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► INTRODUCTION

The electrical system is very important from both a safety and convenience standpoint. Generally speaking, electrical systems are expanded and upgraded over the life of a house, rather than taken out and replaced on a regular basis.

► 1.0 THE BASICS

1.1 Definitions: It is useful to understand some of the basics of alternating current. Incidentally, all typical house wiring is alternating (rather than direct) current. Two very simple formulas will be helpful.

1. V = IR. Here V is the voltage in volts, I is the current in amps, and R is the resistance in ohms.

2. P = VI. Here P is the power in watts, V is the voltage in volts, I is the current in amps.

TABLE 1.
ALTERNATING CURRENT (AC) BASICS

V = Voltage (volts)	P = Power (watts or kilowatts)	I = Current (amps)	R = Resistance (ohms)

Formulas: 1. V = IR
2. P =VI

1000 watts = 1 kilowatt

1 kilowatt = 3,412 BTU/hr (for heating purposes).

1.2 Voltage: Voltage is the potential energy of the electrical system. A large electrical voltage means that a large potential electric force is available. Most houses are equipped with a 120/240-volt system which can provide 240-volts or 120-volts.

Ohms

1.3 Resistance: The resistance of any given material to the movement of electricity through it is measured in ohms. When there is effectively no resistance, the current flow is very large. This is referred to as a short circuit. This unsafe situation will blow a fuse or trip a breaker after some time.

Conductors

Good electrical conductors have relatively low resistance. Copper wiring, for example, is a good conductor. Silver is even better, but considerably more expensive. Aluminum is not quite as good a conductor as copper, but it is less expensive. A larger sized aluminum wire is needed to carry the same current as a smaller copper wire.

Insulators

Materials which are very poor conductors have a high resistance and are referred to as insulators. Materials such as wood, rubber, ceramic and most plastics are good insulators. Air is a very good insulator.

Water

Tap water is usually a very good conductor, and that is why water and electricity are dangerous together. Where water comes into contact with live electrical equipment, it can carry the electricity readily to areas it was not intended to go.

Light Bulb

Every electric appliance (for example, a light bulb) has some resistance. When the small wire (filament) inside a light bulb breaks, the light goes out because the circuit has been opened. The air between the pieces of wire which have broken presents a very large resistance. There is no electrical flow and therefore, no light.

Amps

1.4 Current: The current, measured in amps, is the flow of electricity that results when a voltage is applied across a given resistance. Rearranging Formula 1. from Table 1 we can determine the current by dividing the voltage by the resistance (I = V/R).

Electrical Flow

When an appliance is turned on, electricity will flow. The flow of electricity generates heat. The more amps flowing through a circuit, the hotter a given size of wire will get. Since the voltage is fixed at roughly 120 volts, the amount of current that flows will be the result of the resistance in the circuit. If an appliance malfunctions or too many appliances are plugged in, the current flowing through the wire will be more than the wire can safely handle, and the wire will begin to overheat. The fuse or circuit breaker shuts off the electricity at the point when it may overheat the wire.

The Danger

It is the current flowing that electrocutes people. Generally speaking, a current of less than 1 amp is considered capable of killing someone. A 60 watt light bulb normally draws about 1/2 amp. Remember though, the amount of current depends on resistance. Putting a wet finger into a light socket may be enough to kill someone.

Watts

1.5 Power: Power is measured in watts, and is calculated by multiplying the voltage times the current. For example, a 1200 watt hair dryer when subjected to a potential of 120 volts, will allow (I=P/V) 10 amps to flow through it. A house with a 240 volt power supply and 100 amp main fuses may be said to have a capability of (P = VI) 24,000 watts. This is commonly referred to as 24 kilowatts (1 kilowatt is 1000 watts).

Kilowatt-Hours (kWh): This is a measure of electricity consumption. If 1000 watts are used continuously for one hour, then 1 kilowatt-hour has been consumed. This is how electricity is purchased from the utility. The electric meter records kilowatt hours used in the house. If each kWh costs ten cents and one uses 1000 kWh in a month, the electrical bill for that month would be $100.

1.6 Wire Size (Gauge): The amount of current a wire can carry (in amps) is determined largely by its diameter. A larger wire can carry more current. Normal household circuits are designed to carry 15 amps, and #14-gauge copper wire will do this safely. Table 2 shows common wire sizes and how much current they can safely carry. Notice that aluminum is not as good a conductor of electricity, and a larger wire has to be used to carry the same amount of electricity.

TABLE 2.A
MAXIMUM AMPERAGE FOR COMMON WIRE SIZES PER NATIONAL ELECTRIC CODE (NEC) - U.S.A.

	Copper			Wire Size	Aluminum or Copper Clad Aluminum		
Temperature Rating	60°C	75°C	90°C		60°C	75°C	90°C
	15	15	15	**14**			
	20	20	20	**12**	15	15	15
	30	30	30	**10**	25	25	25
	40	50	55	**8**	30	40	45
	55	65	75	**6**	40	50	60
	70	85	95	**4**	55	65	75
	85	100	110	**3**	65	75	85
	95	115	130	**2**	75	90	100
	110	130	150	**1**	85	100	115
	125	150	170	**1/0**	100	120	135
	145	175	195	**2/0**	115	135	150
	165	200	225	**3/0**	130	155	175
	195	230	260	**4/0**	150	180	205
				250 MCM	170	205	230

TABLE 2.B
MAXIMUM AMPERAGE FOR COMMON WIRE SIZES PER CANADIAN ELECTRICAL CODE (CEC) - CANADA

	Copper			Wire Size	Aluminum or Copper Clad Aluminum		
Temperature Rating	60°C	75°C	90°C		60°C	75°C	85-90°C
	15	15	15	**14**			
	20	20	20	**12**	15	15	15
	30	30	30	**10**	25	25	25
	40	45	45	**8**	30	30	30
	55*	65	65	**6**	40	50	55*
	70	85	85	**4**	55	65	65
	80	100	105	**3**	65	75	75
	100	115	120	**2**	75	90	95#
	110	130	140	**1**	85	100	105
	125	150	155	**1/0**	100	120	120
	145	175	185	**2/0**	115	135	145
	165	200	210	**3/0**	130	155	165
	195	230	235	**4/0**	155	180	185
				250 MCM	170	205	215

Note:
1. *60 amps permitted for house services and subservices.
2. # 100 amps permitted for house services and subservices.
3. Tables based on 30°c (86°F) ambient temperatures, maximum.
4. Tables based on not more than 3 conductors in cables.
5. Several variations and exceptions exist for these general rules.
6. All wire gauges are AWG (American Wire Gauge) except 250 MCM.
7. Wires up to #10 gauge are solid (single strand). Larger wires are multi-strand.

1.7 Voltage Supplied to Homes (220 - 240): Most homes today are provided with a nominal 240 volt service. (Within the house it is broken down for most appliances to 120 volts.) This is the target voltage set by the utility. Their goal is to have 240 volts available to all houses at all times. At high demand times (around 5:00 pm to 6:00 pm daily, for example), the voltage may drop. In severe cases, a "brown-out" occurs. This is a situation where the utility cannot provide anywhere near 240 volts. In most cases, however, the "slight dips" in voltage are not noticed by the homeowner.

In the 1950's, houses were intended to receive 110/220 volts. This was improved to 115/230-volts in the early 1970's. The target voltages have increased over the years to improve the electrical service available to homeowners.

1.8 Cycles: Alternating current changes direction (or alternates) several times per second. In some areas, until the late 1940's, household electricity was 25 or 50 cycle. This means the current flow reversed its direction 50 or 100 times per second. Since the early 1950's, the system has been exclusively 60 cycles per second. This is an improvement to service, as 25 cycles resulted in lights that flickered more than with the 60 cycle power.

1.9 Household Circuits: A typical household circuit has 120-volts available. A typical wire size (gauge) of #14 is used, and a fuse or circuit breaker rated at 15 amps, controls the circuit. This means the circuit is capable of supplying 1800 watts. If a 1200 watt hair dryer is connected to this circuit, everything would be fine. A current of (I = P/V) 10 amps would flow.

1.10 Circuit Overload: If a second 1200 watt hair dryer is connected to the circuit already drawing 10 amps, what would happen? Roughly 20 amps would be drawn, the wire would heat up, but the 15 amp fuse would eventually blow. This safety device keeps the wire from overheating and causing a fire. If someone had accidentally put in a 30-amp fuse, it would allow the wire to overheat, possibly causing a fire.

It is unfortunate that electricity is not smart enough to know what size wire it is running through, and shut itself off if things start to get too hot. Since it does not do that, we need properly sized fuses or circuit breakers to protect the circuit.

Overcurrent Protection Devices

1.11 Fuses and Breakers: Fuses and breakers are both overcurrent protection devices. They shut off the power when more current is flowing through a circuit than should be. Both fuses and breakers perform the function equally well. The advantage of a circuit breaker is that it can be turned back on after the overload situation is corrected. A fuse has to be replaced.

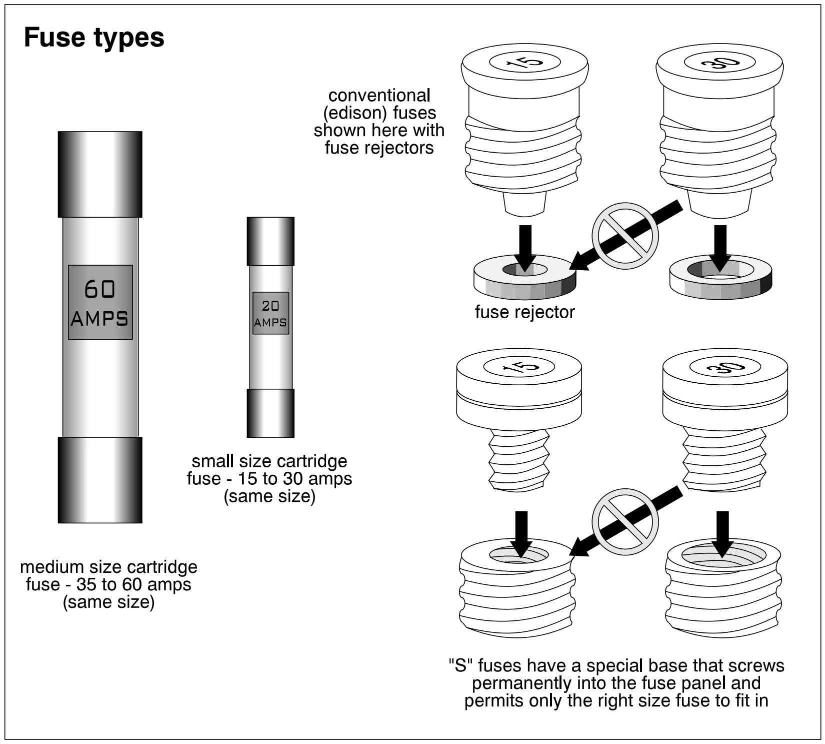
Time Delay: Many fuses today are type "D". These are time delay devices which do not blow immediately. They will, for a short time, allow more than the rated current to flow through the circuit. (Although regular fuses allow some excess current, type D fuses allow even more.) Since overheating develops with time, this is acceptable in the very short term.

Some electric motors starting up will, for a fraction of a second, draw a great deal of current. With an ordinary fuse, this causes nuisance blowing. This may lead people, out of frustration, to put in an oversized fuse. The time delay feature allows these electrical loads to occur briefly without causing nuisance blowing.

Type "P" Fuses: These fuses have an added safety feature. The low melting temperature of this fuse makes it very sensitive to heat build-up around the fuse, which is not the result of too much current flowing. For example, if the fuse is loose, there may be a poor connection between the fuse itself and the fuse holder. With a current of less than 1-amp, this can lead to overheating and eventually, a fire. A type "P" fuse would blow much sooner than an ordinary fuse.

Type S and C Fuses

These special screw-in (plug) fuses are non-interchangeable. This means that the wrong size fuse will not fit into the fuse holder. This provides improved safety over the older fuses which could be interchanged. Modern panelboards incorporate this feature. Type S fuses are not used in Canada.



1.12 Damaged Wire: If a wire is nicked or is poorly connected, the wire effectively is smaller and likely to overheat in that area. In this case, a fuse or breaker would not protect the wire against overheating. A normal 10-amp load from a hair dryer could result in overheating and possibly a fire. It is easy to see why damaged wire is a safety hazard.

► 2.0 SERVICE ENTRANCE

2.1. Service Entrance Cable: A typical house has 240-volts, brought in through overhead or underground wires from the street supply. A normal system is composed of three wires. The black and red wires are live, and the white wire is neutral. The potential between the black and white wire is 120-volts, between the red and white is 120-volts, and between the black and red is 240-volts. (Incidentally, the "red" wire often has black sheathing, just to make things confusing). The size of the service entrance cable determines how much electricity is available to the house. Either copper or aluminum cable may be used. Aluminum connections should be coated with an anti-oxidant (grease-like material) to prevent corrosion.

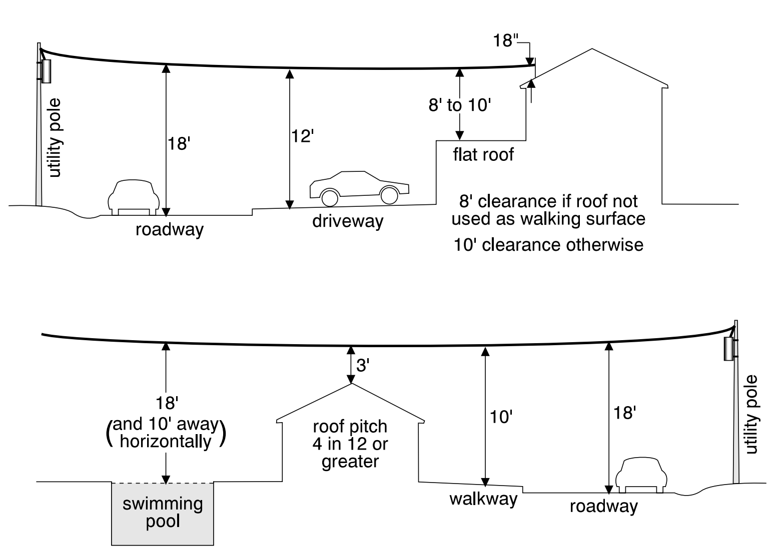
Damaged

Clearance

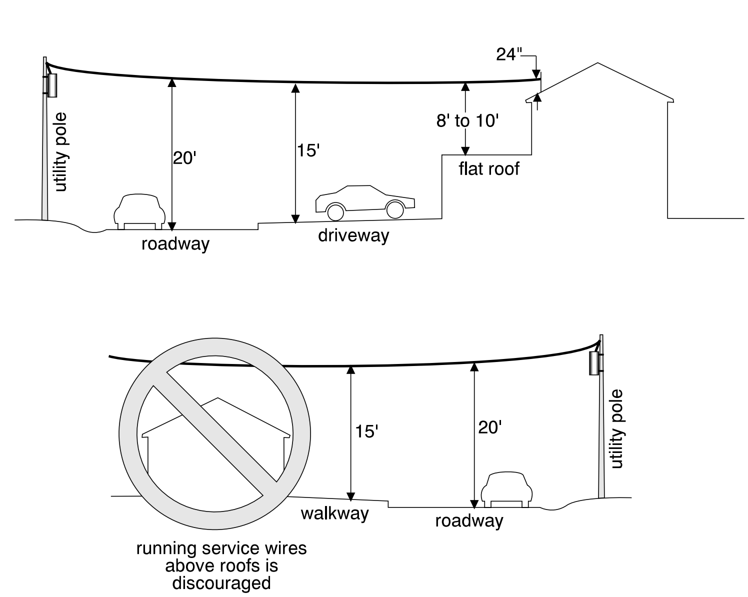
2.2 Overhead Wires (Service Drop): If the overhead wires appear damaged or frayed, notify your utility. They will often repair or replace these lines without expense to the homeowner. If these wires are less than fifteen feet above ground, or are within three feet (beside or below) of a window or door opening, the utility or an electrician should be consulted. Tree branches should be kept trimmed away from wires.

2.3 Conduit or Cable: The electrical conduit or cable coming down the outside of the house from an overhead service should be well secured to the house and should be arranged so that water cannot enter the conduit or cable. The wires should be kept away from window and door openings and the conduit or cable should be arranged so that the overhead wires are high enough to be out of the way of people and vehicles.

Service drop clearances (United States)



Service drop clearances (Canada)



Clearance Generally speaking, the top of the service mast and the wire itself, should be at least fifteen feet above the ground. A thirty-six inch clearance from windows is generally required. Where the conduit protrudes through a roof covering, it should be flashed to prevent leakage into the roof system, and should go at least eighteen inches above the roof. (Thirty-six inches are required in Canada).

Drip Loop A drip loop prevents water entering the service conduit. The service wires form a loop below the service head which allows water to drip off the wire, rather than run along it, into the conduit.

Size The size of the conduit is not a reliable indicator of the electrical service size in the house.

Outside Building The conduit may be run along the outside of the building for a considerable distance if protected from mechanical damage. Worn or frayed cable which allows water into the service box or panel can cause rust or corrosion. An exposed neutral conductor may be a shock hazard if the service grounding system is defective.

Inside Building Once inside the building, the conduit or cable must be kept as short as possible. Ideally, the service box should be located immediately at the point where the conduit or cable goes into the house. This avoids exposing the conduit or cable to mechanical damage.

Underground An underground cable should be at least twenty-four inches deep under normal landscaped areas and at least thirty-six inches deep under driveways or parking areas.

Seal Hole Through Wall

The conduit should be sealed where it passes through the wall to prevent water and air penetration. It is not unusual for condensation to develop inside service boxes as a result of poor sealing of the electrical conduit where it passes through the wall. This can cause corrosion inside the service box, resulting in an unsafe situation.

2.4 Service Size: As the power enters the house, it goes into a service box which has two fuses or two circuit breakers (sometimes connected together to look like one big breaker). One fuse is for the black wire and one fuse is for the red. No fuse is necessary (or permitted) for the neutral wire. The fuses are rated at the amperage that the wire can safely carry (60-amps, 100- amps, etc.). Where there are two 100-amp fuses in the service box, the house has a 100-amp service. Please note that one cannot add the two fuse ratings together to get the house service. See Table 3 for ratings of various service entrance wires.

While it is best to verify the cable size to determine the service size, this is often not possible. In most cases, the ratings on the main fuses or circuit breakers are taken to reflect the service size accurately. With very few exceptions, this is reliable. The nameplate data on the panelboard or hydro meter is not a reliable service size indicator.

In the U.S., the minimum service size on new work is 100-amps. In Canada, 60-amp services are permitted for houses or residential units up to 800 square feet in floor area. On larger homes, 100-amp service is the minimum.

TABLE 3.

TYPICAL SERVICE ENTRANCE SIZES

Minimum Wire Size U.S.A.		**Service Size (amps)**	Minimum Wire size Canada	
Copper	Aluminum		Copper	Aluminum
10*	8*	**30**	10*	8*
6*	6*	**60**	6	6
6*	4*	**70**	4*	N/A
4	2	**100**	3	2
2	1/0	**125**	2	2/0(1/0)
1/0	2/0	**150**	1/0	3/0
2/0	4/0	**200**	3/0	250MCM

Note: 1. *-not found on new work.
2. All wire gauges are AWG except 250 MCM.
3. Several variations are possible, depending on such things as the type of wire, the temperature rating, etc.

Not a Safety Concern

2.5 Larger Service: A house with an electrical service which is too small is not a safety concern, but it is an inconvenience. An electrical service which is marginally sized or undersized may lead to blowing of the main fuses (not the branch circuit fuses in the service panel) or the main breakers. The fuses can be replaced within a few hours by the utility or the breakers can simply be reset by the homeowner. However, this is inconvenient in that the entire house (or at least half of it) will be shut down.

Changing Wires

Increasing the service size may mean replacing the wires coming from the street to the house, installing new conduit, a new meter base and probably providing a new service box. If the wires run overhead, this is not a big problem. If the wires are underground, a problem may present itself. This could mean excavation and replacement.

Meter Location

On old houses, it is often necessary to relocate the service entrance to the side of the house facing the utility lines, so that the meter can easily be accessed by the meter reader. Generally speaking, meters now have to be on an outside wall within three feet of the front wall of the house. Most utilities require the meter to be relocated when upgrading the service.

New Panel

In some cases, enlarging the size of the electrical service will also necessitate replacing the service panel. If the rating of the panel is smaller than the upgraded incoming service, the panel may become overheated under heavy load. It is common to find old houses with 100-amp service boxes with 100-amp fuses, but wire rated for only 70-amps, and a service panel only rated for 70-amps (or 66-amps).

60-amp Service

It should be understood that maximum load occurs only intermittently. There are many houses with 60-amp capacity which provide good service. Normal household lighting and small appliances will not normally draw 60-amps. It is the heavy appliances such as an electric stove, clothes dryer or central air conditioning system that draw 20 or 30-amps each. It is easy to see if three such appliances were in use and other normal house appliances were activated, a 60-amp service would be overloaded. In a small household, it is not difficult to avoid the simultaneous use of an electric stove and an electric clothes dryer. This is more likely to occur with larger families, of course.

Additions and Electric Heat

The amperage drawn by different appliances is outlined in Table 4. A larger service may be necessary where an electrically heated addition is to be built. The same would apply for electrically heated finished attic spaces or finished basements. Depending on how much additional capacity is available, a larger service may be needed.

TABLE 4.

TYPICAL POWER AND CURRENT FOR HOUSEHOLD APPLIANCES

	Typical	
	Watts	Amps
Stove and oven (all burners and oven on)	9,600	40
Clothes dryer	5,000	20
Central air conditioner	5,000	20
Electric water heater	3,000	12.5
Kettle	1,500	12.5
Toaster	1,200	10
Microwave oven	1,500	12.5
Electric frying pan	1,200	10
Coffee maker	1,200	10
Dishwasher	1,200	10
Iron	1,000	8.5
Portable electric heater	1,500	12.5
Room air conditioner	1,200	10
Central vacuum system	1,500	12.5
Hair dryer	1,200	10
Portable vacuum cleaner	800	7
Clothes washer	500	4
Furnace fan	250	2
Trash compactor	500	4
Blender	360	3
Refrigerator/freezer	500	4
Food waste disposal	500	4
Waterbed heater	400	3.5
Color T.V.	360	3
Video cassette recorder	120	1
Stereo	120	1
Electric blanket	180	1.5
60 watt lightbulb	60	0.5
1/4 horsepower motor	700	6
1/2 horsepower motor	1000	8

Note: Watts and amps vary with appliance size and manufacturer.

30-amp Service/120 Volt Service

30-amp services are not considered adequate for modern lifestyles and should be replaced. Similarly, 120-volt services are generally inadequate and again, should be upgraded.

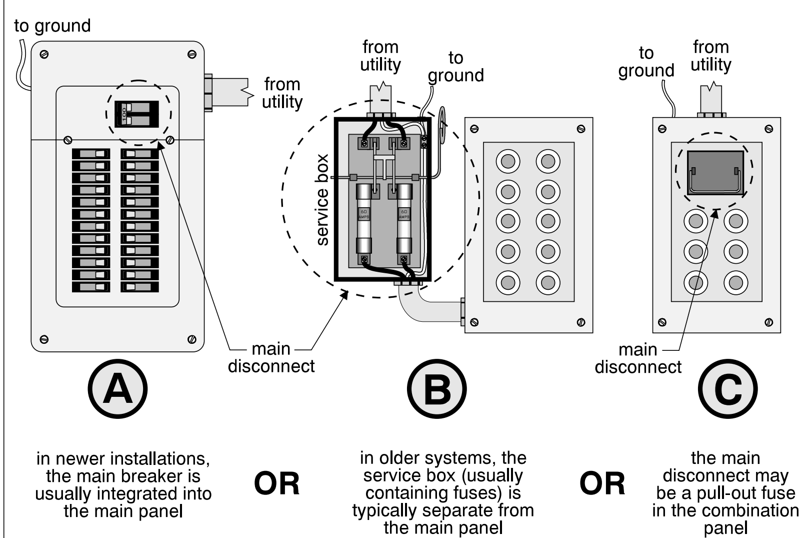
2.6 Service Box: The service box includes a circuit breaker which can be used to shut off all the power in the house, or a switch with a handle located on the outside, and the service fuses inside. The cover on the service box is often sealed by the utility.

The service box may stand alone, although in modern homes, the service breaker is often incorporated into the service panel. In either case, it is important that the rating on the box itself, is at least as large as the service entrance cables and fuses or breakers inside. For example, if a house has service entrance wire and fuses rated for 100-amps, a box rated for only 60-amps is not acceptable. More than 60- amps flowing through this box may lead to overheating.

Every home should have a disconnect means so the system can be shut off. Working on a live electrical system is very dangerous. In the U.S. (and in some Canadian situations), it is permitted on existing installations to have up to six switches to disconnect all the house power.

In the 1950's, a 50/70-amp service box was used in some areas. This is a circuit breaker type disconnect which may be considered equivalent to a 60-amp disconnect. If equal amounts of current are flowing through the black and red wire, the breaker will trip at 50-amps. This situation is referred to as a "balanced load". If there is more current flowing through one of the main wires than the other (an unbalanced load), the breaker will trip when one wire is carrying roughly 70-amps.

Breaker and fuse type service boxes



In a conventional 60-amp service with circuit breakers, the breakers will trip when the current in either leg reaches 60-amps. Where fuses are used in the main service box, each fuse works independently. If more than 60-amps flows through one fuse it will blow. This leaves roughly half the house without power, including part of the electric stove, for example. If more than 60-amps flows through the other fuse, it too will blow, leaving the entire house without power. See Table 4 for the watts and amps used in household appliances.

Damaged or Undersized

2.6.1 Main Switch or Circuit Breaker:

If the main switch is inoperative, or if the box is corroded or damaged, it should be replaced. A service box which is rated at a smaller amperage than the main fuses or breakers should also be replaced. This is very rare.

Sealed by the Utility

Most modern systems have the main breaker incorporated into the service panel. Separate service boxes may be sealed by the utility. These cannot be opened by the homeowner or home inspector. The seals are provided for two reasons. The first reason is safety. There is live electrical power inside this box, even if the main switch or breaker is shut off. Under no circumstances, should the homeowner attempt to work inside this box or change the main fuses or breakers.

The second reason for the seal is that the service box is often located upstream of the meter. The seal discourages people from trying to steal electricity by taking power from the service box without having it go through the meter. If there is a seal on the service box which appears to be very old, it may be wise to contact your local utility and ask them to ensure that the switch is in good operating order.

House Power Left on

The main switch or breaker is not normally shut off during a home inspection, since it would shut down the entire house. This can disrupt clocks, timers and computers, for example, and can result in damage to some motors and compressors. However, once a homeowner takes possession, he or she should ensure that it does operate properly.

Size

2.6.2 Main Fuses/Breakers:

If improperly sized, the main fuses or breakers would have to be replaced. Similarly, if one or both of the fuses are blown, replacement of the fuses is necessary. Fuses cannot be tested without destroying them.

Poor Connections

Poorly connected fuses should be better connected and in some cases it is necessary to replace the service box itself.

TABLE 5.

WIRE SIZES AND FUSE OR BREAKER SIZES FOR ELECTRIC HEATING

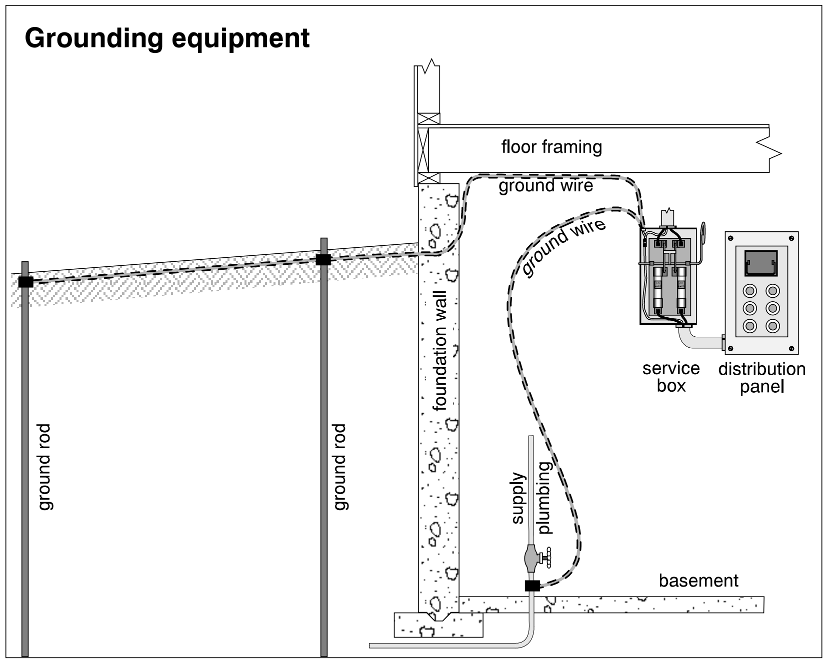
Heater Rating	Voltage	Minimum Wire Size COPPER	Minimum Wire Size ALUMINUM	Maximum Fuse Size
500 watts	120	14	12	15
1000 watts	120	14	12	15
2000 watts	240	14	12	15
5000 watts	240	10	8	30

Fuses should be Type P or D.

Both Fuses Same Size

The two main fuses should be the same size. Where they are different sizes, an electrician should be engaged and the correct size provided. The main breakers should be linked together or provided with a single handle so that both must be shut off together.

2.7 System Grounding: Grounding has always been required on all residential electrical systems. Up until approximately 1960 it was required only on the service panel. Subsequent to 1960, it has been used on all branch circuits, including lights and electrical outlets. A ground wire is a wire that connects an electrical system to ground. Ground is a safe place to dispose of unwanted electricity.



Generally speaking, the grounding wires are connected (via bonding wires) to those metallic parts of an electrical system that are not supposed to carry electricity. These metal components, however, are close to things where electricity is present, and it is recognized that if something goes wrong, the outside of a metal cabinet could become live. Bonding the ground wire to this metal cabinet ensures that if something does go wrong and someone touches the cabinet, he or she will not get a shock. Checking the quality of the grounding system is beyond the scope of a home inspection. The ground wire, the service box, and neutral wire are all electrically bonded together, at the box.

In most houses the electrical system is grounded to the water supply piping. In the U.S. since 1987, a driven ground rod is required in addition. Ideally, the ground wire should be connected to the supply piping near its point of entry into the house. If connected downstream of the water meter, a jumper wire should be provided across the meter.

Ground Rods

In some cases, grounding to the water system is not effective. Where plastic supply piping is used, for example, alternative grounding system must be arranged. In Canada, this is accomplished with two metal rods, driven into the ground. In the U.S. a single ground rod is used.

Ufer Ground

Although uncommon, other grounding configurations may be found where typical methods are not possible. Ufer grounds (concrete encased electrodes) use a long copper wire or bar encased in the concrete footing. Plate and ring electrodes consist of a metal plate or ring of wire buried in the ground. None of these is visible and they are not evaluated during a home inspection.

Ground Wire Sizes

In Canada, #8 gauge wire is used for electrical services up to 100-amps, #6 gauge for 101 to 125-amps, #4 gauge for 125 to 165-amps, and #3 gauge for up to 200-amps. In the U.S., a #8 gauge wire is used for services up to 125-amps, and #6 gauge for up to 175-amps and #4 gauge for 200-amps. Where grounding is to a rod, #6 gauge copper is the largest required. Bare aluminum is not considered acceptable as a ground wire since it is subject to severe corrosion when exposed to moisture. Aluminum ground wire must be one size larger. In Canada, aluminum is not allowed as a system grounding conductor.

Missing

2.7.1 Grounding Problems:

The system ground is missing in some cases. It may have been omitted from the original installation, or removed during amateurish electrical or plumbing rearrangement; or the original ground may have been left behind when the service panel was relocated. Adding a new ground wire is not difficult or expensive. Checking the quality of the grounding system is beyond the scope of a home inspection.

Lack of Bonding

The ground wire, the service box, and the neutral wire are often not electrically bonded at the service box. This situation should be corrected promptly.

Ineffective Grounding

The system ground may be ineffective. If the connections are poor, the quality of ground is suspect. If there is a splice in the ground wire, a potentially weak connection exists. Ground wires are sometimes ineffective because they are secured to pipes which are no longer in service. This is common on galvanized steel supply pipes which are abandoned. If the plumber does not move the ground wire over to the new piping, the grounding system will be defeated.

Ground Rods

Where the plumbing system is partially plastic piping (often at its point of entry into the house), grounding to the plumbing system is not acceptable. Grounding to buried rods is the correct solution. In Canada two rods, each ten feet long are buried in the ground, about ten feet apart. They are bonded by copper wire and the ground wire is connected to one of the rods. These rods may be below the basement floor. In the U.S., a single eight foot ground rod of copper or stainless steel is used. The top of the rods and the connection points of the wire to the rods, should be one foot below grade.

Jumper Around Meter

If there is a water meter on the plumbing system, the grounding may not be effective if the ground wire is connected to the plumbing downstream of the water meter. This can be corrected by relocating the ground wire upstream of the meter, or providing a jumper wire around the meter .

Di-electric Connections

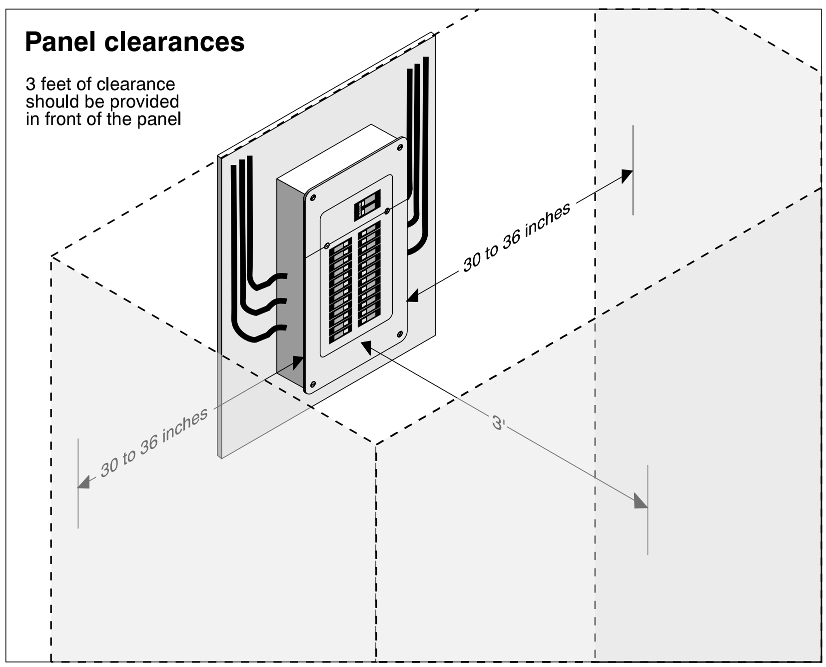
Some piping connections are a special di-electric type, intended to prevent oxidization where two different metals are joined. These special connectors remove the metal-to-metal contact, and interrupt the continuity of any ground wire connected downstream. The ground wire should be relocated upstream of any di-electric connector.

► 3.0 SERVICE PANEL

3.1 Panel Description: Electricity is carried from the service box to the service panel. The black and red wires are each connected to a live busbar (a current carrying metal bar with several connection points) and the white wire is connected to the neutral busbar. Each branch circuit fuse (or breaker) is directly connected to either the red or black busbar.

Location

Panelboards are not allowed in clothes closets or areas where there are flammable liquids (U.S.A.). In Canada, panels are not allowed in clothes closets, bathrooms, stairways, or kitchen cabinets.



Typical Household Circuit

The black or red branch circuit wire for an individual circuit is connected to its own small fuse (or breaker). The current flows from the black or red (usually the "red" wire is also black) service entrance wire, through the service box, to the panel, through the busbar, through the fuse or breaker, and into the black or red wire for the circuit. The current goes out, completes its circuit, running through whatever fixtures or appliances are in use on the circuit, and comes back through the white wire. The white circuit wire is connected to the neutral bar, which is attached to the service entrance white wire. It doesn't matter whether power is taken from the black or the red busbar. The result is the same; a 120-volt distribution circuit has been established. The fuse (or breaker) for this circuit is typically 15-amps and the wire is typically #14-gauge copper.

Number of Circuits

The service panel has several 120-volt circuits (at least sixteen are required for most homes) and one or more 240-volt circuits for large electric appliances. Many codes now require a panel with room for twenty-four or more 120-volt circuits.

Damaged or Loose

3.1.1 Damaged/Loose Panel: Where the panel is damaged mechanically or by water, it should be replaced. Poorly secured panels should be resecured to the wall. Old ceramic fuseholders, which may or may not be in a metal cabinet, are considered obsolete and unsafe. These should be replaced. These panels, which may be found on walls or ceilings, have exposed terminal connections, and it is very easy to accidentally touch a live wire while changing a fuse.

3.1.2 Panel Overcurrent Protection (Undersized Panel): Typically, the panel rating is the same as or larger than the service size and the rating of the main fuses or circuit breakers. Where the panel rating is smaller, the panel must be replaced with a larger one suitable for the incoming service size. Alternatively, the main fuses or breakers could be downsized.

3.1.3 Room for More Circuits in Panel: It is desirable to have room to add more circuits in any panel. If there is no room, an auxiliary panel can be added in most cases. Recognizing the need for growing electrical demands, new homes are required to have room for at least two extra circuits in their panel. When upgrading to a 100-amp service, many jurisdictions require a panel which can accommodate twenty-four or more circuits.

3.2 Auxiliary Panel (Sub-panel): In many homes, when the service panel was filled, an auxiliary panel was added. This does not bring more power into the house; it simply allows for more branch circuits to carry electricity to more areas of the house. Over the years, it is not unusual to find more than one auxiliary panel added.

3.2.1 Auxiliary Panel Problems: Where an auxiliary panel is used, the wire running from the service panel to the auxiliary should be protected by overcurrent devices in the service panel. For example, a 60-amp auxiliary panel should be provided with #6-gauge copper wire. This wire running from the service panel to the auxiliary should have 60-amp fuses or a double pole breaker located at the service panel. It is slightly less desirable, although acceptable, to provide 60-amp fuses at the auxiliary panel end of this wire, as long as the wire does not exceed five feet in length and is in a metal conduit. On very small auxiliary panels, no overcurrent protection device may be needed at the service panel.

Feed Wire

Doubled-up Circuits (Double-taps, Double-lugs)

In some cases, circuits in the panel are doubled by adding another wire to the terminal screw. This is not permitted unless a special connector, designed to hold two wires, is provided. Securing three wires under one terminal screw is never acceptable.

In many cases, an auxiliary panel may be adequate as a corrective measure. It is wise to install an auxiliary panel slightly larger than what is needed immediately, in anticipation of future electrical demands.

Where the service panel has fuses, and circuit breakers are considered desirable, or where the service panel is in suspect condition, it may be best (although more expensive) to replace the service panel with a larger circuit breaker panel. Again, there should be enough room in the new panel to add more circuits. A twenty-four circuit panel is typical.

Bonding

The ground wire and neutral wire should not be bonded in an auxiliary panel.

3.3 Fuses and Breakers: Fuses and breakers perform the same function. The advantage of a circuit breaker is that it can be turned back on after the overload situation is corrected. A fuse has to be replaced. When a new fuse is put in or the circuit breaker is reset, if the overload situation has not been corrected, the circuit will trip again. While it is a nuisance to have to reset a breaker, it is more of a nuisance to have to replace a fuse, particularly if a spare is not available.

Dangerous Practices

Practices such as wrapping a blown fuse with foil or putting a penny in a fuse block, are foolish and may result in a major fire.

Overfusing

One other disadvantage of fuses is that it is possible to put in a wrong size. It is unfortunate that 15, 20, 25 and 30-amp fuses all fit into the same fuse block. Circuit breakers are typically not changed by the homeowner and are less likely to be incorrectly sized.

Which Circuit Is Off?

Most circuit breakers trip by moving the switch to the middle position, others simply switch to the off position. It is usually very easy to see which circuit breaker has tripped. The circuit is re-activated by simply “switching” the breaker off and on again. With fuses, it is not always easy to see which one has blown. On the glass type fuses, you can usually see if you look closely through the glass, but on a cartridge type fuse it is often very difficult to know.

Testing

Some electricians prefer fuses because a circuit breaker is a mechanical device which can fail. While this is true, circuit breakers can be tested; that is, switched to the off position, or subjected to current flow beyond their rating. A fuse can be manufactured incorrectly, with a fusible link which is not the correct size. A fuse cannot be tested without destroying it.

Fuse Rejectors

One of the safety devices available for fuses is a fuse rejector washer. This is a small plastic ring which is retrofitted into the fuse block. Depending on its size, this fuse rejector can prevent the wrong sized fuse from being screwed into the fuse block. Modern panelboards have a fuse rejection feature that prevents inserting a larger size fuse than intended.

Overfusing

3.3.1 Fuse/Breaker Problems: The most common electrical flaw found residentially is fuses which are the wrong size for the circuit wire. This is an unsafe condition and should be corrected promptly. Table 2 indicates the appropriate size of fuse for the given wire sizes. As a very coarse rule of thumb, stoves have 40-amp fuses, dryers and air conditioners have 30-amp fuses, and general household circuits have 15-amps. There are a multitude of exceptions to these rules.

Damaged or Loose Components

A broken or damaged fuse holder or circuit breaker should be replaced. Poorly secured fuse holders or circuit breakers should be resecured or replaced as necessary.

3.4 240-Volt Circuits: Heavy duty appliances, such as electric ranges and stoves, clothes dryers, air conditioners and water heaters, use 240-volts. Here, the black wire and red wire are both used in the circuit. For some of these appliances, a white neutral wire is also used. Three wires run to the appliance instead of two. Two fuses (or breakers) are needed; one for the black wire, and one for the red wire. These two fuses (or breakers) should be the same size, and should be linked so that if one is pulled out, the other must be pulled out with it. This is a safety feature in the event that people forget that these appliances have two fuses. If only one fuse were removed, there would still be power to the appliance. It would not be safe to work on the system. (With breakers, a handle tie is used, so that if one breaker is off, the other must be off too. Alternatively, a single throw double pole breaker can be used).

3.5 Linking Circuits: Linking is used to ensure two fuses or breakers are disconnected at the same time. The overcurrent protection devices (fuses or breakers) for any circuit with more than one powered connection must cut power to both legs simultaneously. This includes 240-volt appliances, such as an electric stove, clothes dryer, water heater, or large air conditioner. This also includes cable used for some electric heaters, split kitchen receptacles, (top and bottom halves of outlet are on different circuits), et cetera.

Pull-Out Fuse Holders

It should not be possible to pull out one fuse without pulling out the other one of the pair. Similarly, it should not be possible to switch off one circuit breaker without switching off the other. With breakers, this can be accomplished with a tie handle which mechanically joins two breaker handles, or preferably, a double pole breaker with a single throw handle. This is important where three wire cable is used, because shutting off one fuse or breaker will leave power to an appliance through the second live wire, although the person intending to work on it thinks all the power is shut off.

Damaged

3.6 Panel Wires: Damaged wires inside the box should be replaced or repaired promptly. Wires can be damaged by pinching them with the cover plate, damaging them as they are pulled through the cable holes coming into the box, or through careless work in the box.

Overheated

Overheated cables or evidence of arcing should be investigated by an electrician; not only should the cable be repaired or replaced, but the source of the overheating should be identified. Looking at a cable, it is difficult to tell whether overheating was a one-time situation or whether it is an ongoing intermittent problem. **This requires immediate attention by an electrician.**

Loose

Wires should be secured in place where they pass through the walls of the box. If the wire outside the box is pulled, the connection itself inside the box will not be pulled loose. Where the wire has not been secured, it should be done.

Missing Damaged or Loose

3.7 Panel Cover Plate: Missing or damaged cover plates should be replaced. Cover plates poorly secured should be resecured. Great care should be taken in removing and replacing cover plates and, ideally, the power should be disconnected prior to removing the cover plate.

3.8 Unprotected Panel Openings: Where the panel does have room for more circuits, or where a fuse block has no fuse, there may be a situation where a person could inadvertently touch a live electrical component. Wherever this situation exists, the opening should be covered or fitted with a fuse. Installing a blown fuse on a spare circuit to fill an opening in the panel is acceptable.

3.9 Abandoned Wire in Panel: It is not considered good electrical practice to abandon wires and leave them loose inside the panel.

Abandoned wires should be removed or appropriately terminated so that there is no chance of them contacting a live electrical component.

3.10 Access to Panel: The panel should be accessible with the center of the panel roughly five-and-one-half feet above the floor. Some panels may be mounted upside down. The three foot area in front of the panel should be kept clear.

3.11 Connections: Loose connections may lead to overheating, arcing, or short circuits. It is often difficult to notice a loose connection during a visual inspection, but where noted, it should be addressed promptly.

► 4.0 BRANCH CIRCUIT WIRING

4.1 Branch Circuit Wire: The wire used to carry electricity from the panels to the fixtures and appliances is typically copper. Each piece of cable is made up of two conductors and one ground wire. The copper conductors are wrapped with insulation, usually rubber or plastic. The ground wire is not insulated. This group of three wires is wrapped in a sheathing which may be paper, cloth, rubber, plastic or metal.

Black and White Wire

One conductor has black insulation and is usually the live or hot wire. The other conductor has white insulation and is referred to as the neutral. Neither wire should be touched when there is power to the circuit. When electricity flows under normal circumstances, the black and white wires carry the current. The voltage available is 120-volts, and the current flow is less than 15-amps.

Ground Wire

The ground wire is normally idle. If there is a problem, the ground acts as an escape route for the electricity, inducing the current to flow through this wire to the ground, rather than into a person, causing an electrical shock. Grounded distribution wiring was introduced to residential electric systems in the late 1950's.

Three Conductor Cable

Some special circuit wiring has an additional live or hot wire. It is color coded red and is included where more power is needed. For example, 240-volt appliances such as stoves and electric clothes dryers use three-conductor plus ground cable. Split kitchen receptacles also use three-conductor plus ground cable, to effectively create two 120-volt circuits.

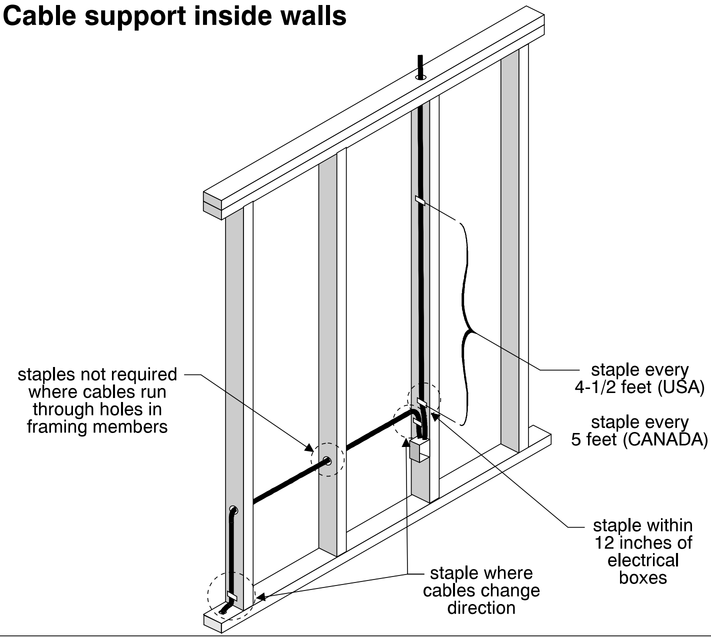
Wire Gauge

The normal wire size is #14-gauge. This is capable of carrying 15-amps safely. A fuse or circuit breaker rated at 15-amps should always be provided on a #14-gauge copper circuit to shut off the power if more than 15-amps flows. In some regions, 20-amp circuits may serve kitchen or other outlets. The wire size for these circuits should be #12-gauge. If no fuse or breaker were present, the wire would try to carry more current, but would overheat, eventually starting a fire. See Table 2 and Section 3.3.

Damaged

4.1.1 Wire Problems: Wire which is damaged mechanically or as a result of overheating should be replaced. Wire which is nicked, for example, is effectively smaller in diameter at that spot. The smaller the wire diameter, the more difficult it is for electricity to move through. (The resistance is higher.) This can lead to localized overheating, and eventually a fire.

Cable support inside walls



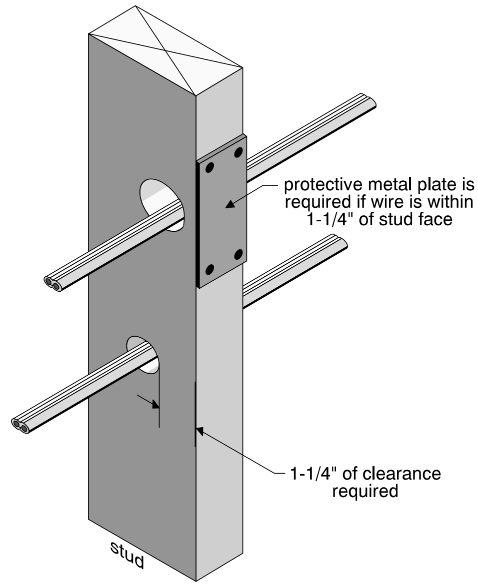
Bushings Wire should be protected from the metal edges of panels and boxes. This is usually done with bushings, grommets or cable clamps.

Loose Wiring which is poorly secured should be resecured as necessary. The wire should be secured where it enters a panel, junction box or fixture. The wire is again secured within twelve inches of the box, and every four and-a-half (USA) or five feet (Canada) thereafter. If cable staples are used, only one wire should be secured under each staple. Staples should be the appropriate size for the wire.

Exposed to Damage Wires should not be exposed to mechanical damage. Wire should be run through joists in unfinished basements, rather than secured to the underside. Care must be taken when drilling wood structural members to avoid weakening them. Where wires are run through studs or other framing members into which nails may be driven, the wire should be set well back from any nailing surface, to avoid a nail being driven into the wire. Alternatively, steel plates should be used to protect the wire from nails or screws.

Exposed in Attic Ideally, the joists should be drilled and the cables should be run through them. Although very common, it is considered poor practice to secure the cable to the top of the joists or to the lower side of the rafters if the joist-to-rafter clearance is more than thirty-six inches.

Edge clearance for wires in studs and joists



Damaged Insulation The insulation on wiring is often gnawed on by rodents. Mice and squirrels in the attic, for example, can damage wiring insulation and create a very real fire hazard. This is often difficult to detect without pulling back the attic thermal insulation. Where pests are known to have been in a home, it is wise to call in an electrician to inspect the wiring.

Surface Wiring Where wiring is run on the surface of walls, baseboards or other interior finishes, it should be protected from mechanical damage with a rigid covering. Alternatively, flexible metal or rigid metal cables can be used.

Ducts and Piping Wiring should be kept at least one inch away from heating ducts and hot water piping. Thermal insulation can be used to separate these materials.

Undersized Wire which is too small for the appliance it serves or for the rest of the circuit wiring should, of course, be replaced.

Junction Box Connections made in branch circuit wiring should be inside junction boxes. Where these boxes are not provided, they should be added, and where cover plates are missing, they should be provided. The only exception to this is the original knob-and-tube connections, which may be acceptable if undisturbed.

Extension Cords Extension cords should not be used as permanent wiring, and should never be stapled to walls, floors or trim. Cords should not run under carpets or go through doorways or windows.

Abandoned Wiring Wires which are not in use should be removed or the wire ends should be terminated in junction boxes.

Exterior Wiring

Exterior wiring should be of a type suitable for outdoor use (typically NMW cable). Exterior wiring should be protected from mechanical damage and special exterior junction boxes are required. Note: Solid conductors (#10 gauge and smaller) cannot be run overhead for fear of fatiguing the metal.

4.2 Overloaded Circuits: While it is difficult to tell from a typical visual inspection, the number of lights and outlets on any given branch circuit should be such that the circuit will not draw more than 15-amps under normal circumstances. At a maximum, twelve outlets may be connected to each circuit. The practical limitation, however, is if one of the outlets is used for a hair dryer which may draw 10-amps, it is probably wise to connect the circuit only to other outlets which will be used for very low drawing appliances such as clocks, radios or lights. Generally speaking, a circuit should have a combination of electrical outlets and lights.

4.3 Dedicated Circuits: Some appliances require a dedicated circuit. That is a circuit where only one appliance is to be connected. This includes the furnace or boiler, dishwasher, food waste disposal, compactor, central vacuum system, refrigerator, freezer, washing machine, whirlpool, and electric heaters. Split receptacles (outlets where the top and bottom halves are on separate circuits) are also usually on dedicated circuits.

A home inspection will not normally reveal which circuits are dedicated. These are determined when the electrical circuits are labelled.

Not a Safety Concern

Dedicated circuits are rare in older houses and it is very difficult to verify during a visual inspection. It is not a major expense to rearrange this, and the danger is not one of life safety, simply of convenience. Without dedicated circuits for each of these appliances, there is the possibility of nuisance fuse blowing or circuit breaker tripping with several appliances in use simultaneously.

Fridge and Freezer

The reason a refrigerator or freezer gets a dedicated circuit is to prevent food spoilage. If it is on a circuit with other appliances, the fuse may be blown as a result of a problem with another appliance. The fuse may not be replaced immediately, if the home owner doesn’t know that the refrigerator or freezer is also on this circuit. As a result, food may be spoiled.

Furnace or Boiler

It is for a similar reason that a furnace should be on a dedicated circuit. If the circuit has an overload due to another appliance, the house will be without heat. This can result in freezing if the home is unoccupied for some time.

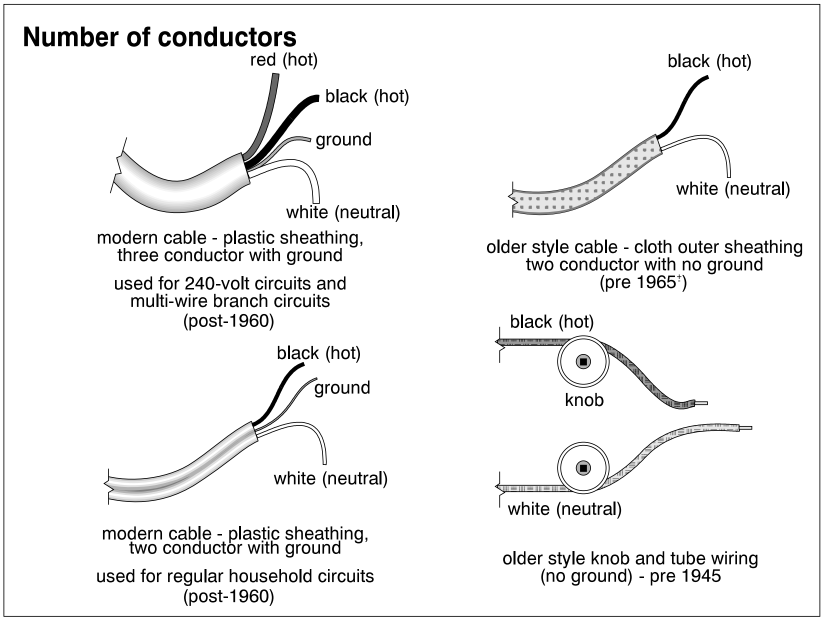
Heavy Current Draw

The other dedicated circuits are so arranged because the heavy electrical draw from the appliances uses most of the 15-amps available to that circuit. Putting additional outlets and lights on the circuit may lead to regular shut-downs.

4.4 Knob-and-Tube: Knob-and-tube wiring was used residentially until approximately 1950. While different than the wiring that is used now, it is not necessarily an inferior wire. This wire gets its name from the ceramic knobs by which it is secured and the ceramic tubes which are used where the wires pass through wood-framing members, such as joists.

Separate Black and White

The main difference between this system and modern cable, is that the black wire and the white wire run separately, independent of each other. In modern cables, the black wire, white wire (and ground wire) are all wrapped up in a single cable. With knob-and-tube wiring, it took roughly twice as long to wire a house, since every light fixture and outlet had to have a black wire and a white wire run to it. Today, running a single cable provides a black and a white (and a ground wire). It was felt originally, that having the black wire and white wire separate was safer, since there was very little chance of the black and white wires ever touching, creating a short circuit. This has not proved to be a big problem with modern cables.



No Junction Boxes

Another difference between knob-and-tube wiring and modern cable is that with knob-and-tube wiring, electrical junction boxes were not used wherever wires were joined together. In modern construction, any time two wires are joined, the connection must be made inside a closed metal box. Knob-and-tube connections were made by twisting the wiring together, soldering the wires, and wrapping the connection in rubber, then in electrical tape. While no longer a common practice, if properly done, these connections will serve indefinitely. Most modern attempts at these connections are woefully inadequate. They are, of course, more susceptible to mechanical damage than modern connections inside boxes.

Wire Insulation

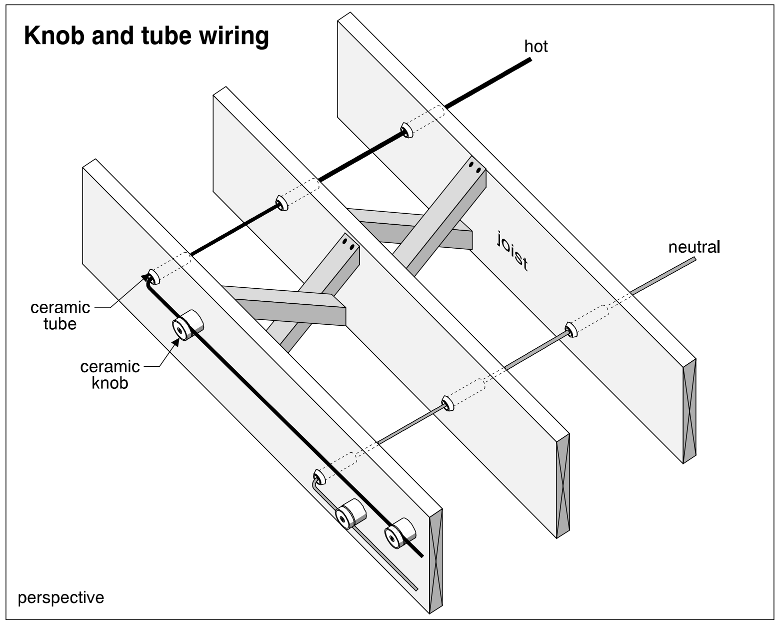
Another distinction between knob-and-tube wiring and some modern cables is in the insulation. The knob-and-tube wiring used rubber and cloth insulation around the wiring. In modern cables, each wire has plastic insulation typically, and the entire cable is wrapped with another layer of plastic. Over the years, these sheathing materials have included cloth, paper, rubber, metal and plastic.

Brittle Insulation

Breakdown of the insulation on knob-and-tube wiring is most often the reason it has to be replaced. This is frequently the result of overheating or mechanical abuse.

No Ground Wire

One last difference between knob-and-tube wiring and some modern cable is the absence of a ground wire. As mentioned earlier, knob-and-tube wiring was used up until 1950. From the 1950's to 1960, two conductor cable was popular although no ground wire was included. In approximately 1960, ground wires began to be incorporated into the two conductor cable, and electrical receptacles included a third hole (U-ground) thereafter.



Replacement

While knob-and-tube wiring must be recognized as old, it is not necessary to replace it as a matter of course. It should be inspected and evaluated on an individual basis.

Poor Connections

4.4.1 Knob-and-Tube Wire Problems: Problems with knob-and-tube wire almost always result from amateurish connections made after original installation. Since original connections were made without junction boxes, many home owners feel that they can make connections to knob-and-tube wiring without junction boxes, as well. This is an unsafe practice, particularly since the chance of making a splice as good as the original connection is very remote. In any case, this violates modern electrical codes.

Since knob-and-tube wiring is invariably old, it has been subjected to more home handymen, mechanical abuse (such as skis, lumber, etc. stored on top of the wire in the basement), and is more likely to have suffered wear and tear. Pinched wiring and damaged insulation is a problem, particularly in unfinished basements, where the wiring is exposed.

Brittle

Another problem with knob-and-tube wiring is, if the wire has overheated in the past as a result of overfusing, a poor connection or damaged cable, the insulation may become brittle. Flexing the knob-and-tube wire will give some indication as to whether it has become brittle, although this can be a dangerous practice. It is not recommended that this be done by a lay person.

Often the wire becomes brittle in areas where heat builds up, such as in panelboards. In exposed areas, where inspection is easy, there is usually good air circulation, and little heat build-up. The wires are least likely to be brittle in these areas.

Circuits Extended

Since older electrical systems had few circuits by today's standards, the chances of a knob-and-tube circuit having been extended over the years are very good. The additional loads and the possibilities of poor connections do create an argument for replacing older knob-and-tube wiring.

Replacement

While it is typically not necessary to pull out all old knob-and-tube wiring and replace it, it is common to remove the sections exposed when renovations are undertaken. For example, when basements are finished, the readily accessible knob-and-tube wiring at the basement ceiling level could be replaced prior to adding a ceiling finish. The wiring running up through the walls to the first and second floors, however, is usually not changed. This is considered acceptable, as long as the wire is in good repair.

Insurance Difficulties

In 1996, many insurance companies began to get nervous about knob-and-tube wiring. We think unduly so. Some companies will only grant insurance after an inspection and approval by the local authorities. Many companies will not offer insurance on houses with knob-and-tube wiring.

Two Fuse Circuits (Fused Neutrals)

Another problem specific to knob-and-tube wiring is the presence of two fuses on a single circuit. Both the black and white wires have fuses on some very old panels. If the fuse on the neutral wire blows, the circuit will be open, and fixtures and appliances on this circuit will not be operative. It is not safe, however, to work on the circuit! Power is still available through the circuit, right up to the blown fuse. A person touching the circuit may well be grounded and could provide a path for electricity to flow. The person would get a shock in this case. In all modern systems, there is only one fuse for each circuit leg. The fuse must be located at the source of the circuit, where the live (black) wire is connected to the panel.

4.5 Aluminum Wire: Aluminum wiring was commonly used from the late 1960's until about 1978. It was introduced because it was less expensive than copper. It was recognized from the beginning that aluminum wiring is not quite as good a conductor of electricity as is copper. Therefore, for a conventional 15-amp household circuit, for example, #12-gauge aluminum was used in place of #14-gauge copper. Other wire sizes were also suitably increased.

Thermal Expansion

Some other properties of aluminum, however, were not recognized and did cause some difficulties. Firstly, aluminum has a higher co-efficient of thermal expansion than copper. This means that when the wire heats up (as all wire does when electricity passes through) the aluminum tends to expand more than copper. This leads to the wire trying to move out from under the terminal screws. This phenomenon is called "creep" and can lead to poor connections and subsequent overheating.

Soft

Secondly, aluminum is softer than copper, and electricians used to working with copper would often nick aluminum wiring inadvertently. Nicking the wire, of course, reduces its diameter, and its ability to carry electricity safely. Localized hot spots can develop where the wire has been nicked. Further, if the wire is bent after it has been nicked, it will often break.

Insulating Oxide

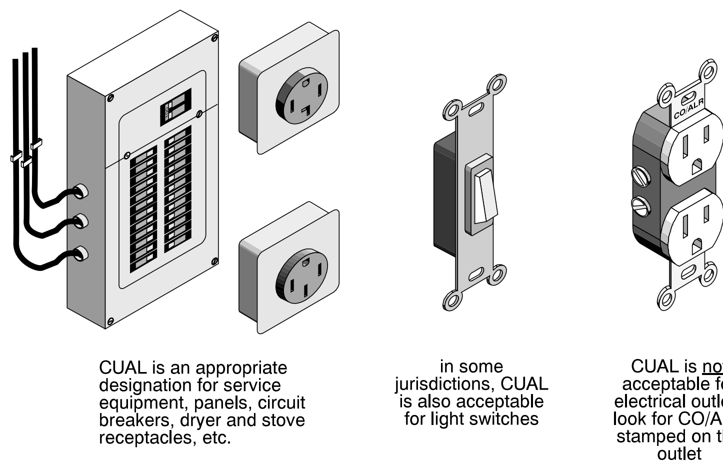
Lastly, the oxide of aluminum that forms on the wire is a very poor electrical conductor. All metals rust or oxidize to some degree. The greenish copper oxide that forms on copper wiring does not result in a problem. The oxide that forms as aluminum corrodes, can lead to higher resistance and higher temperatures.

Cu-Al CO/ALR and COPALUM

As a result of these difficulties, special components, designated Cu-Al, were produced. These included wire connectors (wire nuts), electrical receptacles, circuit breakers, stove blocks, etc. In most cases, these improvements were found to be satisfactory. However, electrical receptacles continued to be a problem. The subsequently designed receptacles, and those that are now required, were designated CO/ALR.

COPALUM connectors, used in the U.S.A., are specially designed to join aluminum wire to copper. The copper wire is then attached to a standard receptacle, switch, etc.

CUAL designation



Acceptable

As long as proper connectors are used, and the connections are made without damaging the wire, aluminum wiring is considered safe. It is permitted for use by many electrical codes, although it is not commonly used in homes due to the adverse publicity it received during its early problem years. It is still used commonly by utilities in street wiring and for service entrance cables.

Connectors

4.5.1 Aluminum Wire Problems: Where aluminum wire exists, and special connectors have not been provided, they should be added. In some cases it is difficult to know whether the connectors are appropriate. The safest thing is to replace them with those known to be appropriate. For example, the small solderless type connectors (e.g. wire nuts) are so small that they are not marked Cu-Al. They are now color coded, but on older ones it is difficult to know whether or not they are appropriate. Since they only cost a few cents each, it makes sense to replace them with those known to be the correct type.

Cu-Al and CO/ALR

Electrical outlets should be replaced with those designated CO/ALR. Service panels and their components, and other connectors designated by the utility should be replaced with components designated Cu-Al.

Pig-tails

One alternative to using special connectors is to join the aluminum wires to short "pig-tails" of copper wire just before they connect to outlets, distribution panel terminals, et cetera. The connection between the aluminum and copper wire is made with a connector known to be appropriate. This is not recommended for two reasons. First, every connection added to an electrical system is one more potential problem area. Second, in some cases, the addition of one more connection in a junction box can lead to an overcrowding situation. However, the COPALUM system is an acceptable way to enhance the safety of aluminum wires.

COPALUM

Summary

In summary, the provision of the special connectors is not an expensive undertaking (usually a few hundred dollars if done by an electrician) and is well worthwhile. In many areas, the utility will inspect a house with aluminum wiring. Where there is evidence of a problem, they will insist that any dangerous flaws be corrected. However, this can hardly be considered a disadvantage, since a safe electrical system should be a priority for any homeowner. Where there is only a small amount of aluminum wire, it is often easier to replace it with copper wire than to replace all the connectors, especially if the service panel would have to be replaced.

► 5.0 LIGHTS, OUTLETS, SWITCHES AND JUNCTION BOXES

Damaged, Poorly Secured, Overheating

5.1 Lights: Damaged light fixtures should be replaced. Light fixtures should be well secured to junction boxes. They should never be supported by the wiring. Light fixtures should be arranged so that they are not susceptible to overheating. Some fixtures require clearance from combustibles, and some can only be installed in certain orientations.

Pot Lights

Recessed light fixtures (unless specially designed) should not be installed in areas where insulation will blanket the fixture, impeding normal heat dissipation. This can be a problem on the upper floor of the house, and although there are ways of overcoming it, it is often difficult to verify whether the installation has been made safely. (For example, in a cathedral ceiling, one would have to disconnect the power and remove the fixture.) Where pot lights are used in a thermally insulated area, an electrician should be engaged to verify the safety of the system. Relocation of the insulation, or replacement of the fixture are the corrective actions.

Damp Areas

Lights used in areas where dampness may occur, should be of a special type. This includes lights in shower stalls, saunas and outdoor light fixtures.

Stair Lighting

Adequate lighting must be provided for all service areas of the house, including the furnace room. Light for stairwells which have more than four steps should be switched both at the top and bottom. This eliminates the need to walk up or down poorly lit stairs. (The basement stairs are generally excluded from this requirement.)

Heat Lamps

Heat lamps at ceiling level should be located beyond the swing of any doors. If a door is left partially open, and it happens to be directly below a heat lamp, a towel or article of clothing flung over the top of the door can be ignited, causing a fire.

Grounding

Lighting fixtures, outlets, switches and junction boxes should be grounded as required by the manufacturer.

Obsolete

Very old style porcelain light fixtures, used without electrical boxes, are not safe and should be replaced. Live electrical connections are exposed on these fixtures.

Light fixtures in closets are a convenient feature, but the lights must be kept clear of areas where they may be damaged, or where storage may accumulate directly against the light bulb. Lights should not be installed above or beside shelving units in closets. Lights above the doorway are usually safe.

Won't Work

Inoperative lights may be the result of:

1. A burned out bulb.
2. A faulty light fixture.
3. A poor connection in the box.
4. A flaw in the wiring leading to the box.
5. A problem with the switch controlling the light.
6. A problem with the wire between the panel and the switch.
7. A blown fuse or tripped breaker.
8. A poor connection within the panel.

If the problem is not simply a burned out bulb or a blown fuse, it is normally necessary to contact an electrician to resolve the difficulty.

Polarized

5.2 Outlets (Receptacles): An outlet is a point where an electric appliance can be plugged in. Until 1950 most electrical outlets were ungrounded. They had only two slots in them, one connected to a black wire and one connected to a white. A small percentage of these had the two slots a different size, (polarized receptacles) so that a polarized appliance could only be installed in the proper orientation. The convention is that the smaller slot is supplied by the terminal connected to the black wire and the larger slot is connected to the white.

Light Socket Polarity

With the exception of a few appliances, polarity was not considered too important for a long time. Even today, some appliance plugs are polarized and some are not. A floor lamp is a good example of an appliance that now has a polarized plug. The reason for this is that when changing a light bulb, there are two electrical components of the light socket which may be live electrically. The threaded collar around the socket is one half of the connection, and the brass button at the bottom of the socket is the other connection. A person is much more likely to touch the threaded collar which comes up to the top of the socket when replacing a light bulb, so it is considered safer to make that the white (neutral) connection. The black (live) connection at the bottom of the socket is less likely to be touched.

Black to Brass

Modern outlets have a brass colored screw on one side to which the live (usually black) wire is connected. The white or neutral wire is connected to the silver colored screw on the opposite side, and the ground wire is connected to the ground screw (usually green) near the end of the outlet.

Push-in, Bayonet or Dagger

Some modern outlets do not have screws on the sides, but have holes in the back, into which the wires are fitted.These are called “bayonet” ,“dagger”, or “push-in” type connectors, because of the way the wire is inserted. These outlets were particularly troublesome when used with aluminum wire.

CO/ALR and COPALUM

Special outlets used with aluminum wire are designated CO/ALR and use larger screw heads and special screw plates to hold the aluminum securely in place. The letters CO/ALR are stamped into the metal tab at the top or bottom of the outlet. They can only be seen by removing the cover plate. COPALUM connectors are also acceptable in the USA.

Grounded Outlets

The grounding of electrical outlets which became popular after 1960, and is now mandatory, affords additional protection. The ground wire is a third wire which normally conducts no electricity. It is there as a safety escape route, in case something goes wrong with the appliance or receptacle. When an appliance malfunctions, a cord is damaged, or a receptacle is faulty, it is possible that live electricity may be brought to a point where it could be touched by a person, leading to an electric shock. The purpose of the ground wire is to provide a path which the electricity will follow, rather than flowing through a person touching the system. Electricity will take the path of least resistance. It should be understood that grounded receptacles are only of value where appliances with grounded plugs are used. There are very few home appliances with grounded plugs. These include refrigerators, washing machines, microwaves, waterbed heaters, computers, and some power tools, for example. Grounded plugs incidentally, also provide polarizing, since plugs can only be put into outlets one way.

Filling the Ground Slot (Some Areas Only)

In some cases, it appears that an electrical system is grounded but it is not. Since the early 1960's, the only type of electrical outlet that could be purchased, in some regions, is one with the third grounding hole. When replacing old two-prong outlets, three-prong outlets must be used. However, unless this grounding hole is wired back through the house to ground, it is of no benefit. Some electrical authorities require that the third pin be filled, when the outlet is not grounded, to prevent plugging in a three-pronged appliance to an upgraded but ungrounded plug.

GFI's as an Alternative

When using a grounded appliance in a home built before 1960, one should ensure that the receptacle is grounded. Use of three-to-two adaptors is not considered safe and has been disallowed by electrical authorities. Similarly, connecting the ground pin to the neutral is not acceptable. Installing a ground fault circuit interrupter on an ungrounded circuit with ground type receptacles will improve the safety of the system. Many electrical authorities will now accept ground fault circuit interrupters as an alternative to grounding.

Where two-prong appliances are used, it does not matter whether the outlet is grounded or not.

For an explanation of split receptacles, see Section 5.2.3.

Location on Walls and Floors

5.2.1 Outlet Problems: Outlets are generally installed on walls about twelve inches above the floor. In older houses, they were installed in baseboards, within two or three inches of the floor. However, electrical outlets located directly in the floor should be removed or should be a special type suitable for this application. Water spilled onto the floor can create an electrical hazard. Other hazards include metal objects such as hairpins and paper clips.

Number of Outlets

In new construction, electrical outlets should be located so that there is an outlet within six feet horizontally of any point along the wall (in finished living spaces). Translated, this means there should be an outlet every twelve feet along the wall. Above kitchen counters, some codes require outlets every four or six feet, and in some areas, they are required to be split receptacles (receptacles where the top half and bottom half of the outlet are on separate circuits).

Bathrooms

Outlets are required in bathrooms or washrooms, although the outlets should be as far away from the bathtub or shower as is practical (at least three feet). Outlets should be close to basins.

Loose or Damaged

Electrical outlets which are loose or damaged should be repaired or replaced. Similarly, cover plates should be replaced when damaged.

Octopus Connectors

Octopus connectors to outlets should be avoided. These connectors allow several appliances to be plugged into one duplex receptacle. These situations can lead to overheating and fires.

Weathertight Outlets

Special weathertight outlets are required outdoors or where water may contact the outlet.

20-amp Circuits

Where local authorities allow or require 20-amp circuits, outlets should be rated for 20-amps.

Worn

Worn outlets may not retain plugs securely. This creates a dangerous situation.

Won't Work

If an outlet is inoperative, it is possible that:

1. The outlet itself is defective.
2. The wires inside the box at the outlet are not properly connected. (Intermittent problems usually mean a loose connection.)
3. There is a problem in the wire between the panel and the outlet (perhaps at another box upstream).
4. There is a blown fuse or tripped breaker in the panel.
5. There is a poor connection or damaged wire in the panel.
6. The power has been turned off.

5.2.2 Ungrounded Outlets: In houses built before 1960, almost all outlets are ungrounded. Where only two-prong appliances are to be introduced, this does not pose a hazard. However, where three-prong plugs (grounded appliances) are used, the electrical outlet must be grounded.

Difficult to Know

It is sometimes impossible to determine visually whether an outlet is grounded. In any house built in the 1960's or later, all outlets should be grounded. The grounded outlets are the three slot type. On an old house, two slot outlets were used. These are definitely not grounded. However, when these outlets are replaced, three slot outlets are often used, because in some areas the two slot type are no longer available. These outlets will not be grounded, since there is no ground wire in the box to connect to. Without testing, one cannot tell whether three slot outlets are grounded.

Adaptors

In many areas, three-to-two adaptors are available. These allow a grounded appliance to be used with an ungrounded plug. The idea is that a grounding connection on the adaptor is extended to a suitable ground. In practice, this rarely occurs and as a result, a potentially unsafe situation may be created. Consequently, these adaptors are no longer approved, or available, in some areas.

Filled Ground Slot

When three slot outlets are installed, but no grounding wire is in place, the third slot should be filled with an epoxy or a pin designed for that use (only where permitted). This will prevent a grounded appliance inadvertently being connected to this outlet.

Broken Ground Pin

In some cases, people have broken off the ground pin on a grounded appliance so that it will fit into an older two slot outlet. This is unsafe and should not be done.

Grounded Appliances

A grounded outlet is required wherever a grounded appliance is used. This may include an automatic clothes washer, portable dishwasher, microwave oven, some refrigerators, vacuum cleaners, kettles, many power tools, electric lawn mowers, personal computers, and waterbed heaters, just to name a few.

Adding Ground Wire

Ideally, the wires supplying an ungrounded outlet should be replaced with a grounded cable, or a solid ground wire (#12-gauge) can be added and connected to a suitable ground (such as a supply water pipe, in most cases). A new grounded outlet can then be installed. This is often a difficult job and may be expensive depending on the location of the outlet and accessibility of a grounding source. Since many people do not understand the importance, it is something that is not done as often as it should be.

Adding a GFI

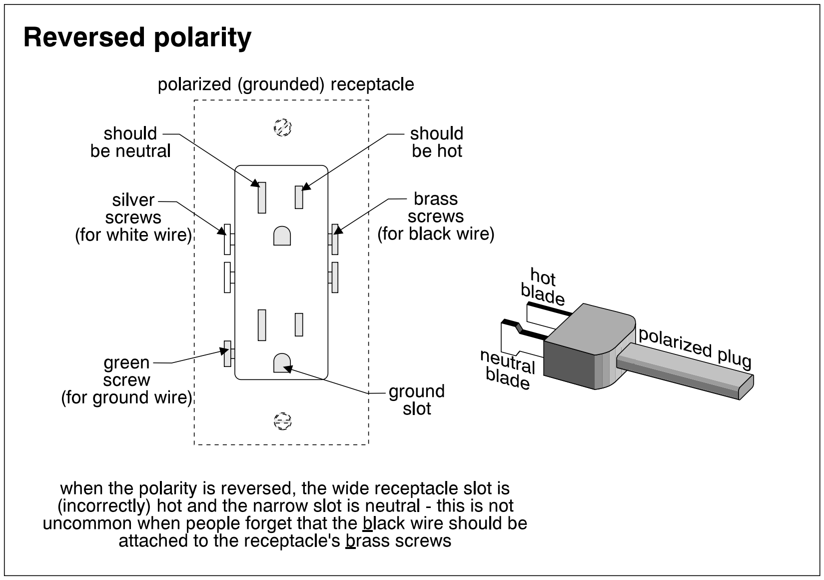
It can be argued that adding a ground fault circuit interrupter on a circuit with an ungrounded outlet will provide adequate protection. Many electrical codes accept the ground fault circuit interrupter as an alternative to grounding, under some circumstances, and this will certainly improve the situation. It is not, however, as safe as a grounded GFI outlet.

5.2.3 Split Receptacles: Split receptacles which are always the grounded type, are commonly used in the kitchen. These are special outlets in which the upper and lower halves of a duplex receptacle are on two different fuses or poles of a breaker. This means that a kettle can be plugged into the upper half of the outlet and a toaster into the lower half, without danger of overheating or blowing a fuse.

Introduced as a requirement by many electrical authorities in the late 1960's, this has become standard practice. Typically, all outlets above counters in new kitchens are now split. The fuses or breakers protecting a split receptacle should be mechanically linked. See Section 3.5.

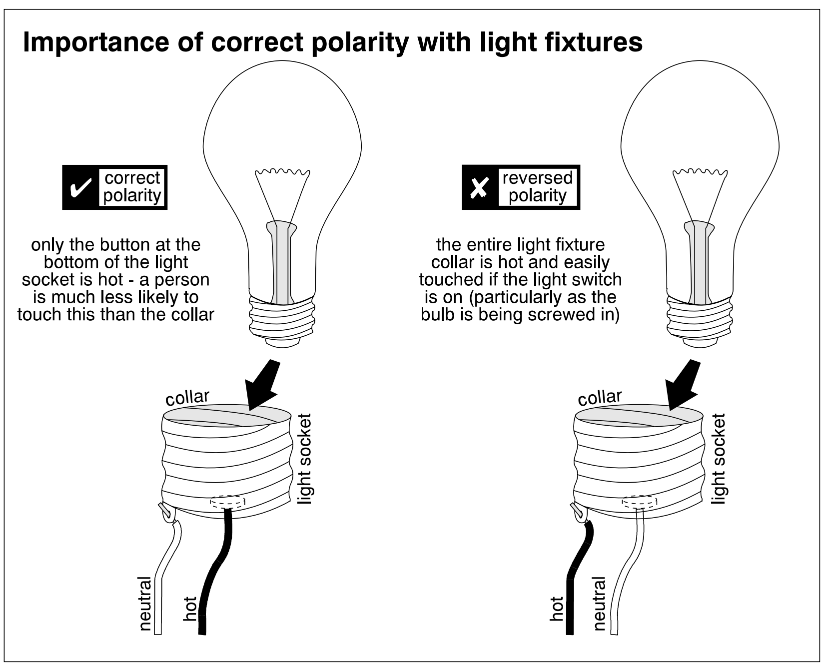
Converting to split receptacles requires running new cable from the panel to the outlet and a second fuse or circuit breaker. The two halves of a split receptacle must be fed from opposite poles of the service (i.e. one side from red the other side from black). Failing to do this creates a potentially dangerous situation. Split receptacles are susceptible to the same problems as conventional outlets.

5.2.4 Reversed Polarity Outlets: When the black wire is connected to the silver terminal screw on an outlet, and the white wire is connected to the brass screw, this is referred to as reversed polarity.



A reversed polarity outlet can compromise the safety of an electric appliance, depending on how it is wired. A grounded appliance may have its grounding made ineffective by reversed polarity.

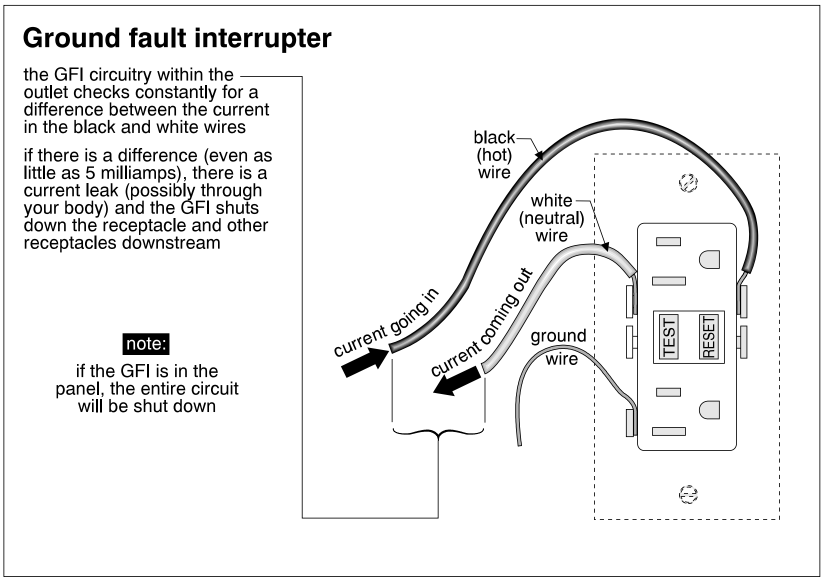
With reversed polarity outlets, it is possible for some appliances to have their housing become live in the event of a malfunction. It is also possible for some electrical equipment to operate improperly with reversed polarity. This may include a home computer, a stereo system, etc.



Corrective action simply involves disconnecting the circuit and re-connecting the wires, so that black joins brass and white joins silver.

5.3 Arc/Ground Fault Protection: Modern electrical systems make use of special electrical devices to reduce the risk of shock and fire hazards. While most codes require the installation of these devices during electrical installation, most do not call for these devices to be installed on older wiring, although the extra protection afforded by these devices is desirable.

5.3.1 Ground Fault Circuit Interrupters: These special electrical devices shut the power off to a circuit when as little as .005 amp is leaking. Under normal circumstances, the current flowing through a circuit is the same at any point. That is to say, if there are 5 amps flowing through the black wire going out, there should be 5 amps flowing through the white wire coming back.



Miswired In addition to the normal problems that may be the result of miswired electrical receptacles, a miswired GFI receptacles may not turn off even if the internal mechanism works properly.

In some jurisdictions, GFI protection is considered an appropriate upgrade where grounded (three-prong) equipment is to be used on ungrounded circuits. Even though GFIs do not add a ground wire to a circuit, they can detect a shock and shut the circuit off before the shock becomes fatal.

Missing GFIs may not be provided in new homes as required by local jurisdictions. Replacing conventional breakers with GFI breakers is not difficult, although GFI breakers are more expensive than conventional breakers.

5.3.2 Arc Fault Circuit Interrupters: Arc fault circuit interrupters (AFCIs) are devices that help protect against fires by detecting arc faults. An arc fault is an electrical problem that occurs when electricity moves from one conductor across an insulator to another conductor. Light and heat are generated as the current passes through the insulator, which may be air or a solid insulating material. Arc faults are common where electrical cords are damaged, or where outlets are not properly installed.

Arc faults are dangerous because the heat generated may ignite nearby combustible material, starting a fire. Arc fault currents are often too small to trip a breaker or blow a fuse. A GFI will not detect many arc faults.

AFCI breakers are like a Ground Fault Circuit Interrupters (GFIs) in that one device protects the entire circuit. While AFCI breakers look like GFI breakers, and have test button, they are different. GFIs are designed to prevent electrical shock. AFCIs are designed to prevent fires. GFIs look for electricity that is not where it's supposed to be by detecting electrical current running through ground wires. AFCIs look for overheating by monitoring the waveform of the circuit voltage. There are some devices that provide both AFCI and GFI protection.

AFCI protection may be provided by a breaker in the electrical panel, or through special AFCI receptacles. Either may protect a number of outlets.

Where Needed In houses built after 2001, AFCIs have been required on circuits serving bedrooms. In some areas, only receptacles need to be protected. In other areas, all electrical fixtures require protection.

Missing AFCIs may not be provided in new homes as required by local jurisdictions. Replacing conventional breakers with AFCI breakers is not difficult, although AFCI breakers are more expensive than conventional breakers.

5.4 Switches:

Damaged Loose or Obsolete Damaged or loose switches or cover plates should be repaired or replaced as necessary. The old push button switches (with two circular buttons which push into the switch and pop out) are generally considered unsafe and should be replaced. Reproduction switches of this type are now approved and available in North America, for the architectural purist.

Improper Operation Any switch that works only intermittently, or that causes the lights to flicker, should be replaced promptly.

Location Generally speaking, switches should be located about forty-eight inches above the floor, and stairwell lighting should be switched both top and bottom. Switches in bathrooms should be as far as possible from bathtubs and showers, ideally five feet or more. Some electricians prefer the light switches outside the bathroom door.

3-Way Switches Three way switches are required in order to control lighting from both the top and bottom of most stairways.

Won't Work

An inoperative switch may be:

1. A problem within the switch mechanism.
2. A problem with the connections of the wire in the box at the switch.
3. A flaw in the wire between the panel and the switch (including boxes upstream of the switch).
4. A problem downstream in the circuit from the switch which makes it seem like the switch is faulty.
5. A blown fuse or tripped breaker in the panel.
6. A damaged or poorly connected wire at the panel.
7. A burned out light bulb.

An electrician should be contacted to locate and correct the problem.

Missing

5.5 Junction Boxes: Where electrical connections are made with no junction boxes, the danger of electrical shock and fire is increased. With the exception of the early knob-and-tube wiring, all connections should be made in certified metal or plastic junction boxes. Junction boxes not only protect the connection itself, but secure the wires coming into the box and hold them in place. Connections made without junction boxes, made with junction boxes not properly secured to framing members, or made without the wires secured.

Special Outdoor Boxes

Special junction boxes are required on building exteriors. This applies to other damp locations as well.

Accessible

All electrical junction boxes should be accessible for servicing. This means they cannot be covered by plaster, drywall or paneling, for example.

5.6 Cover Plates: Missing or damaged cover plates may allow the unintentional touching of live electrical connections, and may also allow dirt, dust and water into electrical connections, causing unsafe conditions.

Light fixtures, outlets, switches and junction boxes should all be provided with cover plates as necessary, to ensure safety.

5.7 Low Voltage Lighting Control: In a small percentage of houses, a special wiring system was installed to control light fixtures. This system, used primarily in the 1950's and 1960's, employed 12 or 24-volt wiring (instead of the more common 120-volt wiring) to control light fixtures. The wires used for the switches are typically much smaller than the #14-gauge wire commonly used. This system can usually be recognized in a house by the presence of the unusually shaped rectangular or oval switches for the lights.

Convenience

The system was employed in order to provide additional safety and convenience. In most of the systems, the light in a room could be turned on by the wall switch near the door, but could also be controlled from a remote central panel, often located in the master bedroom. Many of these systems were set up so that any light in the house could be controlled from the central panel. When going to bed, for example, one could turn off all the lights in the house.

Safety

Because of the low voltage supplied to the light switches, (remember voltage is a measure of the potential electric force available) there was very little danger of electrocution at a light switch. This system is somewhat complex and uses a low voltage transformer and a number of relays. It did not become popular, although it may still be found in some houses.