires that are used to distribute the electrical current throughout a house to the various loads come in many sizes. The electrical wire must be the proper size (diameter) for the load it is required to transport. The size of the wire is determined by the ampacity of the circuit. Ampacity is the designed current carrying capacity of the circuit. For general lighting, circuits of 15 amperes are considered adequate. For kitchen counter top outlets where appliances are used, the required circuit ampacity is 20 amperes. Clothes dryers require 30 amperes and electric cook tops generally use 40 to 50 amperes.

As the ampacity increases, the size of the wire must increase. Wire size is measured in numerical gauges. The lower the gauge number, the larger the wire. Wire used in residential applications ranges from 14- to 6-gauge. Every wire size has a fuse or breaker that goes with it. Each wire also has a corresponding number of amps it can move safely.

More on Copper and Aluminum Wire Sizes

House wires are sized by a numbering system called the American Wire Gauge (AWG). The following table shows the specified breaker size and wire size for both copper and aluminum circuit wires.

Breaker Size (amps)	Copper Wire (AWG)	Aluminum Wire (AWG)
15	14	12
20	12	10
25	10	10
30	10	8
35	8	8
40	8	6
45	6	6
50	6	4
60	6	3
70	4	2
80	3	1
90	2	1/0

As you can see from the table, a copper wire of a specific size can be used for a larger fuse than an aluminum wire of the same size.

For example, a 6-gauge copper wire can be used for a 50 or 60 amp fuse, whereas a 3- or 4-gauge aluminum wire is necessary for the same fuse.

Common copper wire sizes include 8-, 10-, 12-, and 14-gauge wires. Common aluminum wire sizes include 6-, 8-, 10-, and 12-gauge wires.

For example, home electrical circuits for receptacles (plugs) and lights use 14-gauge copper wires or 12-gauge aluminum wires and are on 120-volt circuits. Circuits for 240 volts usually employ larger wires like 10-gauge copper or 8-gauge aluminum wires for powering dryers, air conditioners, water heaters, stoves, and ovens.

The use of appropriate sizes of fuses or breakers is important in homes. If a fuse or breaker is too small (underfused), it will shut off the power too soon even though there is no danger of harming the electrical circuit. This becomes very inconvenient as the homeowner must reset the circuit or replace the fuse each time this happens. If a breaker or fuse is too big (overfused), it will not shut down the power before the wires overheat. This may cause a fire or other serious damage.

Non-Metallic and Flexible Metallic Sheathed Cable

The two most popular wiring cables used for branch circuits are non-metallic (NM) sheathed cable and flexible metallic sheathed cable (BX). Non-metallic sheathed cable may have two, three, or four conductors in one cable. A NM sheathed cable may have one hot wire and one neutral wire with no ground. Or, it may have one hot wire, one neutral wire, and a bare equipment grounding wire. One other possibility is that the cable has two hot wires, one neutral wire, and one bare copper grounding wire. Neither NM nor BX is suitable for use in exposed exterior locations. These are only used in walls, attics, and crawl spaces.

Insulators

To prevent short circuits, wires must be enveloped in a non-conductive material known as an insulator. A short circuit occurs when a fuse blows or a circuit breaker trips due to the contact between a hot and neutral wire. Effective insulators, such as rubber, glass, and plastic, ensure that the flow of electricity is confined to the intended path when a wire is coated with them. Properly insulated wires protect individuals from harm when accidentally touched.

In addition to impeding the flow of electricity, a reliable insulator should exhibit resistance to corrosion, chemicals, moisture, heat, and pests.

The color of the insulation around a wire serves as an indicator of its intended use. Hot wires are denoted by black, red, or blue, while green signifies a ground wire and white indicates a neutral wire. Modern wires often feature color-coded sheathing, facilitating easier identification of the actual wire size for inspectors.

Insulators are also marked with letters and colors that convey information about their composition and intended application.

Types of Insulators

- Mineral (M)
- Asbestos (A)
- Thermoplastic (T)
- Resistance to an additional +15° C (H)*
- Nylon jacketed (N)
- Suitable for wet locations (W)
- Cross-linked polyethylene (X)
- Thermoset (formerly rubber) (R)
- Suitable for underground use (U)

**Note that the base temperature for wire is 60° C.*

The most common copper wire used is designated THHN. The THHN designation means that the wire is thermoplastic, heat resistant by an additional 30° to 90° C, and has a nylon jacket. Romex wiring has multiple THHN wires bundled together in a sheath of PVC.

Another common insulator designation, THWN, means that the wire is thermoplastic, heat resistant to 75° C (an additional 15° C), is suitable for wet locations, and has a nylon jacket.

There is a great deal of information contained in the codes printed on the insulators or cable jackets. By knowing what these letters mean, the inspector can easily determine if the proper gauge wire was used and if the insulator is correct for the conditions.

Sheathing

Sheathing covers the insulation on wires and cables. It serves as another layer of insulation and protection for the wire. Sheathing is the component that can be seen and touched in unfinished parts of the home.

Older wires had rubber sheathing. Now most sheathing is plastic. The actual markings on NM sheathed conductors state the wire gauge and the type of wires inside the sheathing.

For example, 12/3 w/G indicates that the wire is 12-gauge and that there are two hot wires, a neutral wire, and a bare copper equipment ground wire. The designation 14/2 w/G indicates 14-gauge wire with one hot wire, one neutral wire, and one bare copper equipment ground wire.

Conduit

In areas where additional protection is required or desired, wiring is enclosed in either rigid or flexible tubing called conduit or raceways. Conduit is flexible or rigid plastic or metal that houses wiring. Conduit can be made of steel, aluminum, or plastic. Conduit is available with different wall thicknesses that can be chosen depending on the application.

Rigid conduit may be made of PVC plastic, heavy-duty galvanized steel piping called rigid metallic tubing (RMT), or thin wall galvanized tubing called electrical metallic tubing (EMT). Rigid conduit must be supported at least every 10' when it is installed horizontally and within 3' of each termination at a junction box or appliance.

Flexible conduit may include spiral wound, armored sheathing (BX) over the conductors of branch circuit wires and liquid tight waterproof conduit. Flexible conduit must be supported at intervals not to exceed 4.5' and within 12" of each termination.

The conduit should be sized so the wire bundle does not fill more than 40% of its volume. Inadequately sized conduit is a deficiency.

For example, there should be no more than 360° of bend in the length of conduit that runs from one enclosure to the next. This requirement is in place to prevent damage to the insulation when wires are pulled through.

Be sure to familiarize yourself with local building codes to determine whether different requirements and standards exist in your area.

Reportable Deficiencies – Conduit

- Inadequately supported conduit
- Crimped or sagging conduit
- Loose couplings

CHAPTER 2: GENERATING AND DELIVERING ELECTRICITY

Generating and Delivering Electricity

Energy is converted to electricity by power plant generators. The generated electrical energy is sent out from the power plant, making several stops before reaching the residential, commercial, or industrial end users.

Electrical Generation and Transmission

First, the electricity goes to a transformer that increases the voltage (up to 765,000 volts) so that the electricity can be transmitted over long distances. Next, the electric current flows through the high- voltage transmission lines—large diameter wires that conduct electricity from one place to another—to a power substation. The power substation steps down the transmission voltage to between 2,400 to 13,000 volts so the end users can utilize the electricity. The electricity is delivered to the community via distribution lines, which may be above or below ground, to the transformer box. The transformer further decreases the voltage of the electricity to a value needed by the end user.

For residential use, the voltage that comes from the transformer may be 240 volts or 120 volts. The National Electrical Code® (NEC) specifies that the minimum electrical supply for a single-family residence is 120 volts or 240 volts with a minimum current carrying capacity of 100 amperes. The National Electrical Code® is a handbook published by the National Fire Protection Association (NFPA) that establishes safety standards for electrical component installations. In Europe, the voltage that goes into a home is different, which is why Americans who travel overseas have to bring converters in order to use items such as phone chargers and blow dryers.

Very old homes may still be supplied with only 120 volts and may not be grounded. The way to determine the electrical supply is to count the wires that run to the house from the transformer. If there are two wires running to the house, this indicates that the house is only supplied with 120 volts, and that there is no ground. If there are three wires that run to the house, this indicates that it is provided with 240 volts and 120 volts with a ground.

How Transformers Decrease Voltage

How is voltage converted from the 2,400 to 13,000 volts to the 120 to 240 volts of service that are needed at a house service panel? This occurs in transformers. There are two large coils of wire inside the transformer. The two coils do not physically touch each other. However, when current flows through one coil (the primary coil), it creates an electromagnetic field that affects the other coil (the secondary coil). An electric current is induced in the second coil, which is immersed in the electromagnetic field of the first. This results in voltage across the second coil. A characteristic of transformers is that the voltage that goes into the transformer can either be increased or decreased by adjusting the number of turns of wire in the two coils. The ratio of the voltage that goes into a transformer to the voltage that comes out of a transformer is the same as the ratio of the number of turns of wire in the primary coil (supply side) to the number of turns of wire on the secondary coil (outlet side).

Example on How Transformers Decrease Voltage

Example: A supply of 2,400 volts enters the transformer in order to be decreased to 240 volts. This is a reduction of voltage by a factor of 10 to 1. Therefore, the number of turns on the primary coil must be 10 times greater than the number of turns on the secondary coil. If the primary coil has 10,000 turns of wire, then the secondary coil must have 1,000 turns. If that is the case, the voltage measured across the two ends of the secondary coil will be 240 volts.

In this transformer, one can obtain 120 volts by making a connection to the center turn on the secondary coil. When this is done the number of turns of wire between either end of the secondary coil and the center is 1/20 the number of turns on the primary coil, which makes the voltage across either side of the secondary coil 120 volts.

Traditionally, the two ends of the secondary coil are connected to black and red wires. These wires are called hot or ungrounded conductors because they conduct electricity into the house. The conductor connected to the center of the secondary coil is white and is called the neutral or grounded conductor because it does not carry any electricity into the house. The neutral conductor is grounded because it is connected by a bare copper wire to the earth at the power pole. This is done to protect the utility system from lightning strikes in the same manner that a house is protected by its grounding system.

Delivering Electricity

Once the electricity has been converted to the correct voltage, it is delivered to the home in one of two ways. In older communities, the power comes through an overhead transmission line that is hung from a power pole. In newer communities, the power comes from underground lines that run to the home. In either case, the transmission lines serve as conductors.

Overhead Power Delivery

In overhead power delivery, the conductors are led from a transformer at the utility pole to the home. The group of conductors or wires that connects to the house is known as the service drop or supply drop. There is a splice, or joining of two wires, at the point where the service drop wires terminate at the house. This is sometimes known as the service point. The service drop ends at the service point.

The service point usually marks the boundary between the responsibilities of the electrical company and the homeowner. From the service point, the power enters the home system through cables that are known as service entrance cables, which connect the service point to the electric meter. From the service point, the cables usually go into a mast through a masthead. Before they enter the masthead, the cables are bent downward and then upward to form a drip loop. The purpose of the drip loop is to prevent water or melting ice that may be on the service entrance cables from running into the mast and down into the electric meter. From the electric meter, the service entrance cables go to the service box.

Inspecting Overhead Delivery Lines

When inspecting a house, the home inspector should observe several aspects of the electric service to the house. Service drop cables must pass clearly from the pole to the masthead with no interference from tree limbs and must not contact any portion of the roof surface. In addition, service drops must be at least 3' away horizontally from windows, doors, fire escapes, decks, balconies, and porches.

The drip loop must be present, and its individual cables should be separated so that they cannot rub against each other when it is windy. The bottom of the drip loop must be at least 18" above the roof. The service entrance cables must not extend more than 4' horizontally over the roof edge and there must be no more than 6' of service entrance cable over the roof. At places where service drop or service entrance cables pass over a roof, they must be above the roof by an amount that depends on the slope of the roof. For flat roofs and roofs up to a slope of 4/12, the cables must clear by at least 8'. For roof slopes greater than 4/12, the minimum clearance of service drop cables over the roof is 3'.

The conductors must not be lower than 12' above a driveway or general walking area such as a back yard. Look for a clearance of at least 18' above a public street or alley and 10' above sidewalks, platforms, porches, or decks. These restrictions help provide protection against accidental contact and reduce the risk of shock or electrocution.

Remember that different requirements may exist in your area depending on local codes.

Reportable Deficiencies – Overhead Delivery Lines

- Trees or bushes interfere with service drop wires
- Wires too high or too low from the ground, driveway, or roof
- Damaged wires
- Wires too close to windows and doors
- Wires not secured to house
- No drip loop
- Drip loop wires touch each other
- Poor wire connections
- Mast insecurely attached

Underground Power Delivery

Newer communities have underground utility lines. The electric power lines or conductors that enter the home from below grade are referred to as service laterals. Local regulations mandate the kind of cable that is required for underground service. Modern homes have at least a 100-amp capacity and at least an 8-gauge conductor to supply the power. The home inspector will most likely not be able to see problems with underground delivery, except at the service entrance to the home. Deficiencies like loose wires and poor connections can still be a problem and should be noted if observed.

Electric Meter

All electrical power that enters the home passes through the meter, which is usually located upstream of the service box. The electric meter is a sealed device that is used by the utility company to measure the amount of electricity that is consumed at the residence. An inspector should never attempt to open an electric meter box.

CHAPTER 3: SERVICE BOX WITH DISTRIBUTION PANEL OR SERVICE PANEL

Page 1: Service Box with Distribution Panel or Service Panel

From the electric meter, the electricity is delivered to the property’s service box or service panel.

Reportable Deficiencies – Electric Meter

- Broken seals or tampering (to change readings)
- Meter not properly secured to house
- Meter located where it may be damaged by cars or people
- Rusted or damaged meter box

Service Box with Distribution Panel

The service box is the main breaker box and encloses the main disconnect for the home’s power distribution system. The main disconnect is a breaker that can be used to stop electricity from reaching and powering the home.

The service box may have only one breaker installed—the main disconnect. If this is the case, another cable runs from the service box to the distribution panel, where the breakers for all of the home loads are located. However, in most cases, houses have a service panel rather than a service box and a separate distribution panel.

Occasionally, there may not be a service box. In this case, there may be up to six switches that turn off all of the power to the house. There should never be more than six switches.

Service Panel

On the other hand, if a house's service box and distribution panel are combined, together they make up the service panel, or combination panel.

Sub-Panels

From the distribution panel or service panel, cables may run to sub-panels. In such cases, the cable from the service panel is called a feeder cable and the panel where the circuit breakers are located is called a sub-panel.

Being able to distinguish between the service box, distribution panel, service panel, and sub-panels is critical for inspectors. The service panels and sub-panels are not wired the same. The presence of solar panels, electrical vehicle charging station, and other modern technology may cause a home to have a sub-panel.

Electrical Protection Devices

All homes are equipped with protection devices that are built into the electrical circuits, including overcurrent protection devices (breakers and fuses), ground fault circuit interrupters, and arc fault circuit interrupters. In the event of a short circuit or serious overload, the heat that is generated causes these devices to shut off the flow of electrical current to the circuit. These devices are found in the service panel or distribution panel.

Circuit Breakers

Newer homes have circuit breakers for protection. A circuit breaker is like a reusable fuse. The breaker contains a heat-sensitive switch that opens and shuts off the power to that circuit if it detects too much heat. Circuit breakers can be reset after the cause of the overload has been corrected.

The smallest circuit breaker that is used in home circuits is 15 amperes. The largest circuit breakers for individual loads are usually no larger than 60 amperes. The same company should manufacture the circuit breakers and panel. If an inspector finds circuit breakers that were manufactured by a different company than the one that manufactured the panel, he or she should note them in the inspection report.

Circuit breakers come in many sizes according to the amount of current that is expected in the circuit the breaker is protecting. For a given circuit, the circuit breakers installed are sized to protect the circuit and the components being supplied, but the appropriate breaker should have a slightly higher rating than the expected current in the load being supplied. This is because the electrical supply to a home is not constant. There are continual small variations in the power supply that will cause frequent and unnecessary tripping if the circuit breaker is sized to exactly the expected current of the component rather than slightly larger. Because of this, breakers are generally installed with a 25% margin to allow for normal fluctuations in each circuit.

Example: If the ampacity of a kitchen disposal is specified as 13 amperes, the appropriate breaker size is calculated to be 16.25 amps (13 amps × 1.25 = 16.25 amps). Since breakers are sized in increments of 5 amperes, the appropriate breaker is a 20-amp breaker, which is the next larger size than the calculated value.

By looking at the breaker/wire size table that was shown earlier in the Unit, you can see that the correct wire for the circuit is a 12 AWG copper conductor.

Fuses

Older homes use fuses to protect the electrical circuits. A fuse is a heat-sensitive device whose conductor is designed to melt at a preset temperature. If the fuse becomes too hot because of an electrical malfunction or an overloaded circuit, the thermal link in the fuse melts and the flow of electricity is stopped. Fuses are not reusable. Once the thermal link has melted, the fuse must be replaced, preferably after the cause of the overload or malfunction has been addressed. Types of fuses include the Edison fuse and the S-type fuse.

Edison Fuse

The oldest type of fuse is called the Edison fuse. This type of fuse comes in a variety of trip settings. Edison fuses are interchangeable, which means that every fuse fits into every socket, regardless of size. This is somewhat dangerous because one must be careful to avoid placing an oversized fuse into a circuit. An inspector who sees Edison fuses installed in a home should recommend that the client hire an electrician to make professional recommendations, such as replacing them with S-type fuses. Be careful to not suggest repairs or work outside of your role as the home inspector.

S-type Fuse

A newer type of fuse is the S-type fuse. The S-type fuse is a two-piece device. The first piece is called the fuse adaptor. A fuse adaptor is shaped like a hollow cylinder and has threads on the outside and on the inside. The outside threaded area is identical for all fuse sizes, which allows the adaptor to be threaded into any standard fuse socket. The inside of the fuse adaptor is also threaded, but the inside thread diameter is different for each fuse rating. The fuse adaptor has tabs protruding from the outer diameter that allow the adaptor to be threaded into a socket but prevent the adaptor from being removed once it is installed.

The second piece of the S-type fuse device is the fuse itself. Each fuse is threaded to fit into a fuse adaptor and each fuse size has a different thread diameter. Thus, the only fuse that fits into a 15-amp S-type fuse adaptor is a 15-amp fuse. Once an S-type fuse has been installed in the correct socket for the circuit, it is impossible to install an improper fuse in the circuit.

Ground Fault Circuit Interrupters

A critical safety device that is found in the home is a ground fault circuit interrupter (GFCI). Ground fault circuit interrupters are designed to protect people from shock. GFCIs are available in three different varieties: circuit breaker, receptacle, or portable plug in the unit. Receptacle and portable plug GFCIs are discussed later in the unit.

Often, GFCI breakers are used for circuits that are dedicated to only one load that requires GFCI protection. Newer construction codes require GFCI protection for many types of outlets.

A GFCI circuit breaker combines the overload protection of a conventional circuit breaker with the added advantage of being able to detect a grounding problem. GFCI circuit breakers are most often used for underwater pool lights and hydro-massage tubs. It is now possible to purchase breakers that have both the GFCI and AFCI features.

Arc Fault Circuit Interrupters

Arc fault circuit interrupters are designed to protect the house from electric arcing and fire. AFCIs are relatively new products. AFCI breakers are the only form of AFCI device that is currently available. In the 2020 edition of the NEC®, Section 210.12 requires that for dwelling units, all 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets or devices installed in dwelling unit kitchens, family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, laundry areas, or similar rooms or areas shall be protected by AFCIs.

Grounding

Grounding is the term that is used to describe design features that are installed in electrical circuits to protect equipment and to protect people who use the circuits.

Grounding System

The grounding system is the part of an electrical circuit that allows electricity to flow to the ground. This system includes the connection of a separate wire, usually bare copper, between the case or housing of the load appliance and the grounding bus bar in the service panel. The system ground electrically ties together the metal parts of the electrical installation—such as the service box, distribution panel, armored cable, and conduit—and leads from them to a safe ground. If a fault occurs in a system that is grounded, the grounding provides an established flow path for the fault current to travel to the ground so that it does not flow into the home system where a person may come into contact with it. It is important for the home inspector to look for proper grounding systems.

Grounding in the Service Panel

The service panel is the place where the house's entire electrical system is grounded. All equipment grounding wires and the neutral conductor for the service entrance cable are connected to a neutral bus bar in the service panel. The neutral bus bar is bonded to the grounding bus bar, which is where all of the equipment grounds are connected. All grounds and neutral wires may be connected to the same bus bar since they are bonded together. The neutral bus bar is connected to the earth by a solid copper wire that is called the grounding electrode conductor. The grounding electrode conductor is clamped to a rod that is driven into the ground to provide a solid and direct connection between the house's circuits and the ground. If lightning strikes the house, this path leads the extreme electrical current to the ground and minimizes the possible damage to the house.

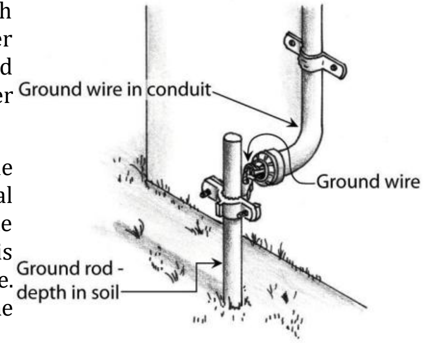
Grounding in Sub-Panels

In systems that have sub-panels, all equipment grounds are returned to the service panel so that they can be connected to ground at that point. In a sub-panel, the equipment grounds and neutral wires are never connected to each other as they are in a service panel. In the sub-panel, the neutral bus bar is mounted on a set of Bakelite feet. Bakelite is a hard, non-conductive material. Neutral wires must not contact a ground wire in any electrical boxes within the house, except in the service panel. In all other panels and boxes, the wires float free from ground contact.

Improper grounding compromises safety. This increases the risk of electric shocks, fires, and damage to electrical appliances. A chaffed wire that comes in contact with the housing of an electrical load, such as a range vent hood or the casing of an electric drill, imposes a voltage (electrical potential) on the casing. Since no safety provisions are installed, a person who comes into contact with the energized component case will provide the completion of a circuit to the earth. Electricity will flow through the person and may cause injury or electrocution. To prevent this from occurring, a grounding system or earth grounding is installed.

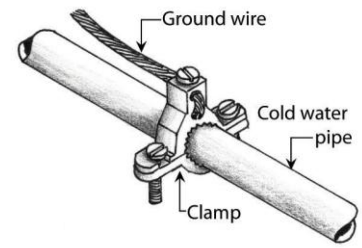
Earth Grounding

A second type of grounding that is employed in homes is called earth grounding. The purpose of earth grounding is to protect the electrical system in case of lightning strike, major overloads from the power company, static electricity, or another malfunction. The electrical service company equipment is protected from lightning strikes by grounding wires that run from the neutral connection at the neighborhood power transformer to the earth at the base of the pole.



The house is protected by a connection in the service panel that is made to the neutral bus bar, through the grounding electrode conductor, and to the grounding electrode rod. A grounding electrode rod is a metal rod that is driven into the ground to provide a ground for the electrical system. The grounding electrode conductor is a heavy-duty wire that runs either to the house's water main or to a grounding rod that is buried in the soil. This wire is usually a protected bare AWG 8-gauge or an unprotected bare AWG 6-gauge. This path is used to guide lightning or static electricity away from items in the home and safely to the ground.

If the connection is made at the house side, then a jumper wire must be provided in case the meter has to be removed. In addition, because most modern underground water piping is non-ferrous (that is, it does not include iron), making a grounding connection to a metal water pipe above ground may not provide proper grounding. Therefore, code standards now specify that if a grounding connection is made to a metal water pipe, the connection must also be made to a driven grounding electrode rod.



Grounding Electrode Rods

To work properly, a grounding electrode rod must make good electrical contact with the earth. Code standards specify that a rod may be made of solid steel, galvanized pipe, stainless steel, or a non-ferrous rod such as a copper-clad steel rod. Aluminum rods are not permitted for use as grounding electrode rods because aluminum oxide insulates and degrades the electrical flow path for fault current into the earth. Because of the differing conductivity of the various rod materials, the minimum contact each must have with the ground varies. Non-ferrous rods have the greatest conductivity and, therefore, must have a minimum diameter of 1/2". Solid steel and stainless-steel rods must be at least 5/8" in diameter. A galvanized pipe that is used as a rod must have a minimum diameter of 3/4".

All rods must be driven 8' into the earth. Specifications allow for the possibility that the rod cannot be driven straight down 8'. Alternative insertion methods include driving the rod at a 45° angle and setting the rod into a trench. In any case, the top 1" to 2" of the rod must be exposed to allow an inspector or other professional to verify that the grounding electrode conductor was properly clamped to the rod. The appropriate method for attaching the grounding electrode conductor to the rod is by using an acorn clamp. An acorn clamp fits over the rod and includes a tightening screw that presses the grounding electrode conductor firmly between the rod and the clamp on the opposite side from the tightening screw.

Be sure to check local codes for any variations in these standards in your area.

Reportable Deficiencies – Grounding

- Missing grounding
- Bad connections
- Spliced ground wires
- Grounding wire is attached to a plastic pipe
- Corroded wiring
- Grounding rod cut too short
- Not large enough gauge ground wire
- Ground wire is attached to the house side of meters or valves

Bonding

Bonding describes the permanent connection of two or more electrical conductors. The result of bonding is that each wire has the same electrical potential as the others and current cannot flow between them. Without bonding, a person may touch an electrically energized wire, provide the connection path to the ground, and be electrocuted. By bonding the conductors to each other and then connecting the bonding wire to the grounding bus bar in the service panel, people are protected from injury due to electrical faults. In locations where equipment is installed in a piping system, jumper wires should be connected to both sides of the equipment so that the bonding is not lost if the equipment must be removed.

Inspecting the Service Panel

Due to its importance, the service panel should be a focal point of the home inspector's evaluation of a residential electrical system. First, observe the space around the service panel or any other electrical panel or meter. There should be a working space of at least 30" wide by 36" deep and at least 66" high. The area in front of the panel must be a sturdy flat surface (in other words, not a stairway). There should be nothing on the wall above a service panel for a distance of at least 6'. Shelves over a service panel should be noted because of the possibility that something will fall off a shelf and into the panel where someone is working. As always, check local codes for any modifications to standards or requirements in your area.

Panel Cover

Next, the home inspector should remove the service panel cover (or dead front cover) to examine the inside of the box. Before removing the screws on the panel, check for the presence of an electrical potential (voltage) on the panel itself. To ensure that there is not a voltage on the panel, an inspector should use a portable voltage detector or hot stick. If a voltage exists, the hot stick will audibly chirp and blink a red light. If voltage is present, it means that it is possible to be injured by electrical shock. By touching the panel, the inspector may complete a circuit to the ground and cause a dangerous electrical current to flow through his or her body. It only takes .1 to .2 amperes of current to kill a person. If the inspector does not have a hot stick, he or she can barely touch the panel cover with the back of his or her hand (preferably the knuckles) as a safety precaution. If the inspector feels a tingle, it means that electricity is flowing to the panel cover (which it should not be doing). If this is the case, do not remove the cover and advise the client to contact a licensed electrician to examine this problem.

When removing the panel cover, scrutinize the panel attachment screws. They should be designed for electrical panels and have blunt ends. Using sharp-ended screws to attach panel covers is very dangerous as the screws can penetrate electrical cables and cause shock or fire.

Contents of the Panel

Once the panel cover is safely removed, the inspector can examine the contents of the box. He or she should determine what types of wires are being used, the size of the conductors relative to the breaker protection, and the adequacy of the installation. Any loose connections should be noted and reported. Continuing with the inspection of the service panel, the inspector should observe the general condition of the panel's contents.

General Conditions

A panel that is covered with dirt or debris should be noted because dirt can get into the breaker contacts and cause arcing, overheating, or a fire. Bushings or sleeves should be installed on all wires that enter the panel to prevent the wire sheathing from being chaffed by the sharp edges of holes in the panel. As each cable enters the panel, there should be no more than 1" of sheathing inside the panel, unless otherwise specified in local building codes. Observe and report any white, red, or black wires that are double lugged, which means that more than one wire is connected to a terminal screw or sub-panel.

All breakers in the panel must be identified according to the load each one serves. This is done by listing the load served by each breaker on a sheet inside the panel door. Inspectors are not required to verify the accuracy of the labeling. They only verify the presence or absence of the labels.

During the panel inspection, the inspector may check for the presence of ground fault circuit interrupter (GFCI) breakers and arc fault circuit interrupters (AFCI).

Look for unplugged holes in the panel box. These are called knock-outs and punch-outs. If these are left open, they provide a path for rodents or other animals to enter the panel box. Creatures that nest in the panel usually end up electrocuted and may cause a fire. Look for signs of intrusion such as nicks in the wires and burnt insulation. Look also for signs of water intrusion.

Obsolete and Unsafe Panels

A home inspector may come across an obsolete or unsafe panel during the inspection. These should be identified and reported to the client. The inspector should recommend that the client consult a licensed electrician.

The most common service panels that are problematic are Federal Pacific Electric (FPE) stab-lok panels. Design weaknesses and reliability issues have been noted in these panels. Thousands of these panels still exist and most of them have not posed a problem for their owners. However, the inspector who finds one should point this out to the client and recommend that he or she consults a licensed electrician.

Two other obsolete and problematic panels are the Zinsco electrical panel and Bulldog Pushmatic. These too should be reported with a recommendation that the client call a licensed electrician.

Reportable Deficiencies – Service Panel

- Service panel not accessible
- Improper screws used
- Insufficient working space around panel
- Service panel not secured
- Water, dirt, or rust in the panel
- Use of a non-waterproof box in exterior locations
- Damaged parts
- Obsolete parts
- Nicked wires and burned insulation
- Unsealed holes in panel cover

- Double lugged hot or neutral wires

CHAPTER 4: METHODS OF WIRING

Methods of Wiring

Today, most houses are wired with branch circuits that carry electricity to the various parts of the house. Older houses were wired using a method called knob and tube wiring. A home inspector may come across houses that have knob and tube wiring in older neighborhoods.

Branch Circuits

Inspectors are seldom concerned with the topic of series or parallel circuits. However, they are always concerned with the topic of branch circuits. A branch circuit begins at the last protective device (circuit breaker or fuse) and ends at the load being supplied. Each circuit that leaves the panel and goes to a load is a branch circuit. In a large service or distribution panel, there may be as many as 42 circuit breakers, which means that there may be as many as 42 branch circuits in that electrical system. Of course, most 240-volt circuits require two full-sized breaker slots. Therefore, for each 240-volt circuit, the maximum number of branch circuits served by a panel is reduced by one.

There are tandem breakers, also known as pancake breakers, that are half the thickness of full-sized breakers. These breakers were created to allow for more circuits within a service panel. When pancake breakers are used, two branch circuits can be installed in one full-sized breaker slot. A home inspector must know that 240 volts cannot be extracted from a pair of pancake breakers that are installed in one breaker slot. 240 volts may only be obtained from connections to two parallel, full-sized breakers that are oriented vertically within the panel.

Layout of Breakers in a Service Panel

A more detailed discussion of the layout of the components within a service panel will clarify how the two hot bus bars are installed and how the breakers and circuits they protect are connected.

Going from top to bottom along each hot bus bar, one can see that two breakers that are side by side horizontally will always be connected to the same bus bar. Moving down from the top breaker slot to the bottom on either bus bar, notice that the breakers installed are connected to alternate bus bars. Let us label the two hot bus bars “red” and “black” respectively. Then, assume that the top breaker slot is a red one. In this case, both breakers that are installed in the top slots are red circuits and both of the breakers that are connected into the second slot down are black. This alternating continues from top to bottom. This is why two breakers that are installed side by side horizontally are always connected to the same bus bar. Two breakers that are installed side by side vertically are always connected to the opposite bus bars and produce 240 volts.

Multi-Wire Branch Circuits

Most modern kitchens have a dishwasher and garbage disposal. The dishwasher and disposal are near each other so that the discharge water from the dishwasher can be sent to the disposal. These two components can be installed with two separate circuits, two breakers, and two receptacles under the kitchen sink. However, inspectors usually find that, in the interest of saving the cost of labor and materials, the electricians installed the two components by using a multi- wire branch circuit. A multi-wire branch circuit supplies electrical current to more than one component by using one cable consisting of two hot wires, one neutral wire and one equipment grounding wire. This is a 12/3 wire with ground. The “12” refers to the gauge, the “3” refers to the number of conductors (in this case two hot wires and a neutral wire), and the ground means that the circuit is grounded.

The two hot wires are taken from separate breakers and are connected to the two different hot bus bars. One hot wire is connected to one socket of the receptacle under the sink. The other hot wire is connected to the other socket of the same receptacle. Since the two wires come from separate sources, they must be electrically separated by removing the metal tab that connects the two sockets on the hot side of the receptacle. Both of the circuits share the neutral wire. That is, the current that returns from the disposal and the dishwasher travels through the one neutral (white) wire that is connected to the neutral side of the receptacle. The removable tab is not removed on this side. Therefore, the current in the white wire is the sum of the two currents that come to the installed components.

Inspecting Branch Circuits

When inspecting branch circuits, look for any evidence of overheating, such as burned or discolored insulators, and evidence of arcing on the panel. No more than one wire, other than bare copper equipment grounding wires, should be connected to any terminal post. Equipment ground wires may be doubled on one terminal screw.

The individual breakers should be tightly connected to the bus bars. They should not be loose or sloppy. Breakers that are double-pole 240-volt supplies must have the two switch arms linked to each other to ensure that they trip simultaneously if a trip condition occurs. These are manufacturer-supplied devices that are known as breaker ties or trip ties.

There should be no overspray of paint on the bus bars. Overspray on bus bars ruins the box. If overspray is present, the inspector should note it and recommend that the client speak to an electrician about addressing it.

The electrical capacity for each circuit breaker can be found on the breaker itself and should be checked to verify that it is not being overdrawn by the wiring. The capacity of the main breaker indicates the system capacity overall and may give clues as to why there are other electrical malfunctions in the home, such as flickering lights and power surges.

If a multi-wire branch circuit is properly installed, the current in one of the two circuits is always negative when the other is positive and vice versa. When properly installed, the current in the white wire is actually less than the individual current in the highest current device.

More on Inspecting Branch Circuits

Example: If the current to a dishwasher is 18 amperes and the current to a disposal is 8 amperes, then the current in the white wire that returns to the breaker will be 10 amperes (18 – 8 = 10).

If the circuit is installed with both hot leads coming from the same bus bar, the supply currents will be in phase with each other and the current in the neutral wire will be the sum of the two currents.

Example: If both hot wires are connected to the same bus bar, then the current in the white wire will be 26 amperes (18 + 8 = 26).

This improper installation is likely to result in an overheated neutral wire and possible damage to the panel.

An inspector can determine whether a multi-wire branch circuit has been installed. If one has been installed, the inspector should verify that it was installed properly. On the service panel, look for a non-metallic (NM) sheathed cable that has red, black, white, and bare copper leads installed inside one sheathing. This is a multi-wire branch circuit. Trace the red and black wires to see if they are connected to two vertically adjacent bus bars. If they are not, it was wired improperly. In such cases, tracing the path of the white wire to its bus bar will probably reveal that the wire is burned and melted near the connection. This should be reported.

Reportable Deficiencies – Circuits

- Improper number of wires connected to a terminal post
- Loose or sloppy breakers
- Evidence of overheating
- No breaker ties where required
- Burnt insulation
- Excessive sheathing on conductors inside panel
- Paint overspray on bus bars
- Incorrect fuses
- Improperly installed multi-wire branch circuit
- Poor connections
- Burned or melted wires at connections

Knob and Tube Wiring

Homes built before 1950 may have a method of wiring called knob and tube. In knob and tube wiring, the wires are supported by a porcelain or glass insulator and are installed along flat surfaces. The insulator is the knob. When the wire passes through a stud or joist, it does so through a tube.

Since knob and tube wiring is an old method, the wires, insulation, and sheathing may become brittle and dried out. Additionally, knob and tube wiring was often buried within insulation in attics or walls. If this is found, it should be reported because it is a safety hazard. Knob and tube wiring must not be covered with insulation.

Knob and tube wiring does not have grounded circuits. Receptacles in these systems do not include one prong that is larger than the other to prevent reverse polarization. In addition, knob and tube wiring systems can only provide 120 volts. Modern homes with electric dryers, ranges, and so forth cannot function with knob and tube wiring. Only two wires come to the house from the power transformer at the pole, one hot and one neutral wire. If a splice is made in knob and tube wiring, there generally must be a knob installed within 6" of the splice to provide support.

Knob and tube wiring is considered to be obsolete. Some insurance companies consider it a safety hazard and do not insure homes with this type of wiring.

However, it is not required that a knob and tube system be replaced with a newer system. In any case, if the inspector encounters this type of installation, he or she should report it to the client and recommend that the client hire an electrician to evaluate the system.

Reportable Deficiencies – Knob and Tube Wiring

- Brittle wires, sheathing, and insulation
- Wiring surrounded by insulation
- Unsupported splices

CHAPTER 5: ELECTRICAL FIXTURES

Electrical Fixtures

A home inspector is also responsible for examining the numerous electrical fixtures within the electrical system. These include switches, receptacles, lights, ceiling fans, smoke detectors, and doorbells.

Switches

A switch opens and closes the electrical circuit by interrupting the flow of electricity. When the switch is open, the circuit is not complete and no electricity flows. When the switch is closed, electricity can flow through it. Switches are located on the hot legs of circuits and are used to isolate loads.

The home inspector should turn on all of the switches in the home to make sure they are working and sending electricity to the circuit to power the loads. Switches that do not work should be reported.

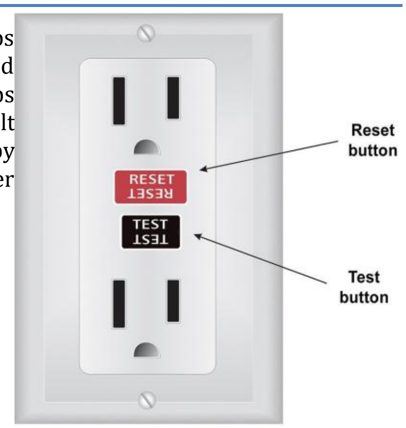
Receptacles

Electrical receptacles or outlets are an integral part of the home wiring system because they deliver current to the plug of an appliance, such as a lamp or a toaster. Receptacles are mounted in a junction box inside a wall. Receptacles that are on the outside of the house must be mounted in weatherproof boxes to prevent moisture from shorting out the circuit. Receptacles have faceplates mounted on them to cover the gap between the receptacle and the wall.

When inspecting outlets, the inspector should feel the outside of the receptacles to make sure they are not hot. Even a receptacle that has nothing plugged into it may run hot if it is passing current through to other outlets on the same circuit. Hot receptacles indicate an improper connection that should be reported.

Receptacles should be tested to make sure that they are functioning properly. All accessible outlets inside and outside a home should be individually checked for the presence of power. This can be done with an electric circuit-testing device that can be purchased at any building supply outlet. The optimum electrical circuit tester is a GFCI testing device. With the GFCI tester, the inspector can check to make sure that each outlet is correctly installed at the sockets. The inspector can use the circuit-testing device to determine whether adequate grounding and open neutrals are present. Additionally, the home inspector should test the receptacles to make sure that the wires have not been reversed within the receptacles, which is a condition called reversed polarity. Further, he or she can use the GFCI testing device to determine whether all installed GFCI devices are operating properly.

GFCI Receptacle



A GFCI receptacle has a built-in detector that is sensitive to current fluctuations as low as 5 to 8 milliamps (thousandths of an amp). GFCIs trip when electric current that is supposed to go through the device is diverted through another path, such as a person. When the GFCI detects that some current has been diverted, it trips open. These devices trip within 5 to 9 milliseconds when a fault is detected. The 2020 NEC states, “All 125-volt through 250-volt receptacles installed in the locations specified in 210.8(A) (1) through (11) and supplied by single-phase branch circuits rated 150 volts or less to ground shall have ground fault circuit interrupter protection for personnel."

Outlets That Must Have GFCI Protection

- Outdoor outlets
- Bathroom outlets
- Outlets on kitchen counters
- Outlets for wet bars
- Outlets in unfinished basements
- Garage outlets
- Outlets for hot tubs, spas, or pool lighting systems

A GFCI device is not an overcurrent protection device. The current may be many times the allowed amount and not trip the GFCI. It is only when a current is taking an unwanted path to some point other than through the GFCI device that it trips open. Most often one GFCI device is used to protect all of the components in a given circuit.

For example, all outlets that are above the counter tops in a kitchen are required to be protected by GFCI devices. There must be a minimum of two dedicated 20-amp appliance circuits installed in each kitchen. Each of the two circuits is likely to have 2 to 4 receptacles installed along the backsplash of the counter.

All of these receptacles are protected by one GFCI device that is properly installed in the circuit receptacle closest to the breaker in the service panel. Therefore, a kitchen in a modern home must have two GFCI devices, each of which is protects one of the two required appliance circuits.

Problems with GFCI Receptacles

Each GFCI device has two pairs of connecting terminal screws. One pair is labeled “line” and the other is labeled “load”. For proper operation, it is important that the wires that come from the service panel be connected to the “line” screws. Downstream receptacles in the circuit are connected to the “load” terminals. When this is done, all of the outlets in the circuit are protected.

If the wires are connected to the wrong terminals of a GFCI device, the improper condition called line/load reversal exists. In a GFCI circuit that has line/load reversal, the downstream receptacles are still protected by the device, but the device itself will not properly trip when a fault condition occurs.

When inspecting GFCI circuits, it is important that the inspector check for the possibility of line/load reversal because it represents a lack of electrical safety in the circuit.

Portable Plug GFCI

A portable plug GFCI plugs into a standard receptacle and adds protection to the circuit. Portable GFCI devices can be found in household items such as hair dryers and contractor grade extension cords.

Reportable Deficiencies – Receptacles

- Damaged or broken
- Loose in the wall
- Reverse polarity
- Open ground
- Open hot wire
- GFCI line/load reversal
- Not working
- Warm or hot to the touch
- Has a broken plug in it
- Not far enough away from bathtubs or showers
- Missing, non-functional, or improperly wired GFCI receptacle
- Improper voltage and incorrect polarity at the receptacle
- Outdoor outlet or switch not mounted in weatherproof box
- Switches, receptacles, and splices not housed in a junction box that is anchored to a stud or joist
- Junction boxes not covered with an appropriate faceplate
- Faceplate that feels warm to the touch

Lights

A home may be wired with many different types of lights, such as recessed lighting, incandescent lighting, fluorescent lighting, LED lighting, and low-voltage lighting.

Today, many people have switched out their incandescent lights for more efficient lights. Incandescent light is produced by a light bulb in which a filament is energized by electric current to make light. Approximately 90% of the energy used by an incandescent lamp is given off as heat rather than light.

Fluorescent lighting is the best source for most building lighting applications because it is very efficient when compared to incandescent lights. Fluorescent light is the light produced by a fluorescent tube. It is caused by an electric current conducted through mercury and inert gases. A compact fluorescent lamp (CFL) is a fluorescent light bulb that is compacted to fit into an incandescent light socket.

There are some problems with fluorescent lights, however. These lights tend to flicker and often have unnatural colored light.

Other types of lights that an inspector may come across include fiber optic lighting and LED lighting. Fiber optic lighting is pure white light that uses less electricity. Fiber optic lighting is illumination using optical fiber. An optical fiber is a very thin fiber made of glass that functions as a waveguide for light. LED stands for light emitting diode. LEDs are a solid-state device and do not require heating of a filament to create light.

Lights may be installed in each room of the home, hallways, and stairways. The inspector must check all of them to see if they work. The home inspector may be able to determine whether the bulbs in the lights are faulty or if the fixtures themselves need to be looked at by an electrician.

Inspecting Lighting Fixtures

All of the light fixtures must also be properly attached and connected. Loose connections or hanging parts must be noted. An inspector also reports damage to electrical fixtures and their coverings.

Closets must have protected incandescent lights, if they are present. In addition, inspectors must make sure that the clearance between lights and closet shelves meets basic requirements. Protected incandescent lights, recessed incandescent lights, and surface mounted fluorescent lights must be installed the proper distance from the vertical projection of a shelf as indicated in local codes. Surface mounted fluorescent lights may be installed directly over the closet door.

Usually, it is easiest to inspect recessed lights, which are sometimes called pot or can lights, from the attic. There are two types of recessed lights: IC rated and non-IC rated. IC stands for insulation contact. Therefore, non-IC rated lights are prohibited from being in contact with insulation. Generally, these lights are not to have any insulation within 3" of the light fixture and there must be 1/2" spacing between the fixture and combustible materials.

IC rated fixtures are designed with a double wall construction. Therefore, these may be covered with insulation and may have contact with combustibles. When in the attic, the inspector should determine which type of recessed fixture is installed and inspect the fixtures accordingly.

Reportable Deficiencies – Lights

- Inoperable lights
- Unprotected incandescent light in closet
- Closet lights are too close to shelves
- Non-IC rated lights too close to insulation or combustibles
- Lights do not stay on or flicker when switched on
- Lights make buzzing sound when switched on

Lighting Controls

Perhaps the best technology to reduce the energy consumption of lighting systems is to have a central controller perform intelligent switching. This can be as simple as a day/night sensor that automatically turns lights off during daylight hours. Intelligent systems know how many occupants are in a building and which rooms they are occupying. The system also measures the level of natural lighting and switches lights on only to achieve a consistent lighting level in the rooms where it is needed.

Motion controls are the most common form of switching. The same technology that is used for garage lights can be used for all indoor lights. Motion controls can be adjusted for sensitivity so that household pets will not trigger the switches. It is common to integrate the lighting control system with the burglar alarm system because they can share sensors.

Reportable Deficiencies – Lighting Controls

- System turns on lights in rooms that are unoccupied and turns off lights in occupied rooms
- Motion sensors not working

Ceiling Fans

Often, a home inspector encounters ceiling fans during an inspection. A fan should have all of its parts and work properly. The inspector must make sure that the fan is securely fastened to the ceiling and that it does not sag. The fan should also be checked to make sure it works at all speeds and that the reverse switch operates properly. Loose wiring near a ceiling fan is a defect that must be reported. A fan that wobbles when operating is not balanced. This condition should be reported.

Reportable Deficiencies – Ceiling Fans

- Missing parts
- Inoperable or malfunctioning controls
- Sagging or loose parts
- Fan out of balance
- Sagging or loose wiring

Smoke Detectors

Smoke detectors help occupants get out of a home in the event of a fire.

Some smoke detectors also detect the presence of carbon monoxide in a home. If the detector senses the presence of either smoke or CO, it sounds an alarm. These dual smoke/CO detectors are becoming more common.

The National Fire Protection Association (NFPA) estimates that the presence of operable smoke detectors in a home reduces the possibility of dying in a fire by 50%. The NFPA also estimates that fully 1/3 of all home smoke detectors do not operate properly and are not properly maintained. Modern standards require that smoke detectors be installed in each bedroom and in hallways outside each grouping of bedrooms. There must be at least one smoke detector on each floor of the house. A home inspector should be familiar with the regulations regarding smoke detectors in his or her market area.

More on Smoke Detectors

In older homes, smoke detectors were battery-operated devices. Modern homes are built with smoke detectors that are wired right into the home's electrical system for increased safety and performance. The home inspector must check the wiring to make sure it is connected and not loose. He or she should also verify that the battery backup is working. The detector should be checked for dust or dirt build-up near the sensors.

When a home is equipped with outside monitoring for security and fire detection, the inspector should know whether the monitoring system is on before testing smoke detectors. If the remote monitoring system is activated and the inspector sets off the smoke detectors, this initiates a series of events involving the arrival of police and firefighters. If the alarm goes off, the monitoring company calls the house. If the inspector does not have the proper security code, these personnel will presume that unauthorized entry into the house has occurred or that a fire is in progress. For this reason, a home inspector should not activate a smoke detector unless he or she knows that a monitoring system is not activated.

Reportable Deficiencies – Smoke Detectors

- Inoperable or dirty sensors
- Missing batteries
- Loose wiring connections

Doorbells

Doorbells allow visitors to signal to the occupant that someone is at the door. The inspector should verify that the chime rings when the doorbell is pushed and that the parts of the doorbell are intact. Newer doorbells are connected via the internet and may or may not be linked to an actual chime.

Summary

Power plants convert another form of energy into electricity and then deliver it to our homes through power lines, relay stations, and transformers. Electricity may be direct current or alternating current. Units of measurement that are used to measure electricity include current, voltage, resistance, and power. The Ohm's Law formulas are used to find these quantities.

Power can be delivered to a home in one of two ways: overhead power delivery or underground power delivery. The inspector must make sure that the delivery lines meet specific clearance requirements. The electric meter is the device that utility companies use to measure the amount of electricity each home uses.

When inspecting a house's electrical system, the home inspector begins at the service panel and the sub-panels. Next, he or she examines the electrical circuits. Electrical circuits must be closed-loop in order to function properly. An electrical circuit includes the source, loads, branch circuits, grounding and bonding components, conductors, and electrical protection devices. The protection devices include the circuit breakers, fuses, ground fault circuit interrupters (GFCIs), and arc fault circuit interrupters (AFCIs).

Finally, the home inspector examines the electrical fixtures that are connected to the house's electrical system. These include the switches, receptacles, lights, ceiling fans, smoke detectors, and the doorbell.

Home Inspection State Requirements

Please review the state-specific regulations and guidance noted on this page if you perform home inspections in any of the states listed below. Each state has its own unique requirements, standards, and regulations that govern home inspection practices.

Understanding and following your state's specific requirements is essential for maintaining compliance and providing professional home inspection services. Be sure to thoroughly review all applicable state laws and regulations before conducting inspections in any new jurisdiction.

Note: State requirements are subject to change. Always verify current regulations with your state's regulatory authority.

Connecticut:

Sec. 20-491-7. Electrical system

(a) The inspector shall inspect the service drop; the service entrance conductors, cables, and raceways; the service equipment and main disconnects; the service grounding; the interior components of service panels and sub panels; the conductors; the overcurrent protection devices; a representative number of installed lighting fixtures, switches, and receptacles; and the ground fault circuit interrupters.

(b) The inspector shall describe the amperage and voltage rating of the service; the location of main disconnect or disconnects and sub panels; and the wiring methods.

(c) The inspector shall report on the presence of solid aluminum branch circuit wiring.

(d) The inspector is not required to inspect the remote control devices unless the device is the only control device, the alarm systems and components, the low voltage wiring systems and components, solar systems, any on-site generators, or the ancillary wiring systems and components not a part of the primary electrical power distribution system.

(e) The inspector is not required to measure amperage, voltage, or impedance.

(Adopted effective July 30, 2002; Amended November 1, 2023)