InterNACHI How to Perform Residential Electrical Inspections Course

Welcome to the free, online InterNACHI How to Perform Residential Electrical Inspections Course

Goal:

The goal of this course is to teach students how to perform electrical inspections on a home. It includes a review of the service entrance, grounding, and electrical safety issues.

Objectives:

Upon successful completion of this course, the student will be able to:

- inspect the various components of the electrical system of a home;
- identify the components of the electrical system of a home;
- understand how the components of the electrical system function and perform;
- describe defects observed at the electrical system to clients

Course includes:

- 30,649 words;
- 2.1 hours of instructional video;
- inspection and writing assignment;
- research and writing assignment;
- 81 quiz questions in 6 quizzes;
- 100-question final exam (drawn from a larger pool);
- instant grading; and
- a downloadable, printable Certificate of Completion.

PDF for Residential Overview for Plumbing Overview for Inspectors Course

This guide can help you:

- Take notes;
- Read and study offline;
- Organize information; and
- Prepare for assignments and assessments

As a member of InterNACHI, you may check your education folder, transcript, and course completions by logging into your Members-Only Account at

www.nachi.org/account.

To purchase textbooks (printed and electronic), visit InterNACHI's e-commerce partner Inspector Outlet at www.inspectoroutlet.com.

Student Verification

By enrolling in this course, the student hereby attests that s/he is the person completing all coursework. S/he understands that having another person complete the coursework for him or her is fraudulent and will result in being denied course completion and corresponding credit hours.

The course provider reserves the right to make contact as necessary to verify the integrity of any information submitted or communicated by the student. The student agrees not to duplicate or distribute any part of this copyrighted work or provide other parties with the answers or copies of the assessments that are part of this course. If plagiarism or copyright infringement is proven, the student will be notified of such and barred from the course and/or have his/her credit hours and/or certification revoked.

Communication on the message board or forum shall be of the person completing all coursework.

Interactivity

Interactivity between the student and the course provider is made by the opportunity to correspond via email. Students will receive a timely response within 24 hours during the work week and by close of business on Monday for questions received over the weekend.

The student can join in the conversation with other students by visiting the online student discussion forum. Students are free to post questions and comments there. The thread will be monitored by the course instructor.

Need Help?

At any time, you may email Director of Education Ben Gromicko at ben@internachi.org.

Introduction

Note to Student

This course is not a formal representation of current standards or code interpretation. The student may use the national electrical code book to check any of the references and standards in this course, but it's not required. Some of the codes and standards referenced in this course may be checked for updates by the student in order to reference the most recent code adoption. Inspectors should reference their local authority having jurisdiction for the interpretation and enforcement of standards and codes in their area.

This course is designed to help the student understand some, but not all, electrical installations. Local codes may have exceptions to the content presented in this course. The student should consult with their local building department in order to learn which codes are being enforced in their area.

International Residential Code

Safety First

Electricity Kills

The primary responsibility for a home inspector, when evaluating electrical systems in the home, is the safety of himself and his clients, both at the time of inspection and after they move into the property.

This is also one of the few areas which most home inspectors would report as a defect -- systems or components that were acceptable when the home was built, but would now be considered defective. A lack of GFCIs in the kitchen, for example, would fall into this category.

Primary Safety

The home inspector should be especially cautious when evaluating the service panels. An electrical system and distribution panel can kill an inspector. According to the InterNACHI's Standards of Practice for Performing a General Home Inspection, a home inspector is not required to do anything that the inspector thinks is unsafe, including removing covers from electrical boxes or panels and exposing electrified, "live", or "hot" electrical components within.

Be sure to refer to InterNACHI's Standards of Practice for Performing a General Home Inspection to read the requirements and exclusions for conducting the electrical portion of a residential property inspection.

A home inspector is not required to remove the dead front (the front cover) of any electrical panel or box. The image above is a panel cover. Removing it is hazardous. InterNACHI does NOT require and does NOT recommend home inspectors to remove the dead front (the front cover).

Inspectors should follow these basic safety rules when inspecting live electrical components:

- Wear protective eye-wear.
- Wear gloves.
- Do NOT wear nylon or polyester clothing.
- Do NOT allow the client to get between the inspector and any live components.
- Visually inspect the panel or box without removing the dead front or cover.
- Do NOT touch a panel or box that is either very rusted or shows signs of moisture.
- Do NOT touch any panel or box that is buzzing or arcing.
- Frequently test for stray voltage using a non-contact AC voltage tester, such as this one.
- Do NOT insert any probes or tools into electrical panels or boxes.
- NEVER carry or position a ladder near an electrical line or cable.

If in any doubt about anyone's safety, defer the inspection to a licensed electrical contractor.

Basic Terms

Using the Correct Terminology

One of the challenges facing home inspectors doing the electrical portion of home inspections is getting the terminology right. Many home inspectors end up looking inexperienced or unprofessional by not knowing the correct verbiage. For example, a wire is more properly called a conductor.

InterNACHI Glossary

Here is a list of commonly used terms and their correct usage. Understanding these terms will help the inspector recognize improper panel wiring, especially in the case of grounded and ungrounded conductors.

Common Terminology Inspectors Use	More Formal Terminology or Description
hot or live wire	ungrounded conductor
neutral wire	grounded conductor
panel earth ground	grounding electrode conductor
earth or ground wire	equipment grounding conductor
ground rod	grounding electrode
main (disconnect)	service disconnect

main panel	service or distribution electrical panelboard with a service disconnect
sub-panel	distribution panelboard without a service disconnect
panel cover	dead front
wires to outlets	branch circuit conductors
outlet	lighting and/or receptacle outlet
service to remote panel	feeder

Ampacity

The maximum current in amps that a conductor can carry without exceeding its maximum temperature rating.

Appliance

Utilization equipment that performs a function such as clothes washing or air conditioning.

AFCI

Arc-Fault Circuit Interrupter AFCI is a device that provides protection from the effects of arc-faults by recognizing arcing and deenergizing the circuit when an arc-fault is detected.

AWG

American wire gauge (AWG) is a standardized wire gauge system used since 1857 predominantly in North America for the diameters of round, solid, nonferrous, electrically conducting wire. The cross-sectional area of each gauge is an important factor for determining its current-carrying capacity. Increasing gauge numbers denote decreasing wire diameters.

AWG tables are for a single, solid, round conductor. The AWG of a stranded wire is determined by the cross-sectional area of the equivalent solid conductor. Because there are also small gaps between the strands, a stranded wire will always have a slightly larger overall diameter than a solid wire with the same AWG.

Bonded

Connected to establish electrical continuity and conductivity.

Branch Circuit

A branch circuit are the conductors between the final overcurrent device protecting the circuit and the outlet(s).

Cabinet

A cabinet is a mounted enclosure with a swinging door.

Circuit Breaker

A device designed to open and close a circuit by non-automatic means and to open the circuit automatically when there's an overcurrent.

Current

A measurement of the rate of flow of electricity through a conductor. Current is measured in amps.

Dead Front

A dead front is without live parts that are exposed to someone on the operating side of the equipment.

Device

A unit of an electrical system, other than a conductor, that is intended to carry or control but not utilize electricity. Examples of devices are switches and thermostats.

Disconnecting Means

A device by which the conductors of a circuit can be disconnected from their source of supply.

Feeder

The feeder is a circuit of conductors between the service equipment and the final overcurrent device. Circuits feeding subpanels are called feeders. The conductors between two overcurrent devices are called feeder conductors.

kcmil

In North America, conductors larger than 4/0 AWG are generally identified by the area in thousands of circular mils (kcmil), where 1 kcmil = 0.5067 mm^2. The next wire size larger than 4/0 has a cross section of 250 kcmil.

GFCI

Ground-Fault Circuit-Interrupter GFCI is a device that protects a person by deenergizing a circuit when a current to ground exceeds the value for the device.

Line

Line refers to the incoming power. The line side of the equipment will be where the source of the power is terminated.

Load

Load refers to the outgoing power.

Outlet

An outlet is a point on the wiring system where current is taken to supply equipment. Examples of an outlet are receptacles, light fixtures, smoke detectors and appliances. A switch would not be an outlet, because no current is taken at a switch. Current simply passes through a switch.

Overcurrent Protection Device

An overcurrent protection device set to open a circuit when the current exceeds a set value. Overcurrent protection devices are usually circuit breakers and fuses.

Panelboard

A panelboard is a single panel, including buses and automatic overcurrent devices, and equipped with or without switches for the controlling of light, heat or power circuits, and is mounted in a cabinet, and is accessible only from the front.

Receptacle

A receptacle is a contact device installed at the outlet for the connection of an attachment plug.

Receptacle Outlet

An outlet where one or more receptacles are installed.

Romex

Romex is a trade name for a type of NM cable. Romex is the most commonly used wiring in homes. The proper name for this cable is nonmetallic sheathed cable. A 14/2 with ground would contain three 14-gauge conductors: one black insulated conductor (the hot); one white insulated conductor (the neutral); and one bare conductor (the ground wire).

Service

The conductors and equipment for delivering energy from the service utility to the wiring system of the home.

SE and SEU Cable

SE Cable stands for service entrance cable, which is not commonly used for service cable any longer, but is used for branch circuit and feeder wiring in homes. SEU is an SE cable and the U stands for underground. SEU cable is identified for underground use. It has a moisture-resistance covering. SEU cable will usually contain three conductors, two of which will be insulated and one will be a bare equipment grounding conductor. SE cables are jacketed with gray, sunlight-resistant polyvinyl chloride.

Nomenclature and Abbreviations

Alternate ways are commonly used in the electrical industry to specify wire sizes as AWG.

4 AWG (proper) could also be written as:

- #4 (the number sign is used as an abbreviation for "number")
- No. 4 (No. is used as an abbreviation for "number")
- No. 4 AWG
- 4 ga. (abbreviation for "gauge")

000 AWG (proper for large sizes) could also be written as:

- 3/0 (common for large sizes), which is pronounced 3 aught
- 3/0 AWG
- #000
- #3/0

Common wires used electric power distribution in homes can be identified by a wire size followed by the number of wires used in the cable assembly. The most common types of distribution cable, NM-B, is generally written in the following three ways:

- #14/2 (also written "14-2"). This is a nonmetallic sheathed bundle of two solid 14 AWG wires. The insulation surrounding the two conductors is white and black. This sheath for 14 AWG cable is usually white when used for NM-B wiring intended for electrical distribution in a dry location. Newly manufactured cables without a separate ground wire (such as #14/2) are obsolete.
- #12/2 with ground (also written "12-2 w/gnd"). This is a nonmetallic sheathed bundle of three solid 12 AWG wires having a bare ground in the middle of two insulated conductors in a flat-shaped NM-B yellow-colored sheath. The color is a North American industry standard for cables made since 2003, and aids identification.
- #10/3 with ground (also written "10-3 w/gnd"). This is a nonmetallic sheathed bundle of four solid 10 AWG wires having a bare ground and three insulated conductors twisted into a round-shaped NM-B orange-colored sheath. The insulated conductors are black, white, and red. Some cable of this type may be flat to save copper.

Pronunciation

AWG is colloquially referred to as gauge and the zeros in large wire sizes are referred to as aught. Wire sized 1 AWG is referred to as "one gauge" or "No. 1" wire. Similarly, smaller diameters are pronounced "x gauge" or "No. X" wire, where x is the positive integer AWG number. Consecutive AWG wire sizes larger than No. 1 wire are designated by the number of zeros:

- No. 0, typically written 1/0 and is referred to as "one aught" wire
- No. 00, typically written 2/0 and is referred to as "two aught" wire
- No. 000, typically written 3/0 and is referred to as "three aught" wire,

Know What You're Talking About

Getting the terminology right will avoid a lot of "Your inspector doesn't know what he's talking about" comments from local electrical contractors.

Please read the following article on common electrical terminology from InterNACHI's Library of Inspection Articles.

Simple Theory

Understanding How Electricity Works

Electrical current is actually the movement of electrons flowing along a conductor in much the same way as water flows through a pipe. The same fundamental principles apply in the same way: the bigger the pipe, the more flow it can handle. Conversely, smaller pipes can handle small supplies. This is the principle behind resistance.

An analogy to understanding electricity is a water pipe, where the voltage is the water pressure, the current is the flow rate, and the resistance is the size of the pipe. Current (flow rate or amps) is equal to the voltage (water pressure or Volts) divided by the resistance (size of the pipe or Ohms).

Amps = E / R

Current = flow rate = Amps = I

Voltage = pressure = Volts = E

Resistance = pipe size = Ohms = R

Let's see how this relation applies to the plumbing system. Assume you have pressurized water coming out of a garden hose. When you increase pressure, more water comes out of the hose. Similarly in an electrical system, when you increase the voltage (pressure, Volts, or E), the current (flow rate, Amps, or I) increases.

Now, assume you increase the diameter size of the garden hose. More water will come out of the hose. Similarly, when you decrease the resistance in an electrical system, the current flow increases.

Power

Electrical power is measured in watts. In an electrical system, power or watts (W) is equal to the voltage (V) multiplied by the current (I).

To understand power, think of taking that water pipe and pointing it at the top of an old waterwheel. To increase the power generated by the waterwheel, you can: (a) increase the pressure of the water coming out of the pipe, or (b) increase the flow rate of the water.

Measuring Electrical Forces

When discussing electrical supply, we use many different terms to quantify the amount of available power, the amount of work it can do, the resistance of the components and, therefore, its safe operating parameters. Here are some easy-to-understand definitions and explanations of the terminology.

Resistance: limits the conductor's ability to allow the flow of electrons, just as friction causes losses in any pipe or duct work. This is expressed in Ohms.

Electromotive Force: is what drives electrons along the conductor, and is expressed as voltage or volts.

Current: is the flow of electrons driven by electromotive force through a given resistance. This is expressed as amps.

Power: is the amount of work that the electrical flow can do. This is expressed as watts or kilowatts (1,000 watts).

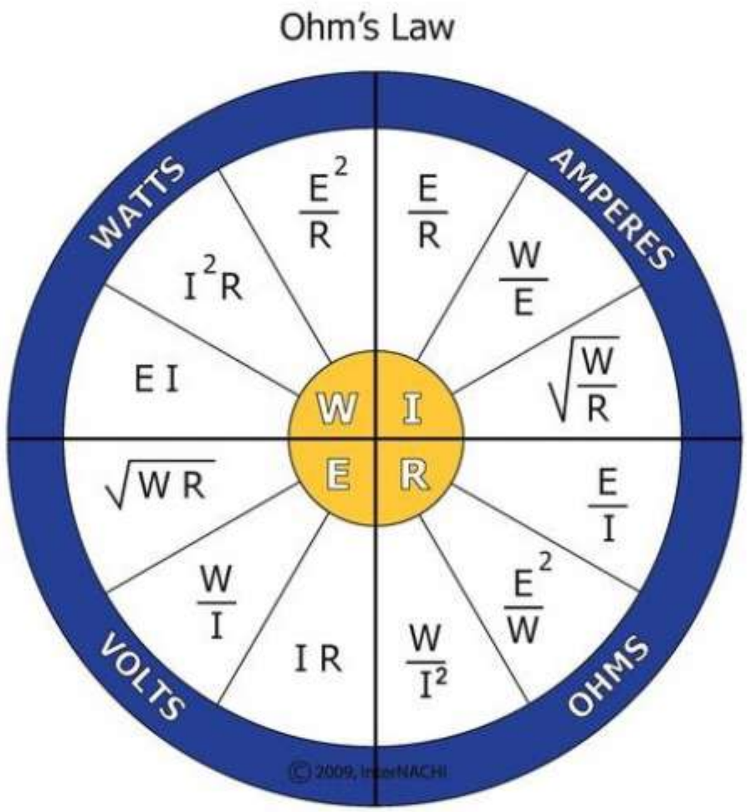
Ohms Laws

Georg Simon Ohm was a German physicist born in Erlangen, Bavaria on March 16, 1787. Ohm started his research with the then-recently invented electric cell (invented by Italian Conte Alessandro Volta). Using equipment of his own creation, Ohm determined that the current that flows through a wire is proportional to its cross-sectional area, and inversely proportional to its length. Using the results of his experiments, Ohm was able to define the fundamental relationship between voltage, current and resistance.

These fundamental relationships are of such great importance that they represent the true beginning of electrical circuit analysis. Unfortunately, when Ohm published his findings in 1827, his ideas were dismissed by his colleagues. Ohm was forced to resign from his high school teaching position, and he lived in poverty and shame. However, his research efforts gained a lot of support outside of Germany. In 1849, Georg Simon Ohm was finally recognized for his efforts by being appointed as a professor at the University of Munich.

How do the Ohms Laws help us?

Ohms Laws are basically a series of mathematical models that show us how to work out safe working loads for conductors and electrical components. This allows us to understand why, for example, a 30-amp fuse should not be connected to a 14-awg wire (that's about resistance and overheating wires).



Ohm's law defines the relationship between Voltage, Current and Resistance. Where I is the current, measured in Amperes (Amps/A). R is the resistance, measured in Ohms (Ω). E is the electrical potential (voltage). And W is power, measured in Watts.

Common Ohms Laws are:

Watts equals Volts times Amps, or W = E x I.

Another would be Amps = Watts divided by Volts, or I = W / E.

AMPS MEASURE CURRENT: The volume of the current (the number of electrons flowing past a given point per second) is measured in amperes, or Amps.

VOLTS MEASURE PRESSURE: The pressure under which electricity moves is measured in volts. Electricity arrives at household circuits at a “pressure” of 120 or 240 volts.

WATTS MEASURE POWER: Power is measured in watts, and you can compute wattage by multiplying amperage and volts.

____
____
____
____
____
____

Examples

Assume that a standard incandescent light bulb is drawing 1/2 amp from a 120-volt circuit uses 60 watts of power (120 volts x 0.5 amps = 60 watts). To calculate amps, divide watts by volts.

Assume an electric clothes dryer is using 240 volts and is rated at 7,200 watts pulls 30 amps (7,200 / 240 = 30). This means that the dryer must be protected by a 30-amp circuit breaker, and the wire carrying current to it must be No. 10 copper, which is rated for 30 amps.

How much does it cost to operate my portable electric heater? An electric heater wattage is usually given on the unit itself. Assume it is 1,000 watts. Assume that the heater is used an average of 45 hours during winter months (1/2 hour per day for the three winter months), and the utility's electric rate during the winter is $.068. Then, 1000 watts/1000 = 1 kW x 45 hours of operation = 45 kWh x $.068 = $3.06.

Now, let's assume that we have an 8-amp heater. The calculation changes just a bit to 8 Amps x 120 Volts of household current = 960 watts/1000 = .96 kW x 45 hours = 43.2 kWh x $.068 = $2.94.

Conductor Sizes

Understanding the Limitations of Conductors

As we saw with Ohms Law, resistance is key to a conductor's ability to safely deliver the amount of power that a circuit needs. Think back to the pipe: the bigger the pipe, the lower the resistance.

Conductor Material

When evaluating electrical supply, we need to recognize that copper and aluminum conductors are not the same. Although they are both commonly used in residential supply, copper inherently has less resistance to the flow of electrons than aluminum does.

For this reason, aluminum conductors are always one to two sizes larger than the equivalent copper one for any given amperage.

Jumping ahead a bit, single-strand (or solid) aluminum branch circuit wiring should always be fully evaluated by a licensed electrical contractor (multi-strand aluminum wires as seen on service entrances and high amperage circuits are not a problem). This issue is studied at greater length later in the course.

Conductor Size

As we have seen, for larger amperages, we need larger conductors. The following table is a general guide to sizing conductors for feeders and services.

Sizing Conductors for Feeders and Services (refer to National Electric Code)		
Service or Feeder Rating (in amps)	**Conductor (AWG or kcmil)**	
	Aluminum or Copper-Clad Aluminum	**Copper**
100	#2	#4
110	#1	#3
125	1/0	#2
150	2/0	#1
200	4/0	2/0
250	300	4/0
400	600	400
NEC 215.2, 230.23, 230.31	Service and feeder conductors must be sized according to the calculated load.	
NEC 310.15	Service and feeder conductors for single phase 120/240 volt electrical systems may be sized using Table 310.15(B)(7).	

NEC 310.15	Table 310.15(B)(7) may only be used for dwelling unit services or feeders if the service or feeder supplies all loads associated with the dwelling unit. The table may not be used for sizing conductors supplying power to panelboards such as HVAC disconnects or subpanels supplying only a portion of the load.

The following table is a general guide to sizing standard overcurrent devices and their related cables.

	Circuit Size (in amps)	**Copper NM Cable**	**Copper SE Cable**	**Aluminum SE Cable**
Sizes of Standard Overcurrent Device (Breaker or Fuse)	15	#14	-	-
	20	#12	-	-
	25-30	#10	-	-
	35-40	#8	#8	#6
	45-60	#6	#6	#4
	70	#4	#4	#3
	80	#3	#3	#2
	90	#3	#3	#1
	100	#2	#2	1/0
	110	-	#1	2/0
	125	-	1/0	3/0
	150	-	2/0	4/0
	175	-	3/0	250 kcmil
	200	-	4/0	300 kcmil
Table is sourced from NEC 240.4, 240.6, Table 310.15, 334.80, and 338.10.				

Overcurrent Protection Required

All ungrounded branch-circuit and feeder conductors must be protected by an overcurrent device. Overcurrent devices consist of circuit breakers or fuses. They are installed at the beginning point of the circuit where the conducts receive their electrical supply. The breakers prevent conductors from carrying current above the determined allowable ampacity. The breaker will automatically open the circuit and protect the conductors if the current is too high and may create a very high temperature hazard.

For small conductors commonly seen by home inspectors in residential buildings, the rating of the breaker must not exceed the ratings for the conductors.

Overcurrent Protection Rating			
COPPER		**ALUMINUM**	
Size AWG	Max breaker rating	**Size AWG**	Max breaker rating
14-gauge	15 amps	**12-gauge**	15 amps
12-gauge	20 amps	**10-gauge**	25 amps
10-gauge	30 amps	**8-gauge**	30 amps

AWG means American Wire Gauge and is a standardized wire gauge system.

Key Point: The maximum breaker rating must not exceed the allowable ampacity of the conductor.

The smaller conductor sizes are normally single-strand conductors, but as they get bigger, they switch to multi-strand so they can be easily worked. It is unusual to see a conductor of less than 8 AWG to have multiple strands.

Again, we'll come back to it later, but remember to look for single-strand (solid) aluminum branch circuit wiring, especially in homes built between the mid-1960s and the mid-1970s. The presence of solid aluminum branch circuit wiring in a home is a major defect. If you observe indications of such wiring type and deem it a defect, report it.

Quiz on Introduction

________ is/are considered unsuitable to wear during an inspection.

- Nylon clothing
- Safety glasses
- Leather shoes

The following item is safe to insert into an electrical panel: _________.

- none of these
- a wire gauge
- a torque wrench
- an amp probe

If __________________ is/are present, the panel should not be opened to inspect.

- any of these conditions
- moisture dripping from the enclosure
- sounds of arcing
- a rusting enclosure

A live wire is sometimes called a(n) __________.

- ungrounded conductor
- grounded conductor
- grounding conductor

The main panel is also called the _____________.

- electrical panel
- meter
- dead front cover
- main disconnect switch

If a service disconnect is not present at a panelboard, the panelboard is sometimes called a _____________.

- sub-panel
- service panel
- main panel
- disconnect switch

Branch circuit conductors are the ____________.

- wires to the outlets
- receptacle wires without insulation
- amp suppliers

________ are the units used to measure resistance.

- Ohms
- Watts
- Amps

Voltage is equal to ________.

- amps x resistance
- watts x current
- power x amperage

W = E x __________.

- I
- R
- Q
- O

__________ branch circuit conductors should be sized one to two sizes larger than copper.

- Aluminum
- Zinc
- Platinum
- Iron
- Tin

A _____-amp breaker should supply a minimum #12 conductor.

- 20
- 100
- 10
- 40

If a service entrance has a 200-amp supply, the minimum cable size should be _____________.

- 2/0 copper or 4/0 aluminum
- 5/0 copper or 1/0 aluminum
- 1/0 copper or 2/0 aluminum
- 4/0 copper or 2/0 aluminum

The maximum breaker rating must _____ the allowable ampacity of the conductor.

- not exceed
- exceed

AWG means _____ and is a standardized wire gauge system

- American Wire Gauge
- All Wire Ganger
- Anti Width Gauge
- American Without Gauge

For a 14-gauge copper wire, the maximum overcurrent protection rating is _____ amps.

- 15
- 20
- 30

For a 12-gauge copper wire, the maximum overcurrent protection rating is _____ amps.

- 20
- 30
- 25

For a 10-gauge copper wire, the maximum overcurrent protection rating is _____ amps.

- 30
- 50
- 100
- 200

Home Inspector Safety and Dangers

Electrical Portion of the House

Home inspection is one largely unregulated industry whose professionals must nevertheless be aware of their safety and that of their clients at all times. Part of this awareness is being mindful of one's surroundings, which can be challenging because the "workplace" changes with every appointment. Aside from inspecting a roof from an area above the ground, the electrical portion of a home inspection is arguably the most dangerous. Many things can go wrong in an instant, and some mishaps can be fatal. That's why, even as generalists, home inspectors should understand what causes electrical shocks and arc flashes so that they can avoid them.

The Basics

The typical electrical service for homes in North America is a 120/240V split-phase system provided by a pole-mounted distribution transformer located at the service drop, which is made up of two 120-volt lines and a neutral line. This triplex cable may include a messenger cable located in the middle of the neutral conductor that provides support over long spans. The neutral line from the pole is connected to an earth ground near the service panel, which is usually a conductive rod driven into the earth. The service drop provides the home with two 120-volt lines of opposite phase, so 240 volts can be obtained by connecting a load between the two 120-volt conductors, while 120-volt loads are connected between either of the two 120-volt lines and the neutral line. The 240-volt circuit is used for a home's electrical appliances that require substantial power, such as a furnace, water heater, air conditioner, washer and dryer, and oven/range. The 120-volt circuit is used for lighter electrical loads, such as household lighting, and portable appliances and electronics that are plugged into the home's standard two- or three-prong (with a grounding wire) electrical receptacles or outlets.

Homes in European countries use three-phase power having longer service drops that can serve multiple residences, which is an economical approach to providing power to dense populations in small areas. This type of service drop consists of three phase wires and one grounded neutral wire.

How an Electrical Circuit Works

Everyone should understand that it's possible to receive an electrical shock whenever electrical power is present, regardless of the level of power or the presence of any protective devices.

An electrical circuit requires a minimum of two wires through which electric current (in the form of electrons) flows. Current is measured in amperes (amps, for short), which travels from a power source (such as the local utility), through the device it operates, called the load, and then back to the source to complete the circuit. In AC or alternatingcurrent wiring, there are about 120 volts in the “hot” or energized wire. This voltage provides the momentum that forces the electrons to flow in the circuit.

The power switches on electrical devices are wired on the hot or “live” side of the circuit. The return conductor, known as the neutral, is at 0 volts because it is grounded at the electrical panel. Most 120-volt circuits are wired to deliver 15 or 20 amps of current.

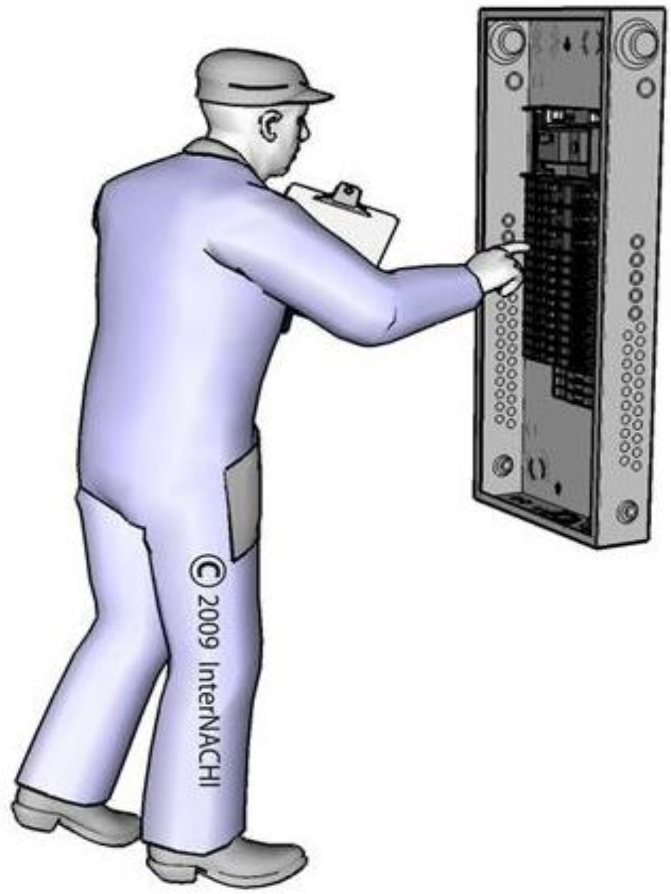
How Injuries Occur

Modern electrical systems are wired with circuit breakers, or with fuses in older construction. These devices serve as over-current protection and are rated in amps. Most household circuits are wired for 15 or 20 amps. Over-current protection devices are designed to protect the electrical system’s wiring and equipment from overheating, but they may not protect a person from electrical shock, which is why any type of component in the system should be approached with caution.

By coming into contact with a live load or energized wire, a person's body (even a finger) can complete a circuit by connecting the power source with the ground. If this happens, it’s likely that the person will sustain an injury. Most fatal injuries result from high-voltage exposure, but it’s possible to incur a severe injury from low-voltage power if it has a high-current flow. Even if the current isn’t high, a person could be shocked or even electrocuted without ever tripping a circuit breaker or blowing a fuse. Currents of 50 to 100 milliamperes (1 mA = 1/1,000 of 1 amp) can be fatal.

Standards of Practice

According to InterNACHI's Standards of Practice for Performing a General Home Inspection, the inspector is not required to:



- measure or determine the amperage or voltage of the main service equipment;
- remove panelboard cabinet covers or dead fronts;
- insert any tool, probe or device into the main panelboard, sub-panels, distribution panelboards, or electrical fixtures; or
- operate any electrical disconnect or over-current protection devices.

However, some inspectors may choose to go beyond the Standards of Practice, because they suspect some sort of defect and want to provide fuller information in their reports for their clients.

Warning Signs

Nevertheless, there are warning signs that a panel, box, or the system in general may be compromised, and these should persuade the inspector to defer further evaluation to a licensed electrical contractor:

- scorch marks on the dead front or the panelboard door, indicating a past or recent arc flash;
- rust, which indicates past or recent moisture intrusion;
- missing or open breakers that cannot be confirmed to be de-energized;
- overloading of the circuits with DIY wiring;
- uninsulated wiring;
- excessive dust, dirt and debris inside the panelboard; and/or
- any signs of water inside, around or below the panelboard, which can lead to shock or electrocution.

What's an Arc Flash?

An arc flash occurs when a flashover of electric current leaves its intended path and travels through the air from one conductor to another, or to neutral or ground. It often happens unexpectedly and can be explosive but brief, or it can last seconds and be rather visually spectacular. It can cause a little damage or it can disable a system and

require the replacement of equipment. An arc flash of any size is quite dangerous because its path is unpredictable; it will be attracted to the nearest item with the greatest conductivity, such as an unsuspecting rodent or house pet, or a person. An arc flash can cause a serious electrical burn or even fatal electrocution.

An arc flash can have various catalysts, including:

- excess dust;
- condensation;
- corrosion;
- component failure;
- faulty system installation;
- dropping a metal tool, which may cause even a small spark; and/or
- accidental contact.

How Serious Is an Arc Flash?

There are three factors that will determine the severity of an injury caused by an arc flash:

- proximity;
- temperature; and
- the time it takes for the circuit to break.

An injury due to an arc flash can be quite serious because of the violent nature of such a powerful burst of electrical energy. The light from an arc flash can be blinding and disorienting. The heat caused by an arc flash can be as high as 35,000° F, causing serious contact burns, as well as risk of catching fire. It can create a blast pressure of up to 2,000 pounds per square foot, sending damaged and super-heated electrical components flying through the air like shrapnel, with a sound blast as loud as a gun firing (140 decibels). Combine all these unexpected jolts of sensory overload and the physical consequences can be impossible to avoid.

In addition to the inspector being blinded (temporarily or permanently) and/or severely burned, another result of an arc flash is that it can set electrical components on fire, and the proximity of the inspector means that s/he'll likely inhale toxic vapors, which can cause respiratory and neurological damage, depending on the duration of exposure. Also, the force of the shockwave can rupture eardrums. Furthermore, being shocked by a current above 75 mA can cause the inspector’s heart to go into a state of ventricular fibrillation, which causes it to beat irregularly and rapidly without pumping any blood. If this condition doesn’t quickly normalize, either by itself, using CPR, or with the aid of a defibrillator, it may lead to a heart attack, which can be fatal. If the brain is deprived of oxygen for more than three minutes as a result, this, too, can be fatal, or it can land the inspector in a vegetative state.

It’s not uncommon for an inspector to never fully recover his previous quality of life after experiencing an injury from an arc flash.

Precautions for Inspectors

1. Assess your risk tolerance. You are not required to perform an invasive electrical inspection. Removing the dead front of the electrical panelboard exceeds InterNACHI’s Standards of Practice. Event if a home inspector is highly confident of their technical training, as well as the situation, and he or she can also confirm that the system is de-energized, any suspected problems that require an invasive inspection should be disclaimed and deferred to a licensed electrical contractor.

2. Wear PPE. Regardless of whether you choose to exceed the Standards of Practice, always have available and wear the appropriate PPE, including fire-resistant clothing and insulated gloves made specifically for working with electrical equipment. It’s also wise to use protective eyewear. Even a small spark can cause a severe eye injury.

3. Check your surroundings. If there is a lack of ground-fault circuit interrupters (GFCIs), or if there is evidence of a water leak or moisture intrusion, or if the panelboard or electric box has scorch marks, potentially indicating a previous arc flash or electrical fire, pay attention to these and other clues, as they may lead you to immediately defer the electrical portion of your home inspection. Again, assess the risk and then decide whether to proceed.

4. Use the appropriate tools. According InterNACHI's Standards of Practice, inspectors are required to:

> *...test all ground-fault circuit interrupter receptacles and circuit breakers observed and deemed to be GFCIs using a GFCI tester, where possible...*

Make sure your tester is working properly before your inspection appointment. An infrared camera is also an tool for helping to detect hot spots during the electrical inspection.

5. Protect your clients. Many inspectors encourage their clients to accompany them during the inspection so that they can point out important shutoff valves and switches, and discuss maintenance items. However, inspectors should use extreme caution when deciding whether to have the client with them during inspection of the panelboard if signs indicate that it may not be safe. This is true for any area of the home that exhibits signs of instability or some apparent hazard. Using the InterNACHI "Stay Back" Stop Sign (available from Inspector Outlet) can help keep clients, their family members and their realtors away from an inspected area. It's also useful for limiting the inspector's liability if the client chooses to ignore your warnings and suffers an injury during the inspection.

Summary

Arc flashes are just one of the more serious examples of what can go wrong during an inspection, which is why inspectors should follow their training, as well as their instincts, and protect themselves and their clients on the job. It's always better to be safe than sorry and incur a grievous injury, which can put both your livelihood and life at risk.

Service Entrance

Service Terminology

The service-entrance cable SEC (blue arrow) is a line of service conductors (white arrows) located between the terminals of the service equipment (main disconnect) and a point usually outside the building, clear of building walls, where they are joined by a tap or splice (orange arrows) to the service drop or overhead service conductors (red arrows).

The blue arrow is pointing to a protected or sheathed SE (service entrance) cable.

The service point is the point of connection (orange arrows) between the facilities of the service utility and the premises' wiring.

The overhead service conductors (white arrows) are also the overhead conductors between the service point (orange arrows) and the first point of connection to the service-entrance conductor (blue arrow) at the structure.

The service equipment is the necessary equipment, usually consisting of a circuit breaker(s) or switch(es) and fuse(s) and their accessories, connected to the load-end of service conductors to a building or designated area, and intended to constitute the main control and cutoff of the supply.

It is understood that raceways, fittings and enclosures housing service conductors are also part of the service equipment. Meter socket enclosures are not considered service equipment. Meter enclosures do not have interrupting ratings, disconnecting means, or overcurrent protection.

Service Drop

The service drop is the overhead service conductors located between the utility electric supply system and the service point.

Service Point

The service point is the point of connection between the facilities of the service utility and the wiring at the house.

Overhead Service

In many older residential areas, and practically all rural locations, the electrical supply is delivered to the property via overhead conductors strung on telegraph poles. The high-voltage lines connect directly to the property through a transformer delivering main power.

While the service overhead belongs to the utility company, the inspector should still evaluate it, particularly to determine the available voltage, its clearances, and any mechanical damage.

The Cable Assembly

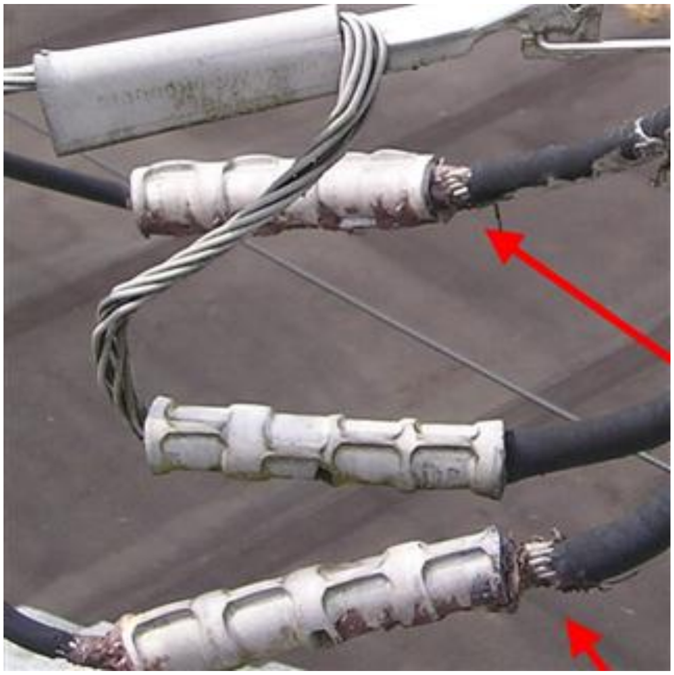
Most residential buildings are supplied with 120/240-volt services. This means that the cable assembly is made up of two ungrounded (live or hot) conductors, each supplying 120 volts, with one neutral or grounded conductor acting as the return.

Many homeowners mistakenly believe that the three conductors include one each of a live, a neutral, and a ground. In fact, to have 240 volts available in the home, we need two separately derived 120-volt ungrounded conductors and a grounded conductor. The ground does not return to the pole through the cable assembly; the grounded conductor serves the role of the return path to the transformer.

There are, however, a few variations on the theme. It is not unusual to see one of the live conductors tied back. This is indicative of a 120-volt-only supply, which is still installed in some older properties, apartments and condos. Conversely, the inspector may see cable assemblies with more than three connected conductors. This is typically a 3-phase supply commonly found in both commercial and agricultural environments.

In the case of 120-volt-only supply, we recommend that the inspector's report shows this limitation. In the case of high-voltage, 3-phase supplies, we recommend that the inspector defers this part of the electrical inspection to a qualified industrial or commercial electrical contractor.


Service Cable Connections



(Image above courtesy of member Steve Stanczyk)

The service cables are connected to the service entrance cables by crimped connectors, which are then covered in an insulated sleeve.

The image above shows these insulators missing completely, and a very dangerous condition exists, especially to the unwary home inspector.

Point of Attachment to the Building or Structure

The neutral (grounded conductor) also serves as the main physical connection (though insulated) to the building.

The inspector should ensure that this strain relief is not detached or pulling away from the structure.

On some older properties, the conductors are not in an assembly, and each has its own connection to the structure, but this is rare these days, and probably in need of replacement.

The image above (courtesy of David Macey) shows one of these older connections.

The point of attachment of the service-drop conductors to a building or structure must have a clearance above the finished grade of at least 10 feet.

Clearances

The overhead service must have some minimum separation from both the structure itself and any walkways, driveways, balconies, patios and swimming pools.

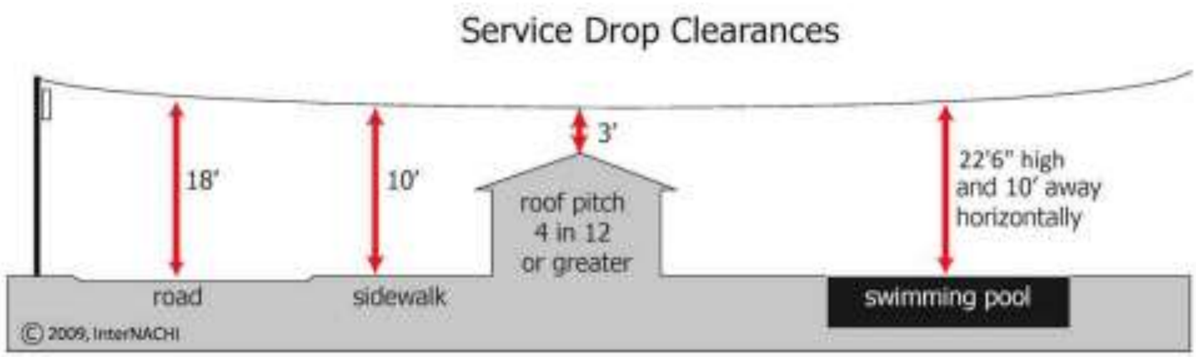
Very often, an inspector will see properties that have been modified, and the service overhead should have been relocated but wasn't. This can obviously lead to some dangerous conditions, especially over swimming pools and decks where the service connections could be accidentally reached by the homeowner.

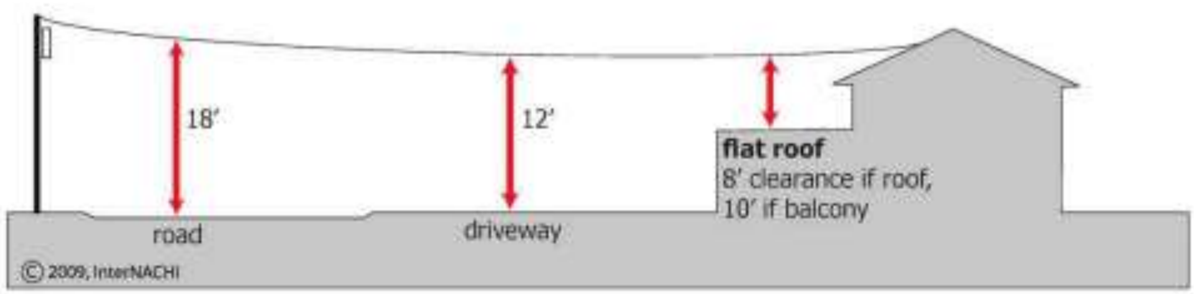
The image above shows where a second-story deck has been added, putting the electrical supply too close to the walking surface.

The image below shows electrical service conductors within reach.

Vertical Clearance from Grade for Open Overhead Service Conductors	
Location	**Minimum Clearance Requirement**
over public streets, roads, alleys, and parking areas with truck traffic	18 feet
over commercial parking areas	18 feet
over swimming pools	22 feet and 6 inches above and 10 feet horizontally
over residential properties, yards, driveways, and any other parking areas	12 feet
over all walking areas, sidewalks, decks, roof surfaces and patios used by pedestrians only, measured from final grade or other accessible surfaces	10 feet at the electrical service entrance, at the lowest point of the drip loop
above roof surfaces having a slope of less than 4:12 and not subject to pedestrian traffic	8 feet, maintained for a distance of at least 3 feet in all directions from the edge of the roof
over roofs surfaces having a slope of 4:12 or greater	3 feet

over roof surfaces where voltage is 300 or less and the roof area is guarded or isolated	3 feet
termination of through-the-roof raceway or approved support above the overhanging portion of the roof that is less than 4 feet measured horizontally	18 inches
from sides of doors, porches, decks, stairs, ladders, fire escapes and balconies, and from the sides and bottom of windows that open	3 feet from the bottom, sides and front





(Photo courtesy of Peter Siposs) The image above shows a tree viciously attacking the service supply.

Another common clearance problem is caused by trees and shrubs interfering with the overhead supply. The inspector should take the time to eyeball the length of the supply from the pole to the attachment point on the structure, and report any tree limbs touching the conductors.

Also remember that the branches are heavier during the summer and weigh down further on the conductors. What may be marginal during the winter months may well cause a problem later in the growing season.

The inspector should recommend that any limbs within 5 to 6 feet of the cable assembly be cut back.

Service Mast and Attachments

In most cases where the home is fed by a service overhead, the supply is fed down the outside of the house through a conduit known as the service mast. In some cases, the cable assembly is of type-SE, which requires no conduit.

Masthead

The masthead, or gooseneck, as it is sometimes called, is at the top of the mast itself. Its purpose is two-fold: first, to act as a rain cap to stop moisture from entering the conduit; and, second, to provide the bushings to prevent the individual conductors from being damaged by rubbing against the metal components.

The masthead should be undamaged and securely fastened to the service mast.

The inspector should report any loose fittings or cracks in the masthead and its clamp.

In the picture at the right (by Brian Goodman), the service has been damaged by a falling tree branch. Not only is the masthead smashed, but also the neutral conductor splice was torn apart and repaired using jumper cables!

Drip Loop

Before the conductors enter the service mast, there should be a loop in the conductors. The lowest point of these loops should be 12 inches below the point of entry into the masthead itself. This is to prevent rainwater from migrating along the conductors or cable assembly and pouring down into the masthead

In the picture at the left (by David Macey), it is clear that there is no loop in the conductors. In this case, it was caused by a failure of the cable assembly connection to the home.

Mast Support

Service masts for supporting the service drop and overhead service conductors should be of adequate strength or be supported by braces or guy wires. A mast in excess of 3 feet above a roof surface may require support. The weight of the cable assembly is considerable and, when applied to an overly tall mast, has the ability to bend it right over.

For the same reason, the inspector should report anything other than the cable assembly being supported by the service mast.

It is far from uncommon to see telephone cables, TV cables, satellite dishes, clotheslines, and supplies to remote buildings being supported by the service mast.

The inspector should report all of these as in need of repair or relocation.

Service Mast Flashings

As with any other projection through the roof surface, the service mast should be adequately flashed to prevent water from entering the building.

It is not unusual to see signs of water leakage through the roof due to poor mast flashings. Because the mast is generally outside of the conditioned space, these leaks commonly go on for years, causing considerable damage to the roof sheathing and fascia.

The picture on the left not only shows a silicon repair to the flashing (common on a re-shingled roof), but also note the complete lack of a masthead.

Service Mast Attachment

In the case of rigid conduit service masts, they should be attached to the structure every 5 to 6 feet throughout their length, and should also have a clamp within 12 inches of either side of the meter base, as well as at the top of the mast, if it doesn't project through the roof.

It is all too common to see the attachment clamps not replaced or loose after the building siding has been replaced.

The picture at the right shows where a clamp has not been re-tightened. Indeed, the clamp bolt is completely missing.

Any defects in this area should be reported as in need of repair by a licensed electrical contractor.

Type-SE Cable

The "SE" in SE cable stands for service entrance. This cable assembly is designed with a high degree of resistance to mechanical damage and the sun's UV (ultraviolet) rays. For this reason, it is not installed in a conduit, but is attached directly to the building.

In the picture above, a clamp should be installed near the top.

This SEC cable is painted over. I can't see any markings.

This is an SEC cable attached to the brick exterior.

This is an SE cable with labeling.

If it is located some place where it is likely to be subject to physical damage from car doors, etc., then it must be protected by a conduit.

It should still feature a gooseneck or service-head cap, and the end where the individual conductors exit the sheathing should be protected from moisture intrusion by a heat-shrunk sock if a gooseneck is used.

This type of cable should be attached to the building every 30 inches along its length, and within a foot of its top and any meter can.

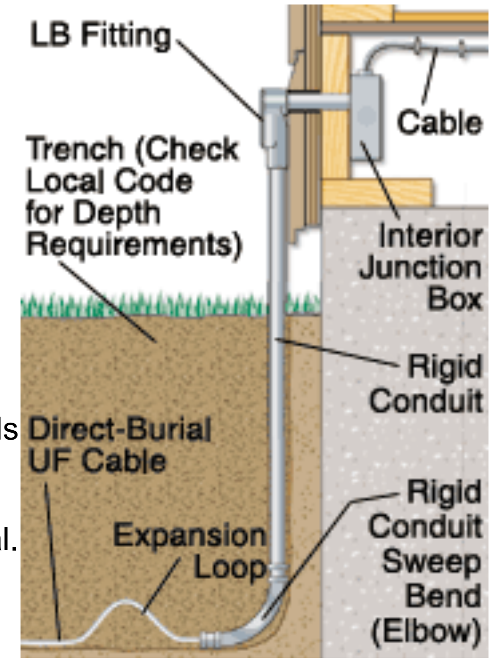
Service Lateral

Underground Service Supply

As previously discussed, in most newer and densely populated areas, the electrical supply is fed underground. This is properly called a service lateral.

Other than during the very early stages of construction, the home inspector is not able to evaluate the conduit or cable, but, for informational purposes, there are some restrictions that apply to underground services that should be noted.

Direct-Burial Cable



Type-UF cable is rated for direct burial, and has outer sheathing that is resistant to moisture and damage from soil. This type of cable must be buried to a depth of 18 to 24 inches (depending on the location, as described in section/table 300.5 of the NEC) and, if embedded in rocky ground, must be installed in a manner that will not damage the cable. This cable still needs to rise in a conduit to prevent mechanical damage before it enters the building.

The image at the right shows a typical installation. Notice the cable loop where the cable turns up towards the home. This is to allow for any building settlement. Also, the conduit features a bend at the bottom to smooth the transition from the horizontal to the vertical.

The visible conduit should be made of either galvanized steel or gray plastic, rated for the purpose.

Underground Conduit

Where the service entrance cable is not rated for direct burial, it needs to be in a full conduit, and must be buried at a minimum depth of 18 inches under landscape, and 24 inches under hardscape, such as driveways.

Where the service conductors are buried underground, they are required to have a ribbon embedded 12 inches above the conductor, unless they are under the exclusive control of the utility company.

The picture at the left shows a commercial building's electrical service.

In residential construction, there would be only one conduit.

Above-Ground Connection

The home inspector should evaluate any visible above-ground conduits and report any damage or open joints that would allow moisture into the assembly.

The images above show (left to right): a typical service lateral riser; and a damaged conduit.
(Photos courtesy of Pat Dacey)

Electric Meter

Electric Meters and Bases

The electric meter is normally part of the service entrance equipment. It is there to measure the amount of power used on the property. Some properties may have more than one meter, maybe due to multiple occupancy or discounted power for heating use.

As the meter is a rated component like any other, the ampacity of the meter and its base cannot be lower than the stated total available amperage. We will look at this further in the next section.

Meter Bases

As meters have increased in capacity over the years, the meter bases have changed. The very earliest meters (as pictured at the right) had no separate base, and are typically rated for only 30-amp supply.

- **Round meter bases:** Common from the 1920s up to the 1950s, they were rated for only 60 amps and are still often seen on older properties.
- **Square meter bases:** Typically found on homes from the 1950s to 1970s, these are still used in some smaller housing units, such as apartments, and were only rated for 100-125 amps.
- **Rectangular meter bases:** are the current minimum on single-family homes. These are rated for 200 amps and typically bear the marking "200CL."

Understanding meter bases is an important part of being able to properly evaluate the maximum available amperage in the home, but should not be relied on completely when sizing a service.

Typical Meter Installations

Pictured above (from left to right):

- multiple 60-amp **round** meter bases on a quadplex;
- 100-amp **square** meter base; and
- a modern 200-amp **rectangular** meter base.



Pictured above (left to right): a 100-amp combination panel next to an older 60-amp meter; a dual meter panel for a property that has off-peak electric heat; and a modern 400-amp supply split between 2 x 200-amp breakers. (*Photos courtesy of Bruce King)*

Service Entrance Cable

SECs

The service entrance cable (SEC) is the conductor assembly that connects from the service supply, through the meter socket, and on to the primary disconnecting means.

Obviously, the conductors are another rated component, and the home inspector needs to be familiar with the current-carrying capacity of the various sizes of cables.

Conductor Materials

Service entrance conductors, like all others, are made from either copper or aluminum. As discussed previously, aluminum conductors need to be sized larger than copper ones for any given amperage.

Aluminum terminations may also be coated with an antioxidant to prevent corrosion, although the more recent AA-8000 aluminum alloy conductors do not require it.

The use of copper is the most common, since it is the default conductor by code, but aluminum is popular for services when cost is an issue.

Service Entrance Conductor Ampacity

The table below shows the common cable sizes for both copper and aluminum, together with their ampacity and wire size.

Service Amperage	Solid Wire Diameter in Inches	**Copper Conductor**	**Aluminum Conductor**
30 amps	0.102	10 AWG	8 AWG
60 amps	0.162	6 AWG	4 AWG
100 amps*	0.204	4 AWG	2 AWG
110 amps*	0.229	3 AWG	1 AWG
125 amps*	0.258	2 AWG	1/0 AWG
150 amps*	0.289	1 AWG	2/0 AWG
175 amps*	0.325	1/0 AWG	3/0 AWG
200 amps*	0.365	2/0 AWG	4/0 AWG
225 amps*	0.410	3/0 AWG	250 kcmil
250 amps*	0.460	4/0 AWG	300 kcmil
300 amps*	0.500	250 kcmil	350 kcmil
350 amps*	0.592	350 kcmil	500 kcmil
400 amps*	0.632	400 kcmil	600 kcmil

Note:

Increasing gauge numbers provides decreasing wire diameters. For example, when the diameter of a wire is doubled, the AWG decreases by 6. The AWG sizes are for single, solid, round conductors. The AWG of a stranded wire is determined by the total cross-sectional area of the conductor, which determines the current-carrying capacity and electrical resistance. The stranded wire is about 5% larger in overall diameter than a solid wire of the same AWG.

* 100-amp to 400-amp services are based on 3-wire, 120/240-volt systems, and 310.15 (B)(6) of the NEC.

AWG = American wire gauge, also known as the Brown & Sharpe wire gauge, is a standardized wire gauge system used in the U.S. and Canada. “AWG” is referred to as a gauge, and the zeroes in large wire sizes are referred to as “aught.” Wire sized 1 AWG is referred to as “one gauge” or “No. 1” wire. Smaller-diameter wires are called “*x* gauge” or “No. X” wire, where *x* is the positive-integer AWG number. No. 0, written 1/0, is referred to as “1 aught” wire. 2/0 is referred to as “2 aught,” and so on.

kcmil = This wire size is the equivalent cross-sectional area in thousands of circular mils. A circular mil is the area of a circle with a diameter of one-thousandth (0.001) of an inch. In North America, conductors larger than 4/0 AWG are typically identified by kcmil.

Quiz on SEC

Which of the following would describe most residential services?

- 120/240-volt
- 120-volt only
- 240-volt only
- 110/220-volt

A service entrance with ________ connected conductor(s) is a 3-phase supply.

- four
- 10+
- one
- zero

The clearance for open overhead service conductors from the front, bottom, and sides of windows that ______ is 3 feet.

- open
- do not open
- are tinted
- are stained glass

If a flat roof is used as a garden, the minimum clearance required for the service drop is _______ feet.

- 10
- 8
- 12
- 18

Service drops around a swimming pool should be __________.

- 22-1/2 feet above and 10 feet horizontally away
- 15 feet above and 8 feet horizontally away
- 18 feet above and 10 feet horizontally away
- 10 feet above and 22 feet horizontally away
- 10 feet above and 20 feet horizontally away
- 12 feet above and 15 feet horizontally away

Service drops should never pass closer than ________ above the ridge of a conventional pitched roof.

- 3 feet
- 5 feet
- 8 feet

A service drop should be at least ________ away from any nearby trees.

- 5 to 6 feet
- 4 to 5 feet
- 1 to 2 feet
- 2 to 3 feet

An electrical service mast that extends 5 feet or more above the roof surface needs to be supported ____________.

- separately
- by a mast
- by the roof structure

T/F: Electrical service masts can support telephone cables.

- False
- True

Every 5 to 6 feet, rigid service masts should be secured to ________________.

- the structure points
- the hitch of the roof
- the base of the home

The method for installing a UF cable is __________.

- direct burial
- neither of these methods
- above ground

An underground service entrance is called a __________.

- service lateral
- subterranean supply
- service drop

The typical supply for a Square brand electric meter is a ______ amps.

- 100
- 60
- 200

Most modern 200-amp electrical meters are marked _______.

- 200 CL
- 100 SEC
- 200 SEC
- 100 UL
- 100 CL
- 200 UL

The minimum conductor size for a ______-amp service is 4-awg copper or 2-awg aluminum.

- 100
- 200
- 400
- none of these

Grounding Systems

What Is Grounding?

Generally speaking, the difference between grounding and bonding is: Grounding is a direct connection to the earth to aid in removing damaging transient over-voltages due to lightning. The purpose of bonding is to ensure the electrical continuity of the fault current path, to provide the capacity and ability to conduct safely any fault current likely to be imposed, and to aid in the operation of the over-current protection device. Properly bonding all metal parts within an electrical system helps ensure a low-impedance fault current path.

The issue of grounding and bonding confuses many inspectors. Due to its complexity, in this section, we will try to break it down to its fundamentals, and look at the basic requirements and common failures that can lead to unsafe conditions around the home.

Grounding

To go back to the beginning, the last stop on the utilities distribution chain, before the supply goes to the home, is the transformer. This steps the high-voltage primary distribution down to the neighborhood, to the 240/120-volt feeds to the homes.

This transformer has a winding known as a phase coil that is center-tapped to provide voltage stabilization, and a return path for the higher voltage system to aid in clearing primary side faults. As discussed earlier, on a typical 240/120-volt service drop, we will have two ungrounded conductors and a single grounded conductor.

This means that we have to establish our own grounding electrode system at the dwelling. It is vital in removing dangerous voltages imposed on the system via lightning strikes and over-voltage surges from higher voltages on power lines. If ground-rod, pipe or plate electrodes are used, they must have a rating of 25 Ohms or less; otherwise, an additional electrode must be added, per Section 250.56 of the NEC.

Grounding Electrodes

There are several methods of connecting the grounding system to the ground, with a driven rod being the most common in most areas. Most residential construction requires two separate grounding electrodes in any combination of the following (which need to be at least 6 feet apart):

- driven rods;
- metal water pipes;
- well casings;
- Ufer grounds;
- ground plates;
- steel framing; and
- ground rings.

Historically, the grounding system had just one connection to ground, and this was nearly always made on the water supply pipe. However, two connections are now required by most jurisdictions to ensure a low-impedance ground (one with little resistance).

Because most utility companies now install plastic potable water supply lines, a water pipe cannot be used as a grounding means, so one of the other electrodes listed must be used. It is also important to note that all electrodes that are present in the dwelling must be bonded together to form a single and complete grounding electrode system.

Typically, the two required grounding electrodes need to be at least 6 feet apart. If one is the water pipe ground and the supplemental is a ground rod, another ground rod may need to be added in order to meet the requirements of section 250.56 of the NEC.

Gas piping CANNOT be used as a grounding electrode for safety reasons, but, in most areas, gas lines are required to be bonded to the grounding system if they are likely to become energized.

Driven Rods

Rods made of stainless steel and copper, or zinc-coated steel, shall be at least 5/8-inch in diameter, if unlisted. Listed rods may not be less than ½-inch in diameter. All rods should be driven 8 feet into the earth. If pipe or conduit is used as a grounding electrode, it must also be no less than 8 feet in length, and no smaller than trade size or ¾-inch. Pipe or conduit made of steel shall have an outer surface that is galvanized or otherwise metal-coated to resist corrosion. The ground wire (the grounding electrode conductor) needs to be fastened with the correct approved clamp/s, and these need to be rated for direct burial, if located below ground.

It is common to see these "acorn" clamps installed improperly, with the conductor clamped under the screw rather than to the solid part of the clamp which has the biggest contact area. The photo at the left demonstrates this problem.

Sometimes, in very rocky earth, the rods cannot be driven perpendicular to the ground, so they may be driven at an angle of less than 45 degrees. If they cannot be driven at all due to unfavorable soil conditions, they can be installed in a trench no less than 30 inches deep. But no part of any grounding electrode can be closer than 6 feet to any other.

Metal Water Pipes

As discussed above, these were the most common connections at one time, with all homes being connected with metal piping.

Where the metal pipe is used as a grounding electrode, the conductor should be connected with clamps rated for water tubing, and needs to be connected within the first 5 feet of piping as it enters the structure.

The image at the right shows the appropriate cast bronze clamps.

Since the water meter is a removable part of this potential circuit, a jumper cable needs to connect the pipework on either side of the meter to ensure continuity at all times.

Well Casings

As wells are bored to a great depth and lined with metal sleeves, they make good grounding electrodes, as long as they are far enough away from other grounds and are properly connected.

Ufer Grounds

More properly referred to as a "concrete encased electrode," the Ufer ground is named after Herbert George Ufer, a retired Underwriters Laboratory vice president, who developed the system during WWII to help ground concrete armament bunkers.

With so many homes and commercial buildings now built on concrete, steel-reinforced slabs, this grounding system has become very common.

The requirements for Ufer grounds are that they have either 20 feet of #4 rebar, or 4-awg copper wire embedded in at least 2 inches of solid concrete within the footer that is in contact with the earth.

This system must also have an external means of connecting other grounded systems to it, such as telephone wires.

The images below *(courtesy of Greg Fretwell)* show both the rebar in place prior to the concrete pour, and the above-ground accessible connection for the grounding system. The rebar is painted green so its presence can be verified by the AHJ.


Ground Plates

In some cases, ground plates are used as the grounding system, but this is uncommon in residential construction.

Ground plates made of ferrous metal (such as iron or steel) shall have a thickness of no less than ¼-inch. Plates made of non-ferrous metal should have a thickness of no less than 0.06 inches. They should be at least 2 square feet in overall size, and be buried to a depth of 30 inches.

Steel Framing

Steel-framed buildings typically use the frame as one of the grounding electrodes, as long as the structure is substantial enough and has at least 10 feet of connection to the earth. Most commonly, the framing is connected to an Ufer ground.

Ground Rings

Again, although it's very rare in residential construction, a ground ring may be installed where a minimum 2-awg conductor is buried to a depth of at least 30 inches right around the structure.

Grounding Electrode Conductors

The GEC is the conductor that connects to the grounding electrode, and its size is dictated by the size and, therefore, the amperage of the service conductors. The table below shows the sizes.

Copper SEC Size	Aluminum SEC Size	Copper Grounding Electrode Conductor Size	Aluminum or Copper-Clad Grounding Electrode Conductor Size
2 awg or smaller	1/0 awg or smaller	8 awg	6 awg
1 or 1/0 awg	2/0 or 3/0 awg	6 awg	4 awg
2/0 or 3/0 awg	4/0 or 250 kcmil	4 awg	2 awg
over 3/0 to 600 kcmil	over 250 to 500 kcmil	2 awg	1/0 awg
over 350 to 600 kcmil	over 500 to 900 kcmil	1/0 awg	1/0 awg
over 600 to 1,100 kcmil	over 900 to 1,750 kcmil	2/0 awg	1/0 awg
over 1,100 kcmil	over 1,750 kcmil	3/0 awg	250 kcmil

Remember: The GEC should be connected only to the neutral at the service panel (the panel containing the service disconnect) and no where else.

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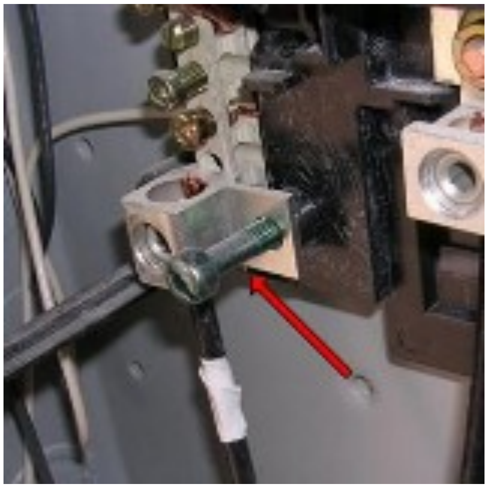
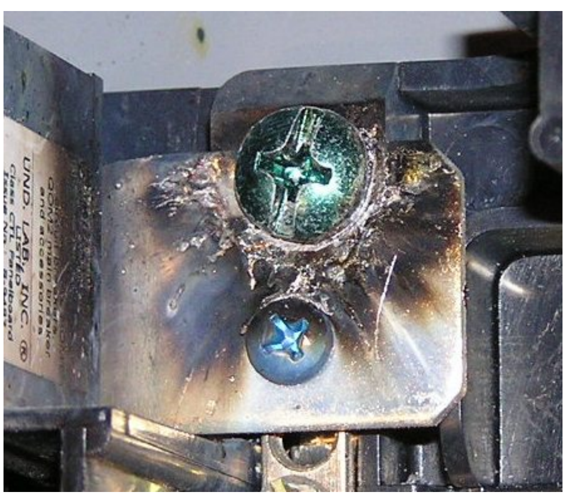
Bonding of Components

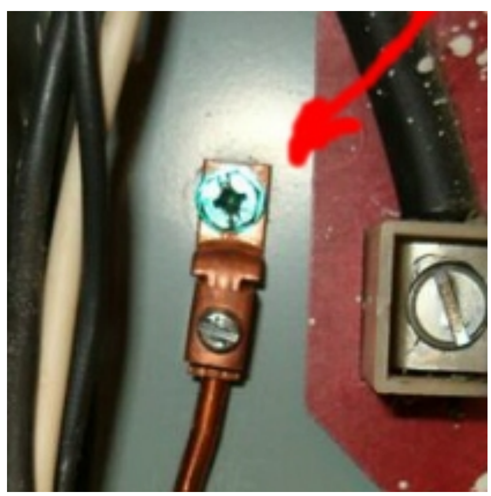
The purpose of bonding is to ensure the electrical continuity of the fault current path, provide the capacity and ability to conduct safely any fault current likely to be imposed, and to aid in the operation of the over-current protection device.

As discussed in the section on panel enclosures, they need to be bonded to the grounding system. But there is also a very long list of other components that need to be connected to ground, since they have the potential to become energized to electrical faults. These components include:

- interior water piping;
- water heaters;
- around water meters;
- gas lines;
- electrical enclosures;
- electrical raceways;
- electric outlets or junction boxes;
- CSST gas piping (manufacturer's compliance); and
- telephone and cable TV systems.







The images above show several different styles of panel bond. Some are straps, some are made up of conductors, and, in some cases, the bond is one of the screws holding the bus onto the enclosure.

In more modern panels, the bonding connector is required to be through an approved green screw so it is more apparent to both the electrician and the code enforcement officer. However, in many panels, there may be a bonding strap or bonding bar.

Panels and Enclosures

NOTE: All conductors in image shown above as copper.

Remote Distribution Panels

Although this topic is covered in other areas, because the emphasis is on safety, it's important to review.

The National Electrical Code (NEC) does not recognize the term "sub panels." From a code standpoint, there are two types of panels:

Service Panels

A service panel is a distribution or load center that contains the main disconnecting means. This is the **ONLY** panel where the neutral and grounds should be joined (bonded) together.

Distribution Panels

Distribution panels, or load-side panels, are downstream from the panel containing the main service disconnect(s). In these panels, the neutral and grounds should be separate, and the neutral bus should be isolated from the panel enclosure.

The only exception to this is in existing detached structures where no metallic path exists between the structures. In this exception, a connection between the grounded conductor and the metal case via a bonding jumper is permitted. According to the 2008 NEC, this is not allowed in new construction, so, in all cases, a 4-wire feed to the detached structure is required in order to isolate the grounded conductors from the equipment grounding conductors.

There are two methods of providing ground continuity back to the service panel:

1. four conductor feeders with:

- two hot or ungrounded conductors;
- one neutral or grounded conductor; and
- one grounding conductor.

2. three conductor feeders with:

- two hot or ungrounded conductors;
- one neutral or grounded conductor; and
- equipment grounding through conduit/tubing, electrically linking the two panels (allowed by section 250.118 of the NEC).

Inspecting Service Panels

1. Are the neutral and ground connected (bonded)?
2. Is the panel enclosure connected (bonded) to ground?
3. Does each neutral conductor terminate at a separate lug on its bus?

Inspecting Distribution Panels

1. How is the service grounded back to the service panel?
2. Are the neutrals and grounds separated?
3. Is the neutral bus isolated from the panel enclosure?
4. Is the panel enclosure connected (bonded) to the grounding bus?
5. Does each neutral conductor terminate at a separate lug on its bus?

An important note: Every structure is required to have a grounding electrode system. If they are present in the structure, they must all be bonded together. If a detached structure has a remote distribution panel located at the structure, then it requires a grounding electrode system of its own. The equipment grounding conductor in a 4-wire feeder does not take the place of the required grounding electrodes. It is also important to understand that if the detached structure is being fed by a single branch circuit, and it contains an equipment grounding conductor which is used for grounding the non-current-carrying metal parts of equipment, then no grounding electrode system is required.

Further Evaluation

The inspector should pay very close attention to the grounding and bonding of all electrical circuits. Sometimes, it is very hard to figure out which components are electrically connected to others.

Do not disturb conductors in the panel! The inspector is limited to a visual inspection only. Probing around inside energized panels may cause loose conductors to become detached or result in electric shock.

When in doubt, defer to a licensed electrical contractor.

Quiz on Grounding & Bonding

Most areas require two means of____________ grounding .

- separate
- joined

The minimum size for a listed, stainless steel, driven grounding rod is _______.

- 1/2-inch diameter and 8 feet long
- 5/8-inch diameter and 6 feet long
- 1/2-inch diameter and 6 feet long
- 5/8-inch diameter and 8 feet long

Gas supply piping cannot be used as a ____________.

- grounding means
- none of these
- breaker
- amp supplier

____________ need to be bonded to ground.

- All panel enclosures
- Only panel enclosures containing the service disconnect

The grounded and grounding conductors ________________ bus in the service panel.

- can share a common
- must have a separate

The ungrounded and grounding conductors can share a common bus __________.

- never
- in the service panel
- in the downstream distribution panels
- in any distribution panels

How can you bond a remote distribution panel?

- By connecting the enclosure to the grounding bus
- By connecting the enclosure to the ungrounded conductor bus
- By connecting the enclosure to the neutral bus

Conductors between the main service disconnect to the distribution panels are called __________.

- feeders
- travelers
- runners
- legs

Grounding gets rid of damage due to transient over-voltages caused by what?

- lightning
- gas leaks
- flooding
- wind

Properly bonding all ____________ within an electrical system helps ensure a low-impedance fault current path.

- metal parts
- amp suppliers
- wires
- none of these

The Service Disconnect

All electrical systems require a means of disconnection so that the service can be shut down quickly if any dangerous conditions exist. In this section, we will look at the types of disconnects, and the common problems that need to be reported.

The service equipment is the necessary equipment, usually consisting of a circuit breaker(s) or switch(es) and fuse(s) and their accessories, connected to the load-end of service conductors to a house, and intended to constitute the main disconnecting means for service. The disconnecting means for service should be located outside or inside the house as close to the point of entrance of the service conductors as possible. The service equipment must be identifiable and marked as a service disconnect. A common service size for a single-family house is 200 amps. And the main 200-amp breaker located at a main panelboard would be the main disconnect for the service.

Requirements

It is required that the entire electrical supply to the home be able to be shut off with six or fewer moves of the hand. This can be in the form of one or more knife switches, one or more fuses or fuse blocks, and, most commonly and in more recently built homes, by throwing the breaker(s).

If the supply cannot be disconnected from one location in this manner, the home inspector should report that the system needs repairs or upgrade.

Types of Disconnect

As discussed, different systems are in common use today, depending on the age of the property:

- knife switch: This is the oldest type of disconnecting means. We all remember the old horror movies where Dr. Frankenstein was shown energizing his creation. The switches he used were knife switches.

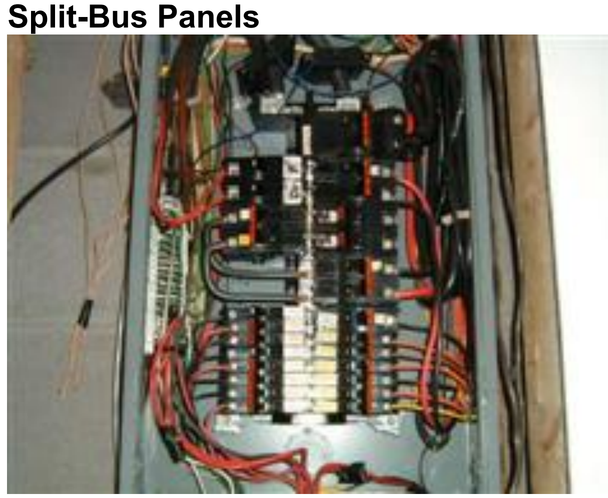
- fuse blocks: Often called mains and range panels, the electrical supply is shut down by pulling the two fuse blocks from the panel.

- breaker(s): This is the most common type of disconnect we encounter. Throwing one or more breakers shuts off the electrical power. In most cases, we see a single main breaker, but there are "split-bus" panels where the homeowner would need to trip several breakers to affect a total shut-down.

Again, the rating (or fuse or breaker size) of the disconnect relates to the total amperage available within the home. If the main disconnect is, for example, rated only at 100 amps, it doesn't matter that the SECs are rated for 200 amps.

The photo at the top depicts a knife-and-fuses-style disconnect -- and there is a big problem with this one. Can you spot it? The photo above-left shows a range and mains fuse-block disconnect. The photo at the right shows a modern breaker-style main disconnect. (Photos courtesy of Jeff Pope and Kevin Williams)

Split-Bus Panels



As discussed, some panels are of a split-bus design, which means that the bus bars that the breakers draw power from do not extend right through the panel.

Normally, these panels will have multiple double-pole breakers at the top of the panel controlling the usual 240-volt circuits, such as for a clothes dryer, stove, and air-conditioning unit.

However, on these panels, one of these double-pole breakers also shuts down power to the lower parts of the bus, which controls the individual 120-volt branch circuits.

The panel at the right clearly shows the connections between the lowest double-breaker on the left-hand side and the lower portion of the bus bar.

Remote Disconnects

In many homes, and in nearly all mobile or manufactured homes, the service disconnect is not in the main distribution panel.

This is not a problem, but care must be taken to fully investigate the grounding and bonding of all downstream distribution panels, as will be covered later.

The inspection image above (courtesy of Mike Rose) shows the main disconnect on the exterior of a home in the same service panel as the electrical meter.

In terms of grounding and bonding, the neutrals and ground should be bonded in this panel only.

Notes on "Mains and Sub" Panels

Remember that the panel with the main disconnect is the service panel, and panels downstream (or on the load side) of the service panel are distribution panels.

Neutrals and grounds should be bonded together ONLY in the service panel, and not in any downstream distribution panels. This will be covered in more detail later.

Service Amperage

Service

For houses serving one family, the ampacity of the ungrounded service conductors shall be a minimum of 100 amperes, 3 wire. For all other installations, the ungrounded conductors should have an ampacity of at least 60 amperes. The ungrounded service conductors should have an ampacity of at least the size of the load served.

Reporting Main Service Disconnect's Amperage Rating

According to the Home Inspector Standards of Practice, the inspector shall describe the main service disconnect's amperage rating, if labeled. That's all a home inspector needs to do here. Reporting the disconnect's amperage rating is important for two reasons. First, an older home may not have enough power for a modern family's needs. Second, many insurance companies will not insure a property with less than a 100-amp service.

As illustrated in the section on meters, electrical services have gotten much bigger since we first started wiring homes for electricity over 100 years ago. When homes were first wired for power, there were few electrical devices available, so a couple of 15-amp lighting circuits, and maybe a radiogram outlet, were all that was needed.

Obviously, in the modern age, we have gotten much more ambitious with our use of electric power. Just about every room in the home has multiple appliances in it, and we need high-amperage 240-volt circuits to run systems such central air conditioning and electric clothes dryers.

Development of Power Needs

The list below is intended to be no more than a rough rule of thumb covering the average unimproved electrical supply over the last century, and would cover the average 1,500- to 2,000-square-foot home.

- 1900s to 1930s: 30-amp supply
- 1930s to 1950s: 60-amp supply
- 1950s to 1970s: 100-amp supply
- 1970s to 1980s: 150-amp supply
- 1980s to 2000s: 200-amp supply

Obviously, larger and more expensive homes have always required more power than the norm, and it is not unusual now to see 400+-amp services in high-end homes.

Calculating Available Amperage

In many cases, the listing information about a home may not be correct regarding the service amperage because brokers or owners rely solely on the size of the main breaker or fuse. Many people are also under the mistaken impression that the total available service amperage is the total of the individual breakers or fuses in the service panel.

One way for a home inspector to help communicate the available amperage is to determine the ampacity of the lowest-rated or the weakest link of the following components:

- service supply;
- electric meter and socket;
- service entrance conductors;
- service disconnect; or
- distribution panel.

Here are a couple of examples:

Example #1:

- 200-amp service lateral
- 200-amp meter and base
- 175-amp-rated SEC
- 150-amp-rated panel
- 125-amp labeled service disconnect

A home inspector should describe the main service disconnect's amperage rating.

Example #2:

- 150-amp service drop
- 60-amp identified meter and base
- 150-amp SEC
- 100-amp-rated panel
- 100-amp labeled service disconnect

A home inspector should describe the main service disconnect's amperage rating. The home inspector may also describe the 60-amp meter as a potentially inadequate that should be further evaluated by a licensed electrician.

A home inspector is not an electrician. A home inspector must be careful in describing total amperage service supplied to the house. A home inspector must follow the Standards of Practice, and be careful in exceeding those Standards.

Please refer to the electrical section of the Home Inspector Standards of Practice.

Inspecting Enclosures, Part I

Electrical panels and boxes, regardless of their purpose, could be inspected for the following safety-related issues. Any deficiencies should be reported as in need of repair or replacement by a licensed electrical contractor.

All of the following refer back to the beginning of this course, as they are all related to safety:

- panel access;
- missing knockouts;
- missing bushings;
- moisture;
- rust;
- signs of arcing;
- incorrect dead-front screws;
- panel listings (UL ratings);
- missing legend;
- damaged breakers; and
- panel bonding.

Panel Access

As can be seen in the header image, all service panels' locations have to provide adequate access for servicing. They should be on a free wall space not less than 30 inches wide, have a clear 36 inches of space in front of them, and have 6 feet and 6 inches of head room. The panel, though, is not required to be centered in this space. In existing homes with a service of 200 amps or less, a reduction in head room is permitted by Section 110.26 (E) Ex. of the NEC.

In older homes, it is also common to find electrical panels inside closets. This is no longer acceptable in new construction. Similarly, service disconnects and remote distribution panels are not allowed in bathrooms.

Frequently, the home inspector will see installations that are either restricted by stored items or other systems have been installed in front of the panel.

Images above depict: (top) an electrical panel behind a bathroom mirror *(photo courtesy of Harvey Gordon)*; (center) an older-style fuse panel built over with kitchen cabinetry; and (above) a panel obscured by boiler plumbing.

Missing Knockouts

There should be no opening into the panel interior. This is to prevent accidental electrocution by someone being able to put a screwdriver or a finger into the panel and touch a live component.

However, inspector frequently see holes where wiring has been changed, or where breakers have been swapped around. All of these should be reported as safety defects with repairs by a licensed professional recommended.

The inspection image above is by Jeff Pope shows a missing breaker knockout. With this particular Zinsco panel, someone would be able to touch the live bus bars.

It is also common to see upgrades where the old panel has been relegated to the role of a junction box, but all breaker holes are still open.

Missing Connectors

Anywhere a cable or cable assembly enters a panel or other enclosure, there should be a connector.

This is designed to do two things: first, to locate the cable securely (called strain relief); second, to protect the cable from chafing against the enclosure itself.

In many cases of homeowner wiring, we will see no connector present at all, or an unlisted item being used.

The inspection image above is courtesy of Jeff Judy and shows how a "Big Gulp" lid has been used as a bushing. What is the UL listing for a soft drink lid?

Inspecting Enclosures, Part II

Moisture

A crucial point to always bear in mind is that water can be a very good conductor of electricity. Any panel that is damp or wet **should NOT be touched or opened** by an inspector.

Before even thinking about touching, inspecting or removing a dead front cover, the inspector should look carefully for signs of water or moisture staining on the panel or on its surrounding wall.

As we saw with the service entrance, any failures of the mast or cable entryways may result in water getting into the panel.

If there is any evidence of water, the inspector should recommend that the panel be fully evaluated and repaired by an electrical contractor, so delving further into the panel is not only potentially dangerous, it's also unnecessary.

In the inspection image above *(courtesy of Jeff Pope),* water is dripping off the branch circuit conductors. This panel should probably not have been opened.

Rusting Enclosures

It goes without saying that any panel or enclosure showing rust has been exposed to a high level of moisture. It may well be that a previous leak has been repaired, but the inspector should be extremely cautious of inspecting the panel any further.

Remember: The inspector's primary goal is to maintain both his own safety and that of his clients.

Damaged Breakers

There are several issues related to circuit breakers:

1. Are they rated for the model of panel they are installed in?
2. Do they have their handle ties in place on double-pole breakers so that both sides of the circuit can be shut off at the same moment?
3. Are there any signs of arcing, burning or smoke damage that would indicate that the breaker is not tripping as intended?

We will look at these issues in more detail later.

Signs of Arcing

As part of the initial visual inspection of a panel, the inspector should look closely for any signs of arcing or burn marks on the panel. Again, these may be the result of previously repaired problems, but don't count on it. Also, take a second to listen to the panel because, in many cases, you may hear arcing.

Arcing or smoke damage on the outside of the panel is obviously indicative of a previously significant and dangerous condition. It is recommended that the inspector, at a minimum, ask the homeowner for details of the damage, and its repair, prior to opening the panel.

Remember, there are many issues that can lead to this kind of telltale marking, and many of those can lead to the panelboard being live, or short circuits being caused by removal of the dead front.

In the inspection images above: Notice the burn mark above the air freshener in the photo at the left. In the center photo, what caused the flash mark on this dead front? *(Courtesy of John Onofrey)* The photo at the right shows a smoke-damaged fuse panel *(courtesy of Charles Buell).*

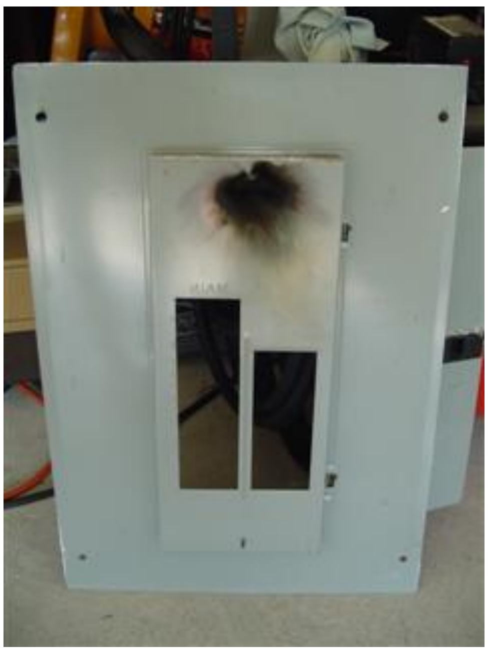
Inspecting Enclosures, Part III

Incorrect Dead-Front Screws

As was discussed for arcing issues, many faults related to damage to conductors inside the panel are caused by either the wrong screws being used, or the correct screws running up against the live conductors and causing a dead short against the panelboard.

The result is that an arc flash vaporizes the steel of the screw and panel, or the copper of the conductor, and can send a cloud of molten metal and sparks straight out.

That's why the inspector needs to be wearing **safety glasses and cotton clothing**.



In the inspection images above, the burn mark was caused by the dead-front screw cutting through the insulation of the conductor. The images at the center and the right *(courtesy of John Onofrey)* show what happens when a pointed sheet-metal screw is used, rather than the correct snub-nosed machine screw -- a hole can be seen in the insulation.

Missing Legends

All fuse or breaker panels are required to have an accurate listing of what the circuits are connected to. This is properly called a legend.

An unsafe condition can easily exist if the homeowner turns off a breaker, believing to have killed the power on the circuit, only to find that s/he tripped the wrong breaker. For this reason, any deficiencies in the labeling of panels should be noted, with the client made aware of the need for this to be rectified.

The legend at the right is a very rare thing. It was printed out by the installing contractor and stuck to the panel cover.

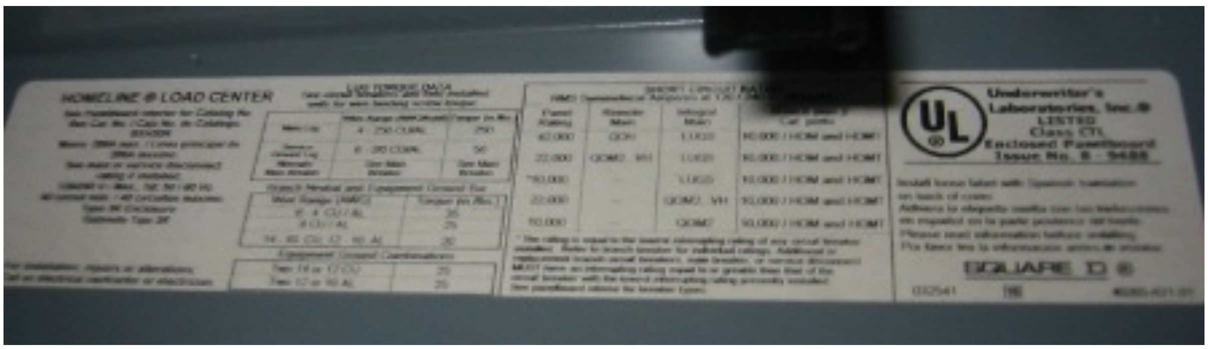
It's more typical, however, that the legend is missing, incomplete, inaccurate or illegible.

Panel Ratings

Panels, like any other components, are rated or UL-listed (by the Underwriters Laboratory). Every panel must carry a label explaining where it can be used, what it can be used for, how many circuits it can support, and, most importantly for inspectors, the maximum amperage it can support.

In many cases, these panel markings are obscured, but, wherever possible, the home inspector should attempt to check the labels to ensure that the panel is rated for the correct amperage.

The panel label below is typical:



Panel Bonding

While looking at general panel conditions, the inspector should pay attention to the requirements for all panels to be bonded to the grounding system.

This ensures that any electricity that is imposed onto any metal parts of the electrical system is safely transferred to the grounded conductor, and, in the case of a fault condition, allows the over-current protection device to activate properly. In applications where the grounding bus is screwed directly to the panel, this connection is already there.

Where the grounds and neutrals (grounded conductors) share a bus, a bond should bridge between that bus and the enclosure.

If the ground bus is isolated from the enclosure (for example, by an insulated plastic bushing), a bonding jumper needs to be installed between the bus and the metal enclosure.

In all cases, look for a **green-headed screw** signifying that the panel is bonded to the ground.

The inspection image above *(courtesy of Andy Way)* shows a panel bonding screw that has been backed out from the neutral bus bar. This would be correctly installed if this panel is remote from the main disconnect. However, for safety reasons, the screw should have been fully removed to ensure in the future that it was not connected in error. If this panel contains the main disconnect, the screw should be driven in to provide an electrical connection between the bus and the enclosure.

Fuse Panels

Edison Base Screw Fuse Panels

These panels were universal from the earliest days of electricity in the home, right up to the 1950s when breaker panels started to appear in residential construction. Many homes built up until the late 1960s still had fuse panels.

Fuse panels are generally seen as being more reliable than breaker panels because of the fact that they will always blow when overloaded, either by loads imposed on them or under dead-short conditions. Breakers, on the other hand, have been known not to trip at the specified amperages.

Many insurance companies, however, will either not insure these homes that still have fuse panels, or will insure them at higher premiums. This is not due to any danger from the fuses themselves; rather, it is indicative of a generally older, unimproved system which, statistically, is more likely to produce an electrical fire.

Fuse Blocks

Many fuse-style panels use a fuse block as both the primary over-current protection and also as the disconnecting means. These Bakelite blocks contain two cartridge (or "shotgun shell") fuses.

This block (or blocks) must be pulled to disconnect the power to the home.

These fused panels are normally rated at either 60 or 100 amps.

The picture at the right *(by Dave Macey)* shows one of these blocks removed to expose the internal fuses (one on each 120-volt supply). In this case, the fuses are each 100 amps, indicative of a fuse panel installed in the 1960s.

Main and Range Panels

Many homes from the 1930s onward used main and range panels. These have two fuse blocks: one acting as the main disconnect and primary over-current device, and a second block supplying power for the electric ranges.
These became very common from this time on.

Some fuse panels may contain as many as four fuse blocks, commonly having one as the main disconnect, with the others supplying other 240-volt circuits for appliances, such as ranges, air-conditioning equipment, clothes dryers, and even other distribution or "sub" panels.

In all cases, all the blocks must be removed to completely disconnect all the power to the home.

The image at the left is of the panel from the fuse block pictured above. Notice the two fuse blocks and the Edison base fuses. This panel has multiple double taps, which is especially dangerous, as there is one free circuit available which could be safely supplying a separate circuit. *(Photo courtesy of Dave Macey)*

Edison Base or Plug Fuses

These are the fuses that screw into many older panels and have the same thread that Edison used for other applications, such as the common light bulb. This obviously creates a problem, since a higher-amperage fuse can be screwed into a location supporting lower-amperage conductors, effectively turning the conductor into the fuse (not a great idea).

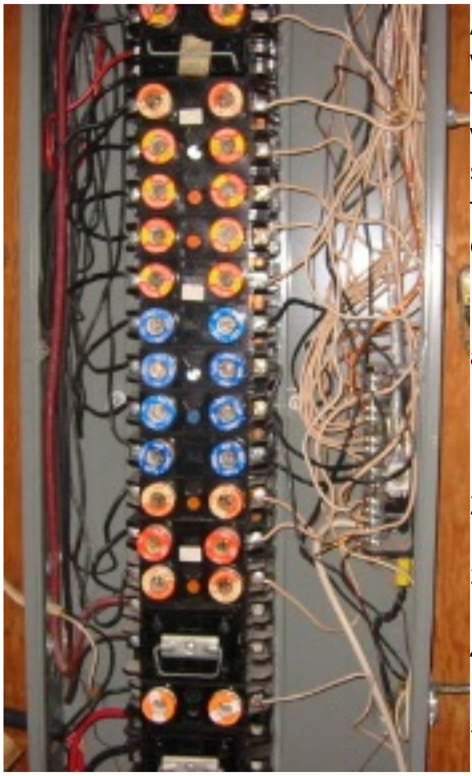
The inspector should recommend the installation of S-type fuses and adapters to ensure that the circuits cannot be overloaded. These adapters screw into the standard fuse location and reduce the thread size down. Various sizes are available, from 15 to 30 amps, and allow only the correct amperage type-S fuse to be installed. These adapters are designed so that, once installed, they cannot be removed.

They also have the added benefit of stopping someone from repairing a blown fuse by putting a penny under the blown fuse, an old practice.

It is very common to see over-fused circuits on older fuse panel installations. The inspector needs to remember that, in most cases, the installation was designed to supply a relatively small number of circuits with relatively few receptacles. That would have been fine for the average family's needs in the 1950s and 1960s, but that's now exceeded by modern demands.

Several types of fuses are available. Some blow very quickly, while others are designed to cope with short, extra start-up loads associated with electric motors. These will blow after a short time if the amperage draw does not revert to normal levels.

Inspecting Fuse Panels



As discussed above, there are two major problems with inspecting older fuse panels. First, check the main fuse amperages. The blocks have to be pulled out, which shuts off all power to the home. The second issue is that these panels tend to be unsuitable for modern, high-amperage demands, and they tend to exhibit double taps and over-fusing.

Pay special attention to the following questions during an inspection:

1. What is the main fuse rating?

2. Are there double taps?

3. Does the rating of the fuse match the conductors?

4. Are the fuses updated to S-type?

5. Is there any sign of conductors overheating?

The panel at the left is very large for a fuse panel and is somewhat typical of the larger service panels installed in bigger homes of the 1950s and early 1960s.

Breaker Panels & Breakers

Circuit Breaker Panels

These are probably the most common type that home inspectors will come across, as they have replaced fuse panels over the last 40 years or so. As we saw for fuse panels, breakers are far from foolproof and require some particular checking.

Breaker panels go farther back than many people realize, having been patented in 1910. However, it is unusual to see a residential breaker panel from before WWII. Prior to this, electrical breakers were primarily used in manufacturing and naval applications.

Breaker panels started appearing in homes in the mid-1950s in small numbers, and were universal in most areas by the late 1960s.

As discussed, they did not replace fuses due to any deficiency of the older technology. The problem was that when a fuse blew, one needed to go find a replacement. Breakers are obviously more convenient because when they trip after a fault, they can be reset without replacement.

We now have added benefits from circuit breakers with the advent of both GFCI and AFCI protection, in many locations.

The photo above shows an early residential circuit breaker panel manufactured by Trumbull Electrical in the late 1940s.

Circuit Breakers

Breakers fall into four categories, which we'll look at in more detail:

1. 240-volt double breakers;
2. 120-volt single breakers;
3. GFCI breakers; and
4. AFCI breakers.

All of these require some specialized knowledge to properly evaluate. Remember, we are talking about energized components. Safety is paramount when investigating electrical panels.

The breaker at the left is a Square D single-pole. This breaker is rated for two conductors only, but many are rated for a single conductor only, so this is something to be aware of when inspecting the breaker. Square D and Cutler-Hammer currently manufacture breakers which are UL-listed for this application.

240-Volt Circuit Breakers

Many of our homes now require high-voltage and amperage circuits to run appliances such as dryers, air conditioning, stoves, and some load-side distribution panels, etc.

240-volt appliances are fed from two 120-volt conductors, each connected to a separate bus bar in the distribution panel. It is imperative that, when one of the circuits trips due to an over-current condition, both conductors are de-energized at the same time. If not, someone could be trying to repair an appliance that is still partially live.

For this reason, all breakers supplying 240 volts are required to have the handles tied together by a listed handle tie. Nails, screws, or scraps of wire, for example, are unacceptable. Sometimes, the breaker is molded with this connection in place, and sometimes they are linked by a listed handle tie. The inspector should ensure that the tie is present and has not been damaged.

A 240-volt circuit breaker also acts as the main disconnecting means in modern panels, disconnecting all the electrical power in the home.

The picture above is of an older Bryant panel. Also notice that the 240-volt circuit breaker is being back-fed and held in place with a properly listed holding device; in this case, it’s a screw provided by the manufacturer.

120-Volt Circuit Breakers

Regular 120-volt circuits are fed from one bus bar only. Also in use are tandem breakers, which are 120-volt breakers that feed two separate circuits, each controlled by its own handle. (These should not be linked.) As with fuses, the inspector should ensure that the rating of the breaker does not exceed the rating of the conductors, unless allowed by 240.4 (E) or (G) of the NEC. Otherwise, something other than the breaker is likely to overheat and fail.

There are two manufacturers of single-pole, 120-volt breakers who have their products listed for two conductors. These are made by Square D and Cutler-Hammer. These should not be confused with double-tapped breakers, where more than one conductor has been incorrectly connected to a single breaker.

The picture above shows a "triple-tapped" breaker. A condition like this should be further evaluated by a licensed electrical contractor.

GFCI Breakers

Ground-fault circuit-interrupting breakers are one of the ways to protect circuits and their users from ground faults. Not all circuits are required to have GFCIs and, in many homes, the locations that require this protection have their own GFCI outlets. However, if a GFCI breaker is used, it will provide protection to all receptacles in that branch circuit.

GFCI breakers feature trip and reset buttons to ensure that they are working correctly. The inspector should trip the breaker using the test button and ensure that the circuit has indeed been switched off.

The image above shows both a GFCI breaker and a receptacle. Remember that either is acceptable to protect a damp location, or a circuit to a damp location. Additional locations are listed under Section 210.8 (A) and (B) of the NEC.

AFCI Breakers

Arc-fault circuit interrupters have been required in new construction since the 1999 edition of the NEC. Many jurisdictions are now observing recent code editions which has expanded the use of AFCI devices to nearly everywhere within a dwelling except the kitchen, bathroom, and most areas where GFCI protection is already required. These breakers are designed to trip if they sense arc faults in the circuit, which are caused primarily by damaged wiring.

What is an AFCI?

Arc-fault circuit interrupters (AFCIs) are special types of electrical receptacles or outlets and circuit breakers designed to detect and respond to potentially dangerous electrical arcs in home branch wiring. As designed, AFCIs function by monitoring the electrical waveform and promptly opening (interrupting) the circuit they serve if they detect changes in the wave pattern that are characteristic of a dangerous arc. In addition to the detection of dangerous wave patterns (arcs that may cause fires), AFCIs are also designed to differentiate safe, normal arcs. An example of this arc is when a switch is turned on or a plug is pulled from a receptacle. Very small changes in wave patterns can be detected, recognized, and responded to by AFCIs.

Brief History

In the 1999 NEC, these breakers were required only on bedroom receptacles. In the 2002 NEC, they expanded to all 15-amp and 20-amp, single-phase, 120-volt branch circuit-supplying outlets. The 2005 NEC expanded their use to allow AFCI devices similar to GFCI receptacles, but none existed on the market, and their use was limited by 210.12(B). Finally, in the 2008 NEC, the use of combination-type AFCIs expanded to 15- and 20-ampere branch circuit-supplying outlets installed in a dwelling unit’s family room, dining room, living room, parlor, library, den, bedroom, sun room, recreation room, and similar rooms, including hallways and closets. Many people confuse the term "combination" to mean AFCI and GFCI together in a single device. This is partly correct only in that most AFCI devices offer Class B- type of GFCI protection, which usually starts at around 20 to 30 milliamps, and do not offer any personal protection as do conventional GFCIs.

The combination-type AFCIs are designed to activate when there is a parallel arc that reaches a peak of 75 amps. The "combination" refers to the fact that AFCIs now protect against series arcs, as well. They have a 5-amps peak threshold. This is where the term "combination" comes from.

Remember, the term "outlet" is not interchangeable with "receptacle." Outlets are defined by the NEC as "a point on the wiring system at which current is taken to supply utilization equipment." Recess lights, smoke alarms, receptacles within outlet boxes, and so on, are supplied from outlets.

It is likely that many more locations (maybe even the whole house) will be required to have arc-fault protection with future code revisions. As with GFCI breakers, these should also be tripped with their test buttons, and the circuit should be checked to make sure it has been shut down.

The image above shows of a pair of AFCI breakers. Notice the test buttons, and also the second conductor that connects the breaker to the neutral bus. (This is not a double tap.) Many early Square D AFCI breakers had to be recalled due to manufacturing defects. Currently, however, many AFCI manufacturers are in their 10th+ generation, and are proving to be worth every penny when saving lives and property.

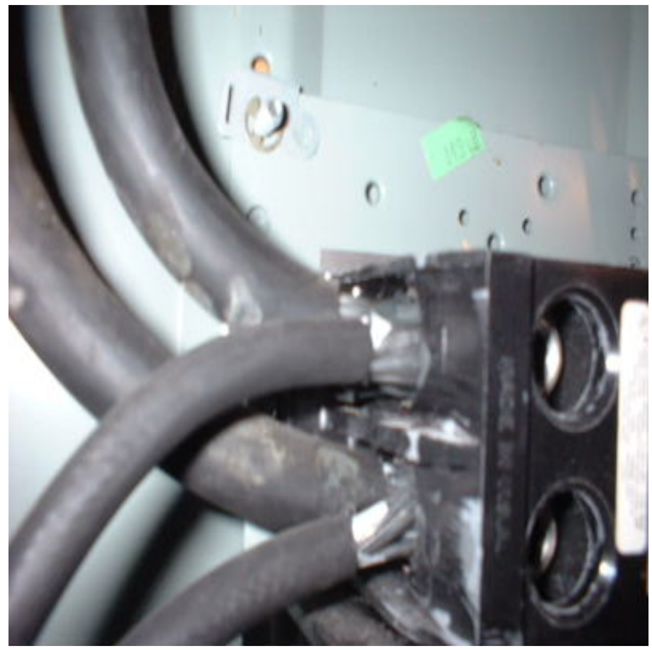
Inspecting Circuit Breakers

The inspector should pay special attention to the following questions and report any deficiencies as in need of immediate repair:

- Does the breaker exceed the capacity of the conductor?
- Does the breaker have multiple incorrect "taps"?
- Do the 240-volt breakers have their handles tied properly?
- Do the GFCI breakers test and reset properly?
- Do the AFCI breakers test and reset properly?

- Is there any sign of overheating, arcing or smoke damage on any of the breakers?

The image below shows an inspector using a digital laser temperature gun to check for hot spots, or significant temperature differentials between breakers. (Note that GFCI and AFCI breakers will always be about 5 to 10 degrees hotter than standard breakers due to their internal circuit boards and windings.)



Images above: (top left) using a laser temperature gun to check for hot spots; (top right) a double-tapped main breaker; (above) a breaker which has been badly burned due to arcing, and is rusting as a result

Problem Panels

Panels Types to Be Aware Of

There are several makes of panels whose breakers are no longer available. Also, there are a couple of manufacturers whose panels are known to be problematic.

Pushmatic Panels

These are still fairly common. The breakers are of a "push-for-on," "push-again-for-off" design. The issues with these tend to be:

1. lack of panel capacity;
2. sticking breakers; and/or
3. difficulty finding replacement parts.

While the panel may be in clean condition, the client should be advised that these older panels are fast becoming obsolete as parts are becoming harder to find. Recommend that an upgrade may be in order, as well as a full evaluation by a licensed electrical contractor.

Federal Pacific Electrical

The problem with this brand is primarily with their Stab-Lok® range of panels and breakers. These featured stamped sheet metal or copper bus bars and breakers with thin copper tabs that were designed to lock into the bus. These have the unfortunate habit of falling out when the dead front is removed, and this has caught many newer inspectors by surprise.

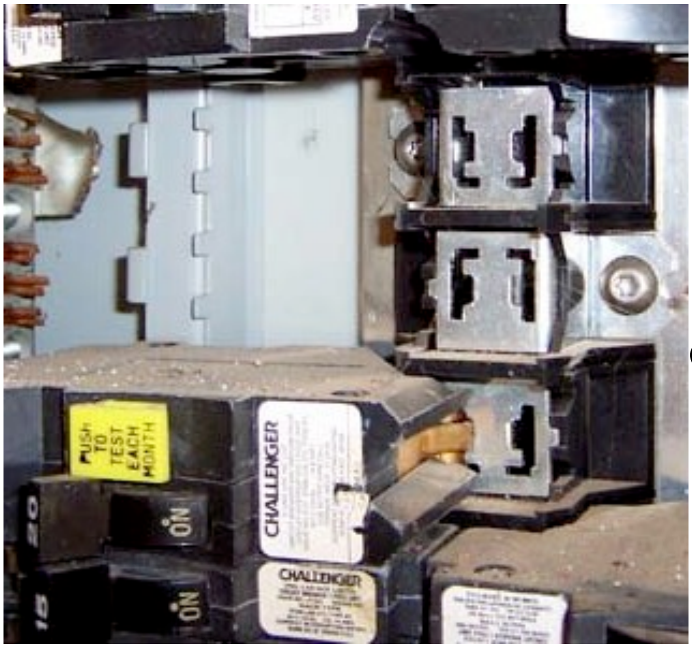
Federal Pacific panels were subject to warnings issued by consumer protection groups, which include:

1. loose breakers;

2. non-tripping breakers; and

3. arcing problems between the breaker and its bus.

The inspector should defer full evaluation of FPE panels to a licensed electrical contractor.



These images are of FPE panels:

Top left: typical Stab-Lok® panel

Top right: three loose breakers

Bottom left: FPE Stab-Lok® with a Challenger replacement breaker

(Photos courtesy of Jeff Pope)

Zinsco-Sylvania Panels

The earliest Zinsco panels had busses made of copper bars and were very reliable. However, during the copper shortages of the mid-1960s, the copper was replaced with anodized aluminum bars. This led to problems of poor contact between the breaker and the bus bar, and many have failed since due to arcing between the components. The problems continued after Zinsco's sale to Sylvania in the early 1970s.

Due to the frequent failure of the connection between the breaker and its bus, the inspector should recommend full evaluation and possible replacement of the panel.

Pictures above *(courtesy of Jeff Pope):*

Top left: typical Zinsco panel (notice the blue diamond label)

Top right: older Zinsco panel with copper bus bars

Bottom left: casing cracked due to heat from arcing *(Photo courtesy of J. Simmons)*

Bottom right: flash marks on breaker casing from arcing on bus

Quiz on Amperage & Panels

The electrical supply __________________ able to be shut down with 6 or fewer moves of the hand.

- should be
- should not be

A split-bus electrical panel uses a double-pole breaker to _______________ the 120-volt circuits.

- isolates
- combine
- Federal Pacific
- part-load

100 amps is the ____________________________ service required for a new single-family home.

- minimum
- maximum

The available service amperage is based on the __________-rated component.

- lowest
- highest

Most homes constructed between 1930 and ______________ originally had a 60-amp service.

- 1950
- 1980
- 1960

Which of the following would not be an electrical panel defect?

- wire splices
- lack of a legend
- rusted enclosure
- missing knockouts

Electrical service panels should be in a clear space measuring _____________.

- 30" wide by 78" high by 36" deep
- 36" wide by 78" high by 36" deep
- 30" wide by 60" high by 36" deep
- 36" wide by 80" high by 30" deep

Electrical panels do not have to be fully enclosed as long as no hole is bigger than _________.

- none of these
- 1/2 an inch
- 3/4 of an inch
- a 1/4 inch

Water dripping from an electrical panel should be __________________.

- tagged as an immediate hazard and deferred to an electrician
- fully investigated by the homeowner
- fully investigated by the home inspector

A(n) __________________ cause of arc flashes when removing panel fronts is incorrect fasteners.

- common
- uncommon

Which of the following should the inspector be wearing while evaluating electrical panels?

- all of these
- safety glasses
- electrician's gloves
- non-synthetic clothing
- none of these

Which of the following should be reported as a problem with an electrical panel?

- unlinked double-pole breakers
- GFCI breakers
- splices in the panel
- pigtails (two wires joined to a common breaker)

A bonding connection ______________________ connect the grounding bus to the electrical enclosure.

- should
- should not

3-Phase Panels

Phased Supply and Distribution

As discussed earlier in the course, 3-phase supply is common in commercial, agricultural, and some apartment properties. Evaluation of these panels is well beyond most home inspections and should be deferred to a specialist commercial electrical contractor.

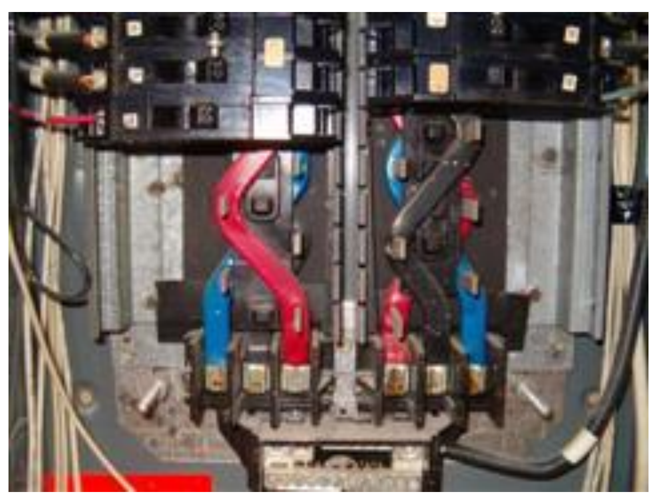
While we are not going explore in-depth the methods of evaluating 3-phase supply, some knowledge is useful to the home inspector.

As discussed in the Service Drop section, 3-phase supplies have three hot (or ungrounded) conductors, and there may also be a neutral or grounded conductor. Each of these phases, or legs, carries 120 volts at a different phase from the others.

How and from where power is taken in these phased supplies produces different types of supply current. The common services include 120, 240, 208 and 480 volts.

In all 3-phase panels, the conductors are color-coded to identify which phase they are attached to using **black**, **red** and **blue**. While there is no required standard of color coding demanded in the NEC, the code does tell us that on a 120/208 Delta High-Leg system, the center "B" eg (208V to ground) should be marked with orange tape to identify it as the "high leg."

These legs can supply 120 or 240 volts, as one would see in a standard 120/240-volt residential supply. So, it is possible for the average inspector to evaluate some electrical branch circuits in offices or other non-industrial settings. But beware of evaluating the distribution panels themselves.



The images above *(courtesy of Jeff Pope)* show a Zinsco commercial panel in an apartment building.

Remember: When in doubt, defer to a licensed electrical contractor!

Panel Oddities

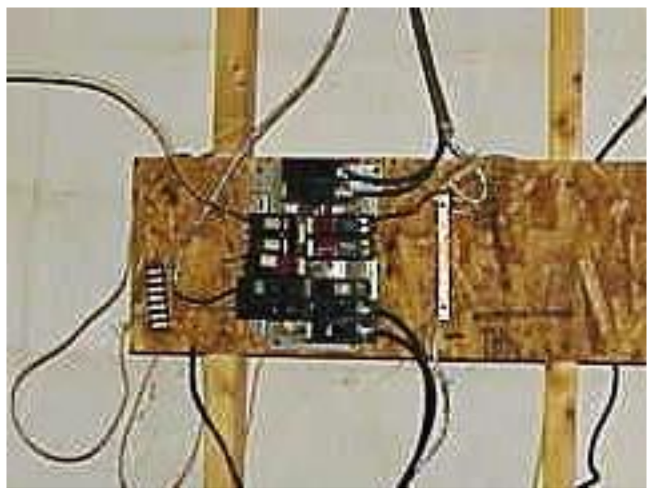
The Weird and the Wonderful!

The inspector will occasionally see some very unusual panels in the home. Some are now obsolete. Some are just plain dangerous.

No Panel

A hundred-plus years ago when we started wiring homes for electricity, there were no standards for panel enclosures. In fact, if an early panel had any kind of enclosure, it was probably built on site from timber and may have had an asbestos liner.

Even today, some homeowners will build a distribution center without the benefit and protection of a listed enclosure.



The pictures above show: (top-left) a 1920s panel with no enclosure *(courtesy of Jeff Pope)*; (top-right) a "homeowner special" with panelboard only mounted on particle board!

Fused Neutral Panels

For a period in the 1920s, fused neutral circuits were very common. They were outlawed in 1928 by the NEC.

The problem with these is that if the neutral -- rather than the live -- fuse blows, then the circuit will appear not to be live. However, someone working on the system would easily be able to complete the circuit to ground, providing a return path for the current, and thus be electrocuted.

above left: fused neutral main disconnect *(courtesy of Pat Dacey)*; above-right: fused neutral load center *(Photo courtesy of Jeff Pope)*

Non-Metallic Panels

As discussed, wood enclosures were very common at one time, but other materials have also been used. In particular, Bakelite and other plastics have been used for panel enclosures since the 1940s. They never achieved significant market share, but the inspector may see them on occasion.


The picture at the left is of a molded plastic panel produced by GE in the 1970s. While plastic panels are rare in residential use, they are very common in automotive and marine applications.

Non-Rated Enclosures

Man's ingenuity never ceases to amaze...

Homeowner "engineers" can miss the mark with their ideas on electrical safety. The photo at the right shows a solution that, while functional, is still unacceptable.

Does anyone know the UL-rating of a tackle box?

Quiz on Panels

Fused main disconnects are usually a maximum of _____.

- 100 amps
- 30 amps
- 60 amps
- 200 amps

Screw-in fuses are more properly called _________.

- Edison base fuses
- Tessler-type fuses
- Westinghouse fuses

Upgrading to ___ fuses stops over-fusing.

- S
- F
- P
- A

Which of the following statements is true about 240-volt breakers?

- 240-volt breakers are connected to two separate bus bars in the panel.
- 240-volt breakers draw power from one bus bar.
- 240-volt breakers should always be located at the very top of the panel.
- 240-volt breakers are always 15- or 30- amps.

GFCI breakers have _____ conductors.

- two
- zero
- three
- one

The inspector will find overheating _____________ breakers.

- with any type of defective
- only with Zinsco and FPE
- only with Sylvannia

AFCI breakers made by ________ were subject to a recall notice.

- Square D
- Cutler-Hammer
- Federal Pacific
- Challenger

Zinsco electrical panels are sometimes branded as ________.

- Sylvania
- Federal Pacific
- Challenger

Electric panel buses colored red, blue and black are indicative of a _____________.

- 3-phase supply
- 4-phase supply
- 120/240-volt panels
- 120-volt only supply

Zinsco electrical panels are problematic due to __________.

- poor connections to the bus
- loose breakers
- not enough amperage for modern needs
- difficulty obtaining replacement breakers

Fused neutral circuits were common in the _________.

- 1920s
- 1910s
- 1890s
- 1900s

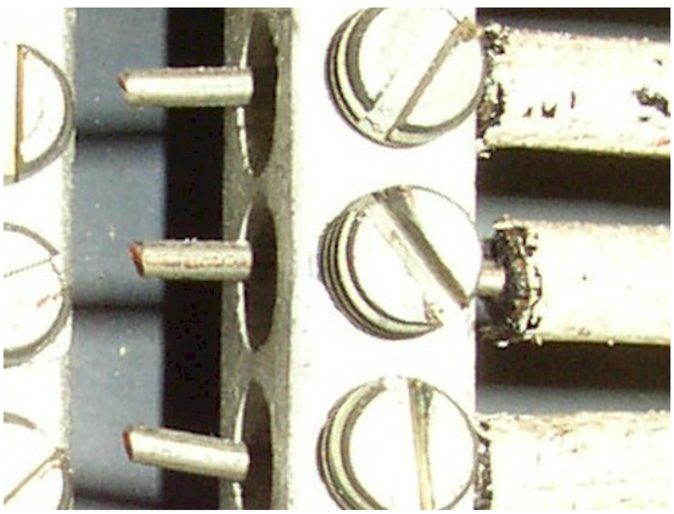
Electrical Distribution

Wiring Types

Wire types for North American wiring practices are defined by standards issued by Underwriters Laboratories, the Canadian Standards Association, the American Society for Testing and Materials, the National Electrical Manufacturers Association and the Insulated Cable Engineers Association.

Most circuits in the modern North American home and light commercial construction are wired with non-metallic sheathed (NM) cable designated type (often referred to by the brand name "Romex"). This type of cable is the least expensive for a given size and is appropriate for dry indoor applications.

Conductor Materials



As discussed above, we are dealing with:

- copper: absolutely the best conductor in common use, as it has low electrical impedance, so a relatively small conductor can deliver a lot of power over long distances without too much power loss or heat generation.

- tinned copper: still sometimes seen on older properties. Copper is tinned for two reasons: to aid soldering; and to stop the copper from reacting with old rubber insulation.

- aluminum: a good conductor of electricity but has higher impedance to the flow of electrons, which means that larger conductors need to be used for any given amperage. Aluminum was used for residential branch circuit wiring from the mid-1960s to the late 1970s, but was found to be unreliable. (We'll explore this later.)

- copper-clad aluminum: coating aluminum in copper was an attempt to overcome the issue of oxidization of the aluminum conductors that was leading to failures. It did not have the failures associated with pure aluminum and is considered safe. However, copper-clad should be sized the same as normal aluminum.

The picture (courtesy of Richard Moore) shows tinned copper. This is often mistaken for single-strand aluminum wiring, but is given away by its rubber insulation, as well as the cut copper ends, which can sometimes be observed upon closer examination. One will never find aluminum wiring with anything other than plastic insulation in residential construction.

Knob-and-Tube

Knob-and-tube wiring is so named because of the porcelain fittings used to support and insulate the conductors from the timber components in the home. The knob holds the wire away from rafters and joists, while the tubes are inserted into holes bored though joists and studs to protect the conductor and its rubber insulation.

Knob-and-tube wiring was the common method used to wire homes in the United States prior to 1930.

Knob-and-tube is a two-wire system with a hot (ungrounded) and a neutral (grounded conductor) only. No separate ground is used, so all receptacles would have been two-prong only.

The home inspector should report any knob-and-tube wiring as in need of further evaluation by an electrical contractor due to the following reasons:

1. The insulation is often very brittle and leaves conductors exposed when disturbed.
2. All circuits are ungrounded, which will not suit many modern electronics, such as computers, televisions and stereos.
3. The conductors are often buried in attic and wall insulation. This is a problem, as they were designed to work in free air.
4. The wire gauge is commonly 14-awg only, which is not sufficient for most modern household needs.
5. It's very common for knob-and-tube wiring to have been added to over the years, and it may contain many splices outside of approved enclosures. (Originally, joints in knob-and-tube were all spliced, soldered and taped outside of enclosures.)

The junction box pictured contains knob and tube wiring and no grounding wires.

Armored Cable (AC)

Conductors protected by a spiral-wound outer metal sheathing have been around since the early part of the century, and they gained wide acceptance in the 1930s, especially after the NEC's acceptance in the 1932 Code.

Several types of AC cable exist and they are not all the same. The earliest type was introduced by General Electric under their brand name "BX." Many people still wrongly call all type-AC cables by this name.

Type-AC cables fall into two categories: those with an internal bonding conductor and those without. In many cases, the sheathing itself, or its internal bond, has been used improperly as the grounding conductor, or, even worse, as the neutral conductor.

As of 1959, the NEC has required that all type-AC cable includes a bonding strip which connects all the individual convolutions. The older "BX" cable did not have this, and the exterior metal casing was not meant to be an effective fault current path. Since the 1960s, a newer type of AC-cable assembly came onto the market. The improved MC cable includes a proper grounding conductor.

Exterior Flexible Conduit

This is often seen by the home inspector as the supply conduit to outside installations, such as air-conditioning compressors.

This AC/BX-type conduit has a PVC outer sheathing to render it watertight, which should be marked "UF" for exterior use. (It is not approved for direct burial, however.)

The picture at the left (courtesy of John Murray) is of ENT conduit supplying an air-conditioning compressor. There is evidence of damage to the outer sheathing, allowing moisture into the cable assembly. This requires replacement of the conduit.

Rigid Conduit

Different types of rigid conduit are available for different applications, and some are more common in some regions than others. The three primary types used are:

- EMT/thin-wall: this is Electrical Metal Tubing, which can be bent to shape for installation.
- RMC/thick-wall: this is threaded Rigid Metal Conduit, where any changes of direction require angled fittings.
- RNC/PVC conduit: often referred to as Schedule 40 or 80 plastic, this gray-colored Rigid Non-metallic Conduit is very common in newer construction, but should not be confused with white or ivory-colored PVC piping, which is not rated for electrical use.

The image above (courtesy of Ben Kelly) is of EMT in an industrial location. Notice the curved bends.

Non-Metallic Cable (NM)

Many people use the name Romex® when referring to type-NM cable. Romex® is a trademarked name that has come into common usage for referring to plastic-covered wires, but type-NM just means "non-metallic" and also applies to other cable styles.

The earliest NM cables were, in fact, rubber-insulated copper conductors bound together as an assembly, with a woven-cloth sheathing. Originally approved by the NEC in 1928 as replacement for knob-and-tube wiring, it became the most common residential wiring used from the late 1940s, up to the introduction of modern thermoplastic (Romex®) type wiring of the early 1960s.

The image above shows some 1950s cloth-covered NM, with clear markings. The legend reads "Napax Type NM 14-2 600V." This is a non-metallic, 14-gauger two-conductor (no ground), rated for a maximum of 600 volts.

Prior to 1985, standard NM was rated for 60-degree applications, which was increased to 90 degrees and is now marked NM-B.

In type NM cable, conductor insulation is color-coded for identification, typically one black, one white, and a bare grounding conductor. The National Electrical Code (NEC) specifies that the black conductor represent the hot conductor, with significant voltage to earth ground; the white conductor represent the identified or neutral conductor, near ground potential; and the bare/green conductor, the safety grounding conductor not normally used to carry circuit current.

Aluminum Wiring

According to the InterNACHI Home Inspection Standards of Practice, a home inspector is required to report upon single-strand, solid conductor aluminum branch-circuit wiring, if observed by the home inspector.

Between approximately 1965 and 1973, single-strand aluminum wiring was sometimes substituted for copper branch-circuit wiring in residential electrical systems due to the sudden escalating price of copper. After a decade of use by homeowners and electricians, inherent weaknesses were discovered in the metal that led to its disuse as a branch wiring material. Although properly maintained aluminum wiring is acceptable, aluminum will generally become defective faster than copper due to certain qualities inherent in the metal. Neglected connections in outlets, switches and light fixtures containing aluminum wiring become increasingly dangerous over time. Poor connections cause wiring to overheat, creating a potential fire hazard. In addition, the presence of single-strand aluminum wiring may void a home's insurance policies. Inspectors may instruct their clients to talk with their insurance agent about whether the presence of aluminum wiring in their home is a problem that requires changes to their policy's language.

Facts and Figures

- On April, 28, 1974, two people were killed in a house fire in Hampton Bays, New York. Fire officials determined that the fire was caused by a faulty aluminum wire connection at an outlet.
- According to the Consumer Product Safety Commission (CPSC), "Homes wired with aluminum wire manufactured before 1972 ['old-technology' aluminum wire] are 55 times more likely to have one or more connections reach fire-hazard condition than a home wired with copper."

Aluminum as a Metal

Aluminum possesses certain qualities that, compared with copper, make it an undesirable material as an electrical conductor. These qualities all lead to loose connections, where fire hazards become likely. These qualities are as follows:

- higher electrical resistance. Aluminum has a high resistance to electrical current flow, which means that, given the same amperage, aluminum conductors must be of a larger diameter than would be required by copper conductors.
- less ductile. Aluminum will fatigue and break down more readily when subjected to bending and other forms of abuse than copper, which is more ductile. Fatigue will cause the wire to break down internally and will increasingly resist electrical current, leading to a buildup of excessive heat.
- galvanic corrosion. In the presence of moisture, aluminum will undergo galvanic corrosion when it comes into contact with certain dissimilar metals.
- oxidation. Exposure to oxygen in the air causes deterioration to the outer surface of the wire. This process is called oxidation. Aluminum wire is more easily oxidized than copper wire, and the compound formed by this process – aluminum oxide – is less conductive than copper oxide. As time passes, oxidation can deteriorate connections and present a fire hazard.
- greater malleability. Aluminum is soft and malleable, meaning it is highly sensitive to compression. After a screw has been over-tightened on aluminum wiring, for instance, the wire will continue to deform or “flow” even after the tightening has ceased. This deformation will create a loose connection and increase electrical resistance in that location.
- greater thermal expansion and contraction. Even more than copper, aluminum expands and contracts with changes in temperature. Over time, this process will cause connections between the wire and the device to degrade. For this reason, aluminum wires should never be inserted into the “stab,” “bayonet” or “push-in” type terminations found on the back of many light switches and outlets.
- excessive vibration. Electrical current vibrates as it passes through wiring. This vibration is more extreme in aluminum than it is in copper, and, as time passes, it can cause connections to loosen.

Identifying Aluminum Wiring

- Aluminum wires are the color of aluminum and are easily discernible from copper and other metals.
- Since the early 1970s, wiring-device binding terminals for use with aluminum wire have been marked CO/ALR, which stands for “copper/aluminum revised."
- Look for the word "aluminum" or the initials "AL" on the plastic wire jacket. Where wiring is visible, such as in the attic or electrical panel, inspectors can look for printed or embossed letters on the plastic wire jacket. Aluminum wire may have the word "aluminum," or a specific brand name, such as Kaiser Aluminum, marked on the wire jacket. Where labels are hard to read, a light can be shined along the length of the wire.
- When was the house built? Homes built or expanded between 1965 and 1973 are more likely to have aluminum wiring than houses built before or after those years.

Options for Correction

Aluminum wiring should be evaluated by a qualified electrician who is experienced in evaluating and correcting aluminum wiring problems. Not all licensed electricians are properly trained to deal with defective aluminum wiring. The CPSC recommends the following two methods for correction for aluminum wiring:

- Rewire the home with copper wire. While this is the most effective method, rewiring is expensive and impractical, in most cases.
- Use copalum crimps. The crimp connector repair consists of attaching a piece of copper wire to the existing aluminum wire branch circuit with a specially designed metal sleeve and powered crimping tool. This special connector can be properly installed only with the matching AMP tool. An insulating sleeve is placed around the crimp connector to complete the repair. Although effective, they are expensive (typically around $50 per outlet, switch or light fixture).

Although not recommended by the CPSC as methods of permanent repair for defective aluminum wiring, the following methods may be considered:

- application of anti-oxidant paste. This method can be used for wires that are multi-stranded or wires that are too large to be effectively crimped.
- pig-tailing. This method involves attaching a short piece of copper wire to the aluminum wire with a twist-on connector. the copper wire is connected to the switch, wall outlet, or other termination device. This method is effective only if the connections between the aluminum wires and the copper pigtails are extremely reliable. Pig-tailing with some types of connectors (even though Underwriters Laboratories might currently list them for the application) can lead to increasing the hazard. Also, beware that pig-tailing will increase the number of connections, all of which must be maintained. Aluminum Wiring Repair (AWR), Inc., of Aurora, Colorado, advises that pig-tailing can be useful as a temporary repair or in isolated applications, such as the installation of a ceiling fan.
- CO/ALR connections. According to the CPSC, these devices cannot be used for all parts of the wiring system, such as ceiling-mounted light fixtures or permanently wired appliances. As such, CO/ALR connections cannot constitute a complete repair. Also, according to AWR, these connections often loosen over time.
- AlumiConn®. Although AWR believes this method may be an effective temporary fix, they are wary that it has little history, and that they are larger than copper crimps that are often incorrectly applied.
- Replace certain failure-prone types of devices and connections with others that are more compatible with aluminum wire.
- Remove the ignitable materials from the vicinity of the connections.

Aluminum wiring can be a fire hazard due to inherent qualities of the metal. Inspectors should be capable of identifying this type of wiring.

Repair Methods

Since the early 1970s, several methods have been tried to improve the contact between aluminum wire and junctions and receptacles. The single biggest issue is that it is very difficult for a contractor to know where all of the hidden junction boxes are in an older home.

Re-wiring in copper: This is obviously the best choice by far, as it completely replaces the aluminum branch-circuit wiring. However, this is very costly and disruptive.

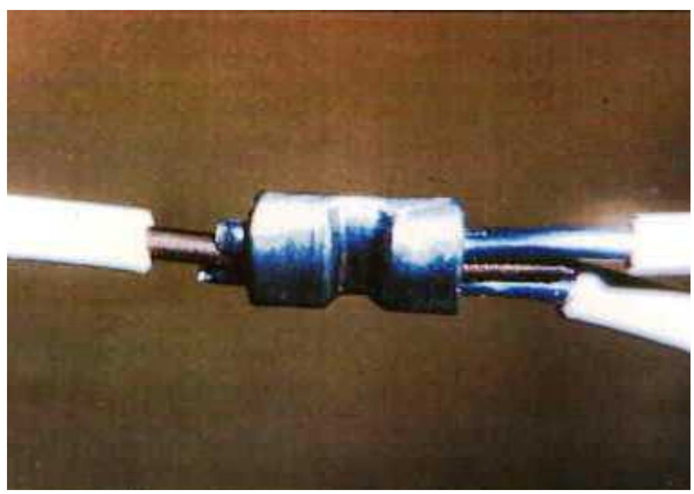
Pig-tailing copper: A method many electricians tried was to pig-tail a piece of copper wire onto the aluminum using a wire nut. There were even special purple wire nuts produced with anti-oxidant paste in them designed for this application.

As can been seen in the image above, this repair did not work as intended, as wire nuts are not able to overcome the expansion problems of aluminum.

This is not considered an effective repair.

CO/ALR switches and receptacles: These were designed to replace previous CO/AL receptacles, as they had a higher-quality conductor lug assembly. However, this addresses only the issues of switches and outlets, but not the connections in boxes.

This is not considered an effective repair.



COPALUM connectors: These are the recommended upgrade for aluminum wiring.

A special crimp connector and crimping tool are used to pig-tail a piece of copper wire onto the aluminum conductor. It is then covered with a heat-shrunk insulation.

The image above shows the crimped connection prior to the heat-shrink insulation being applied.

This is the only CPSC-approved repair, but some connections still may be inaccessible.

Branch Circuit Connections

Evaluating In-Panel Wiring

The purpose of this section is to look, in more detail, at the connections themselves inside the panel. We have already discussed the panel conditions and the breaker/fuse issues, but there is still much to inspect.

Probably the most common electrical defect that an inspector will report is "double-tapping" of fuses and breakers, but there are many other connections that may also be incorrect.

Conductor Sizing

One of the first things the inspector should evaluate is the size of the conductors relative to the amperage rating of the fuse or breaker. As we have seen, if the breaker is rated for 30 amps but the conductor is a 14-awg rated for 15 amps, we are likely to see the conductor overheating and potentially starting a fire. Bear in mind that there may be exceptions under special conditions. For example, the NEC allows 12-awg on a 30-amp under 240.4 (E) or (G). A nameplate on an AC unit or a specific motor load may indicate such exceptions to the standard rules.

The table below shows the most common conductor sizes used in residential branch circuits, along with their maximum permitted breaker or fuse sizes.

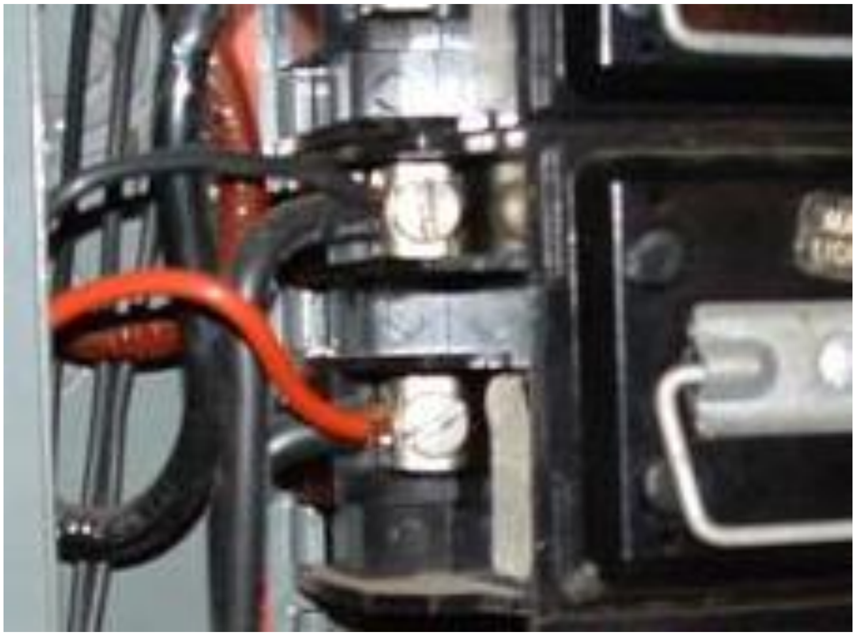
Breaker or Fuse Size	Copper Conductor	Aluminum Conductor	Common Usage
15-amp*	#14/2 with ground NM	-	Lighting circuits and typical general-use receptacles in living area. Dishwasher. Disposal. Refrigerator/freezer.
20-amp*	#12/2 with ground NM	-	Receptacle and switches in kitchen, laundry, bathrooms, and dining rooms. Microwave, Dishwasher. Disposal. Refrigerator/freezer. Hydro massage tub.
30-amp*	#10/3 with ground NM	-	Water heater. Clothes dryer. Condensing unit.

40-amp*	#8/3 with ground NM	6/6/6/6 AL SER	Oven. Cooktop. Range.
50-amp	#6/3 with ground NM	4/4/4/6 AL SER	Oven. Cooktop. Range.
100-amp	3 AWG	1 AWG	remote distribution panel
100-amp**	4 AWG**	2 AWG**	SE cable
150-amp**	1 AWG**	2/0 AWG**	SE cable
200-amp**	2/0 AWG**	4/0 AWG**	SE cable

* Aluminum single-strand wiring should always be deferred to a licensed electrical contractor for inspection.

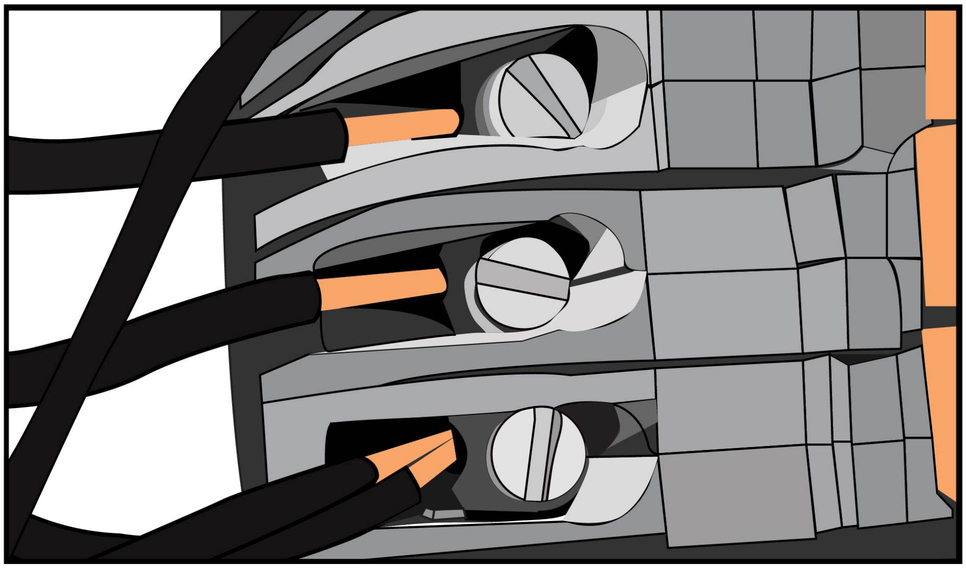
** Based on NEC 310.15(B)(6) and 2015 IRC E3702.9.1.

Double-Tapping

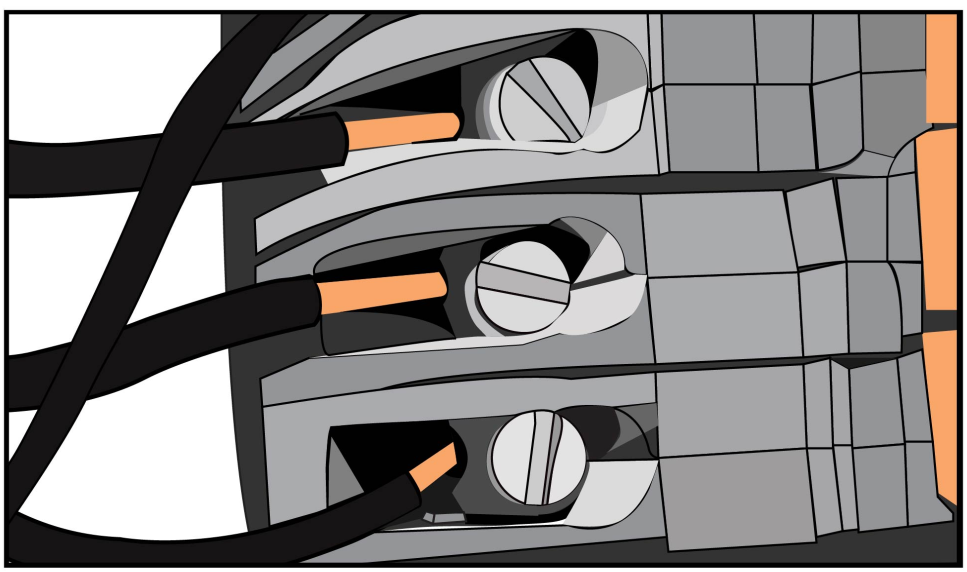


Double-tapping is sometimes also called "double taps" or "double-lugging." This is when there are two conductors terminating under a screw or lug which is rated for only one. The problem here is that each conductor will not have enough contact area against the screw or its lug, which may lead to arcing and overheating of the conductors.

Double-Tapped Breakers



Don't



Do

These should always be fully evaluated, as there are a couple of exceptions:

- breakers rated for two conductors (made by Cutler-Hammer and Square D); and
- conductors spliced together and pigtailed into a breaker or fuse.

____
____
____
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Neutrals-Sharing Lugs

As the neutral is also a current-carrying conductor, the neutrals should each be terminated separately on the neutral bus.

An inspector will often find signs of arcing and overheating where any multiple conductors share a common lug.

This condition is basically just another double-tapping situation.

Unrated Conductors

The inspector will often see homeowner wiring using things like doorbell or speaker wire, and cut-down extension cords supplying circuits derived from the panel.

This is always unacceptable and should be replaced by a licensed electrician.

Nicked Conductors

Any conductor that has been nicked (cut, scratched, incised, or damaged) as the insulation was removed is now of a smaller diameter than intended and has a higher resistance to the flow of electrons.

This higher impedance is just the same as having too small a conductor on the circuit, since the damaged area will be the weak link and may either act as the fuse or overheat.

The conductor at the left has several issues, not the least of which is the way it was trimmed down to fit the breaker.

(Picture courtesy of Todd Allen)

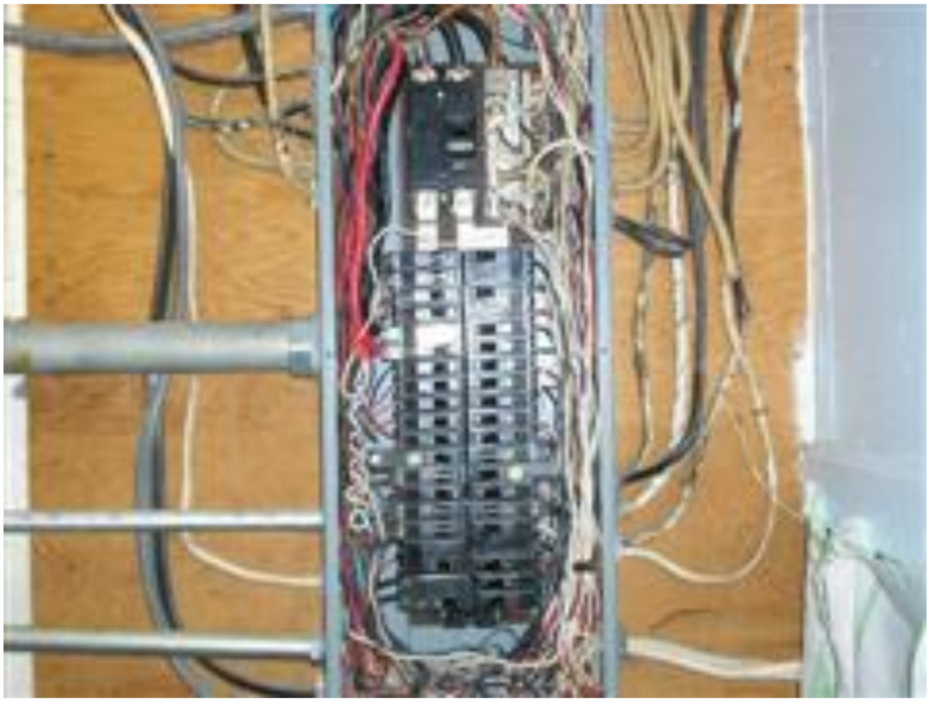
Antioxidant Paste

This grayish paste is commonly found on older aluminum multi-strand conductors and is still required by some city electrical inspectors. This paste was designed to stop the aluminum from oxidizing, and thus be better able to maintain a clean contact footprint in its lug.

Interestingly, the NEC has never required its use; rather, they have "permitted" it. The alloys used in aluminum wire have greatly improved since the early 1980s, and while many manufacturers used to recommend its use on their conductors, few do so now.

The image above *(courtesy of Kevin Williams)* has no antioxidant on the conductors. As this is a new panel, it is probably not a significant issue, or even required.

Abandoned Wiring

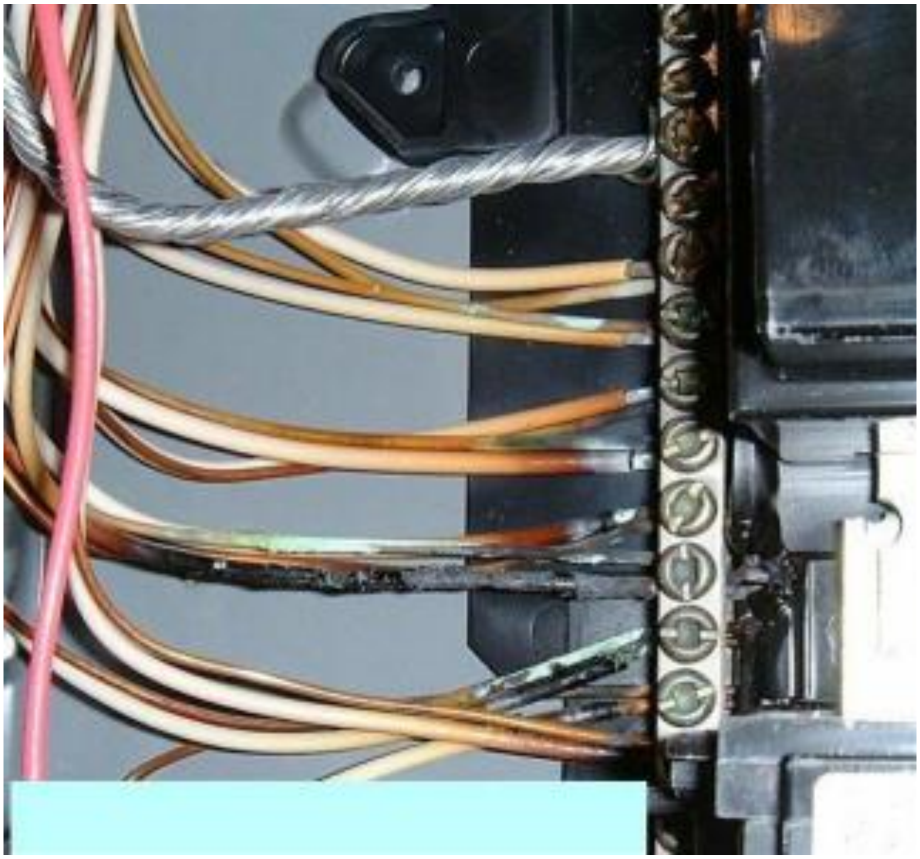


All abandoned wiring should be removed from the electrical panel, or, at the very least, it should be properly isolated so that the conductors are not able to make contact with any live components.

The panel at the left is an inspector's worst nightmare. Not only is it overloaded (too many conductors), but it also contains a lot of abandoned wiring.

(Photo courtesy of Dave Bush)

Arcing and Overheating

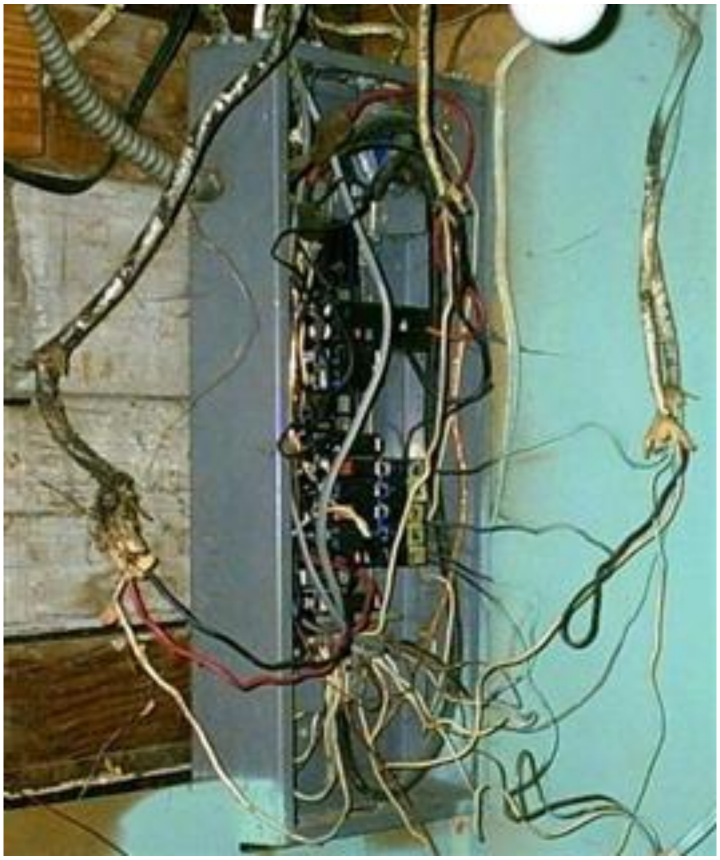


As we have seen, any of the conditions covered may cause overheating to the conductors.

The inspector should recommend further evaluation of any wiring that is in any way deficient, as failures can and do lead to fires, which can lead to loss of life.

The picture above shows many overheating neutral conductors. Notice how they are all double-tapped.

Splices in Panels

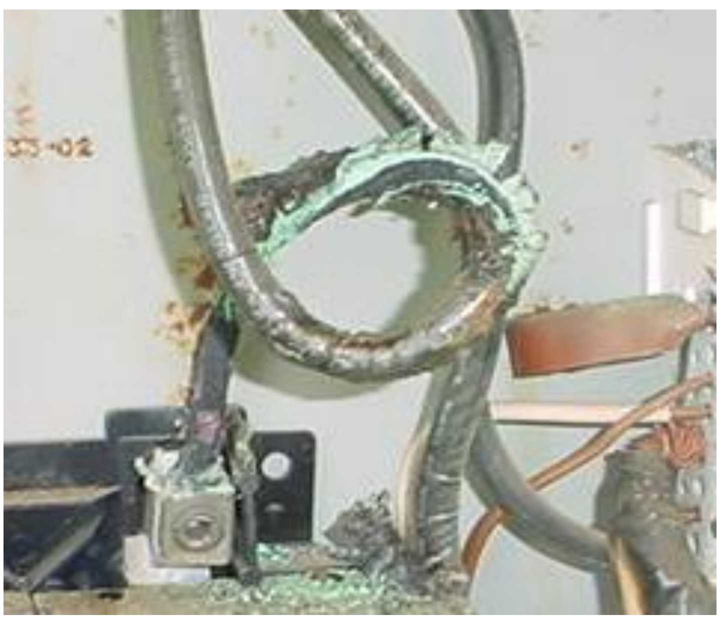


While electrical splices in panels are not in and of themselves improper, the home inspector should bear in mind that, like double taps, they are the line of least resistance and often done by unqualified persons.

Generally untidy panel wiring, double taps, lots of splices, and wire nuts are indicative of homeowner wiring, which probably requires further evaluation.

The image above is of a typical homeowner wiring job. This is a potentially very dangerous situation.

Lightning Damage



Occasionally, the inspector will open a panel and see most or all of the neutral conductors fried.

This may have been caused by the property having been struck by lightning. The neutrals will be most affected by this, since they are, of course, connected to the grounding system.

The image above shows a badly scorched SEC caused by a lightning strike on the home.

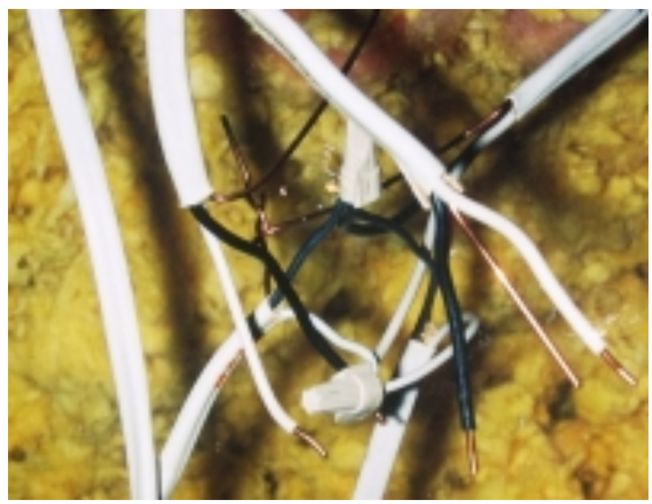
Many times, these conditions go unnoticed. A panel that has been hit like this should be fully evaluated.

Protection of Wiring

Conductor Protection

All current-carrying wiring needs some form of protection from mechanical damage. Also, the occupants of the home need protection from potential shocks where wires are spliced together.

Exposed Wiring



Obviously, there should be no exposed wiring in the finished or livable areas of the home, but this means that some unfinished areas may have exposed, non-metallic Romex®-type cables. In this section, we will look at those areas and discuss what is and is not acceptable.

The guidelines in this section are based on current adopted NEC codes, and may not be applicable in your area, or may not apply to an older property. Remember: Code is based on previous failures that have produced unsafe conditions.

The image at the right shows exposed wiring in an attic space. All of these wires were live and potentially lethal to both the unsuspecting home inspector and the homeowner.

Exterior Wiring

The home inspector should report any exposed wiring at the exterior, especially interior-type wiring, such as Romex® types, which are not rated for exposure to ultraviolet light (sunlight). Also, any exterior conductors should be protected against mechanical damage to a height of 8 feet.

Crawlspace and Basement Wiring

In most jurisdictions, exposed wiring is allowed in basements and crawlspaces. In the northern U.S., we commonly see Romex® conductors unprotected as they leave the panel, and the circuits generally run unprotected on the ceiling joists.

Crawlspaces are the same unless a prohibitive condition exists, such as a very damp area; then, exposed cable assemblies are the norm.

According to the 2008 NEC, crawlspaces and unfinished basements that have NM cable installed shall be drilled through the joists unless installed on a running board. Cables with three 8-awg or two 6-awg and larger shall be allowed on the surface of the joists.

The photo at the right shows a basement panel installation. Although exposed Romex® is allowed in many jurisdictions in uninhabited areas, this installation would not be proper anywhere.

Attic Wiring

Although exposed conductors are allowed to run in attics, there are some safety concerns that the home inspector needs to be aware of, especially as the homeowner is going to enter the attic space to store seasonal goods.

All conductors should be protected within 6 feet of the scuttle opening. This means that no cables should be run on top of joists in this area. This dimension also includes the underside of roof framing rafters.

If they run perpendicular to the joist, they should either be drilled through the timbers and have a running board over the top, or be stapled to the side of a running board.

The picture at the left shows not only loose attic wiring, but also signs of rodents in the attic. The damage, in this case, was caused by squirrels (photo courtesy of Ben Kelly).

Wiring in Cabinetry

The home inspector will often see unprotected wiring in under-sink locations, especially supplying waste disposals. If any hard-wired appliances have exposed conductors, they should be protected with metal spiral armoring.

The image above by John Murray shows a typical under-sink area with both exposed and unprotected conductors.

In this case, it is likely that a disposal unit has been removed, but the wiring has not been properly removed.

Protection of Wiring Through Studs

In frame construction, all of the home's conductors must be run through the wall stud work to supply the outlets. These hidden conductors need to be protected from accidental damage.

Most frame homes are built with either timber or steel studs, and each have separate protection requirements:

- timber studs: Any cable assemblies closer than 1¼ inches from the front face of the stud need to be protected from damage from drywall screws, and the homeowner hanging pictures, etc. This is achieved by installing a nailing plate on the stud. Note that the 1¼ inches applies to both sides of the stud if the required distance is not maintained.
- steel studs: Where NM cable or electrical non-metallic tubing is run through openings in steel studs, protection against penetration is required. A steel sleeve, steel plate or steel clip not less than 1/16" in thickness shall be used to protect the cable or tubing. An opening in the stud requires a plastic bushing to protect the cable from chafing against the steel's raw edge. This protection must encircle the entire opening, and not just the bottom half, as shown in the photo above.

Support of Cables and Conduits

All cables, cable assemblies and conduits need regular support from the structure. The home inspector will often see great lengths of Romex® and other conductor types strung unsupported through crawlspaces and attics. This, again, is indicative of homeowner work and needs correcting.

The basic specifications for supports are outlined below:

- NM/Romex® cables: stapled within 12 inches of metal enclosures (and 8 inches from plastic gang boxes), and every 4 feet and 6 inches of run length.
- AC cables: stapled within 12 inches of metal enclosures, and every 4 feet and 6 inches of run length. MC cable has a run-length that is extended to 6 feet between the required supports.
- metal conduit/EMT: clamped within 36 inches of enclosures, and every 10 feet of run length.

Protection of Personnel

Exposed wiring, and especially exposed splices and connections, are obviously a danger to the home's inhabitants.

All connections in conductors need to be made in approved enclosures, typically panelboards, junction or J-boxes, and gang boxes (a gang box is what is behind switches and receptacles).

The home inspector should report any splices or other connections that can be seen either outside of enclosures, or in enclosures where the cover plate is missing.

All enclosures and J-boxes should also have proper cable connectors where the conductors enter the box. (Plastic gang boxes do not require these, since strain relief is built in.)

The image above shows an old fuse panel that is being used as a junction box. Not only is the cover missing, but at least one conductor is not bushed, and the box appears to be over-filled.

120-Volt Receptacles

The term "receptacle" actually covers all types of applications, whether they are light fixtures or wall outlets. Every habitable space in the home is required to meet minimum standards of power and lighting availability. Never install a switch receptacle fully inside of a room where both the top and bottom of the duplex is controlled by a switch. A switched receptacle may be acceptable to meet the 210.70(A)(1) Exception 1 for using a receptacle to meet the lighting outlet requirement in rooms other than bathrooms and kitchens. It will not meet the 210.52(A)(1) wall spacing requirements.

In this section, we will look at the current standards for outlets around the home, and the methods for testing them.

Many older homes, however, will not have what would now be the required number of outlets. This would not necessarily be a defect, but the home inspector would be well-advised to point out to the homeowner (or home buyer) that there may not be enough outlets to suit a modern family's needs.

Homes with many appliances connected through extension cords are typical of properties built with insufficient outlets.

Habitable Spaces

All habitable spaces are required to have electrical power and, in new construction, one would expect to see an outlet at every 12 feet of wall space. Even hallways longer than 10 feet are required to have power.

Floor-Mounted Receptacles

Standard wall-type receptacles pose a danger when mounted horizontally in a floor structure.

Dirt, dust and any spilled water will affect the outlet, plus children or pets will always play with anything on the floor.

Recommend upgrading floor receptacles to the approved type, with special covers.

The image at the right shows an approved floor box with its mounting hardware. Also notice the bonding jumper required on a metal cover plate.

Service Locations

Any unfinished space that houses serviceable equipment, such as furnaces and air handlers, is required to have not only a light but also a power outlet. This includes attics and crawlspaces.

Kitchen Circuits

All kitchens are now required to be supplied by two 20-amp circuits over and above any requirements for dedicated outlets for stoves, etc. These circuits shall not serve any lighting needs.

One of these branch circuits should be used for small appliance receptacles no more than 20 inches above the countertop. These outlets must also be GFCI-protected. The minimum two 20-amp circuits shall both supply receptacles serving the countertop space.

As of the adoption in 2002 by the NEC, all kitchen receptacles installed in new construction are required to be GFCI-protected.

All counter spaces wider than 12 inches should have an outlet, and the maximum distance between outlets should be no more than 4 feet. There should also be a receptacle within 2 feet of each end of the counter ends, and from any break in the countertop (such as for a range, refrigerator and sinks).

Islands and peninsulas are also required to have at least one receptacle to serve the countertop space. If the space is not available on the countertop area, the NEC allows the receptacle to be installed below the countertop's surface, which must not be more than 12 inches below the countertop, and not installed under any overhang 6 inches or more from the base of the island or peninsula to the edge of the overhang. No countertop outlets are allowed to be installed face-up in the horizontal surface.

When dealing with the space behind a corner-mounted sink or counter-mounted cooking unit, the 2008 NEC requires that if such space is less than 18 inches, it is not considered a wall space. If that space is 18 inches or more, it must meet the same spacing requirements previously discussed. A countertop with an extended face sink or a counter-mounted cooking unit, such as when that counter sticks out and creates a space behind the sink or cooking unit, is not considered counter space if that space is less than 12 inches. If that space is 12 inches or more, then that space must meet the same spacing requirements previously discussed.

When dealing with islands and peninsula, the 2008 NEC requires that where a range, counter-mounted cooking unit, or sink is installed in an island or peninsular countertop and the width of the countertop behind the range, counter-mounted cooking unit, or sink is less than 12 inches, the range, counter-mounted cooking unit, or sink is considered to divide the countertop space into two separate countertop spaces. This would mean both sides would need a receptacle to meet current codes.

Most jurisdictions require dishwashers and waste disposals to be on dedicated circuits. Often, refrigerators are plugged into dedicated outlets, which is allowed by the NEC, to prevent nuisance tripping from installed GFCIs.

Bathroom Circuits

In newer homes' bathrooms, outlets are required to be on dedicated 20-amp, GFCI-protected circuits, and at least one receptacle is required to be installed within 3 feet of any vanity basin.

The home inspector is justified in suggesting that non-GFCI receptacles in older bathrooms should be upgraded for safety reasons.

There is also a common misconception that no switches or receptacles may be installed within 3 feet of a bath or shower enclosure. This is correct for Canada, but not a requirement in the United States.

The switch plate in this picture is arguably within the footprint of the tub or shower enclosure. For safety reasons, the recommendation should be to have it relocated.

Laundry Rooms

There must be a minimum of one 20-amp circuit within 6 feet of the appliance location. Dryer outlets will be covered in the 240-volt section, but they should have a 4-wire, 30-amp minimum supply.

Garage Receptacles

Garages were required to have a minimum of one GFCI outlet, and inspectors may find that they also have non-GFCI receptacles dedicated to appliances, such as door openers and extra refrigerators and freezers. Lighting is also required. However, be aware that under the 2008 NEC, the exceptions that allow dedicated receptacles for specific appliances were removed. Now, all receptacles in garages and unfinished basements must be GFCI-protected, including sump pumps. The only exceptions are for fire alarm and burglar alarm systems, and receptacles outside installed for roof snow-melting equipment.

Exterior Receptacles

Newer homes are required to have a minimum of one outlet at the front and another at the rear. These receptacles are required to be weathertight while in use, and GFCI-protected.

Recommend upgrading of the older receptacles, as this is a safety enhancement that should be considered.

Non-GFCI outlets are allowed for dedicated single outlets only, such as one will find supplying heater strips in colder climates.

The photo at the right shows a receptacle with many reportable safety issues:

- exposed live conductors;
- no GFCI;
- no in-use cover;
- no protection for conductors; and
- no grounded conductor.

Visual Inspection

The inspector should visually inspect all outlets and report the following:

- 2-wire-only circuits;
- damaged or missing cover plates;
- missing screws;
- damaged receptacles;
- signs of overheating on receptacles or surrounding walls; and
- lack of GFCIs in where specified in 210.9 of the 2008 NEC.

above: a melted outlet

above: a burned outlet

above: an outlet displaying signs of arcing

(Photos courtesy of Jeff Pope)

Inspecting Receptacles

Branch Circuit Outlet Testing

The Standards of Practice require that the inspector inspect a representative" number of receptacles, including those deemed to be GFCI- and AFCI- protected.

It's a good idea to check every receptacle that can be physically accessed that does not have something plugged into it, as well as every GFCI- or AFCI-protected circuit.

Before exploring these protocols, we must understand how receptacles should be correctly wired. A receptacle has the following characteristics:

- small slot: is the hot or ungrounded supply;
- large slot: is the neutral or grounded return; and
- round pinhole: is the grounding conductor.

This is very important if the receptaacle has reversed polarity (hot and neutral switched), because then things like lamp holder collars may become live and pose a great electrocution hazard.

It is very common to find 3-prong receptacles with no ground, or, worse, receptacles with a false or bootleg ground where the grounding terminal has been illegally connected to the neutral.

Circuit Testers

There are many different types of circuit testers available, starting with very basic continuity testers, which cost a few dollars, up to full-function testers, which cost several hundred dollars.

The image above shows some commonly used testers:

1. left: an older-style SureTest® ST1;
2. center, top: a GFCI tester;
3. center, middle: a Sperry "traffic-light" tester;
4. center, bottom: a GB Sure Wire™ tester;
5. right: an Ideal SureTest® 61-165 multi-tester.

The differences between the various models are what they are able to test for and how they display the results.

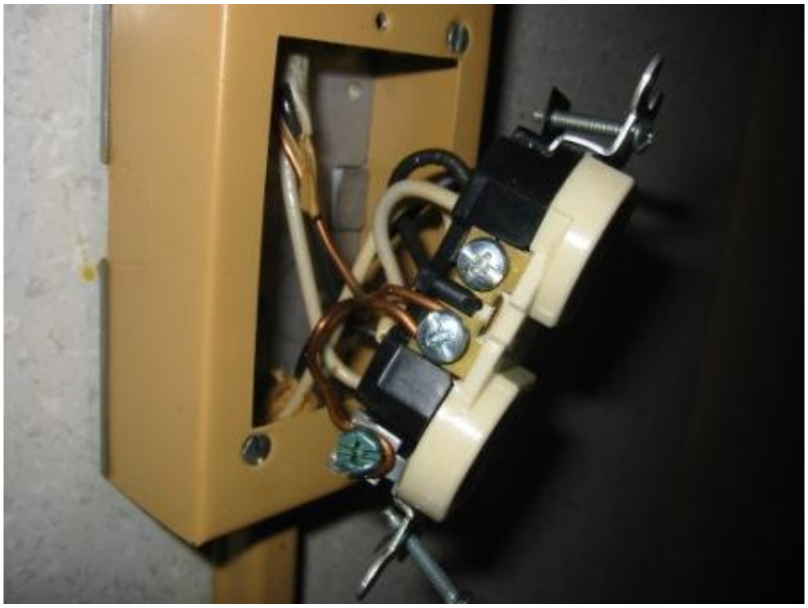
It is good practice for an inspector to have and use a receptacle tester with a GFCI and AFCI test button.

The image above shows a GFCI / AFCI testing device indicating a wiring defect.

The functionality of some common testers include:

- open ground;
- open neutral;
- open hot;
- hot/ground reversed;
- hot/neutral reversed;
- normal;
- GFCI trip;
- bad (high resistance) ground;
- AFCIs for proper operation;
- GFCIs for proper operation;
- shared neutrals; and
- correct wiring.

False Grounds



Sometimes referred to as "bootleg" grounds, false grounds occur when the grounding terminal on the receptacle has been improperly connected to the neutral.

Most testers will not be able to read this condition, as the grounds and neutrals are correctly terminated together at the panel anyway.

The inspector should be suspicious of older-style wiring in the panel that tests like a grounded circuit at the receptacles. It is very common to find an old home with 2-wire conductors upgraded to 3-prong outlets where the ground has been "faked."

This can lead to very dangerous conditions downstream of the receptacle with the illegal connection, especially should there be any wiring or appliance failure.

The image at the right shows a grounding wire clearly connected to the silver neutral screws on the receptacle.

Voltage Drop

Some inspectors are now starting to check voltage drop along conductors. This falls well outside of industry standards of practice, but with electrical components becoming ever more sensitive to voltage fluctuations, many more inspectors will start to check for this.

Also, voltage drop can be indicative of too many outlets on a circuit, poor connections, or undersized conductors on long wiring runs, all of which could lead to overheating and failures.

The National Electrical Code recommends that voltage should not drop more than 3% on branch circuits, and a 5% overall drop, including the service itself.

Ungrounded Two-Prong Receptacles

The image above is an old 2-prong, ungrounded wall receptacle. Two-prong receptacles, often found by an inspector in an older home, that are connected to two-wire cables do not have the ground wires, which protect people and electrical devices in case of a fault. It is possible to retrofit a new three-prong or GFCI receptacle into the same receptacle box without any rewiring, as long as the box itself is grounded.

Metal boxes attached to armored, or BX, cable, which is a type of wiring commonly found in old homes, are typically found to be properly grounded. The armored or BX cable's flexible metal jacket serves the same purpose as a dedicated ground wire.

If the box is not grounded, a GFCI can be installed or an electrician can be hired to fix the wiring.

The image above is a GFCI that was installed to replace the old, 2-prong ungrounded wall receptacle in an older home. This GFCI must be labeled as a GFCI without an equipment ground. It was not, and that's a defect.

Simply replacing an older 2-prong outlet with a 3-prong outlet can be hazardous, because the receptacle will appear to be functional with a ground, but in fact there isn't one. If someone were to plug a faulty 3-prong device into that “fake” grounded receptacle, a shock hazard is very likely. Electricity moving through the device casing would create an energized surface from which a person could be electrocuted.

Another problem with replacing ungrounded 2-prong receptacles with 3-prong one is in relation to surge-protection device, which relies on a solid ground to route any transient activity. The ungrounded receptacle would not be able to protect the device from a surge.

It is permissible to replace a 2-prong ungrounded outlet with a 3-prong GFCI outlet, but it must be labeled as “GFCI Protected Outlet, No Equipment Ground.” Even though there is not a grounding conductor, there is still some protection against shock provided by the GFCI.

If an inspector has doubt as to what is being inspected, a qualified electrician should be consulted.

Inspection Recommendations

The home inspector should check the following conditions on a representative number of receptacles:

- no power present;
- no ground;
- open neutral;
- reversed polarity (hot and neutral); and
- reversed ground and hot.

The inspector may also choose to invest in equipment to enable him to report on:

- low resistance grounds;
- bootleg grounds;
- true voltage; and
- voltage drop.

The image above shows a Sperry tester in a receptacle. On this model, the single lit bulb signifies that the circuit has an open ground (or no ground).

240-Volt Terminations

In today's homes, we typically see appliances, such as clothes dryers, ranges, heating units, and air-conditioning equipment, which use two to three times higher amperage than in homes built in the past.

As many of these appliances are required to be hard-wired, the home inspector does not do the same evaluation of 240-volt outlets that s/he would for 120-volt receptacles. However, all attachment plugs inserted into receptacles should be removed so that both components can be checked for signs of overheating and damage. One method is to check the 240-volt systems with a voltage ticker. Placing the end in each slot, one at a time, will at least determine there are 120 volts on each leg and none on the grounded or grounding legs.

3-Wire Appliances

Prior to the adoption of the 1996 NEC code revisions, 3-wire, 240V supplies were common. The cable assembly carries:

- two 120-volt ungrounded (hot) conductors; and
- one grounded (neutral) conductor.

As there is no separate grounding means in this installation, the metal frame of the appliance was allowed to be bonded to the neutral. This is no longer allowed in new construction.

4-Wire Appliances

Since adoption of the 1996 NEC, all 240V circuits are required to be 4-conductor assemblies carrying:

- two 120V ungrounded (hot) conductors;
- one grounded (neutral) conductor; and
- one equipment grounding conductor.

Some appliances still have the bond between the cabinet and the neutral, and this needs to be removed when used on a 4-wire circuit.

If a 3-wire configuration exists and one wishes to extend the circuit (for example, in a renovation), it would be considered a new installation and must be re-wired in a cable with four conductors.

Receptacle Blade Patterns

There are many odd receptacle styles out there, but the two that are most common around the home are:

- **dryer outlets:** A 240V clothes dryer receptacle has four prongs. The top prong is round and is for the ground connection. The bottom prong is shaped like an "L" and is for the neutral wire. The two vertical slots on the sides are for the two hot wires.

- **range outlets:** A 240V oven receptacle also has four prongs, but the neutral prong is straight and not L-shaped. It is, however, narrower and thicker than the hot-wire prongs. These two plugs have four prongs because they use two hot wires to provide the 240-volt power.

These receptacles have different designs so that a 30-amp dryer cannot be accidentally connected to a 50-amp range circuit, for example.

The image at the left is a 240V, 50-amp range receptacle.

The image at the right is a 240V, 30-amp dryer receptacle.

Some things we never want to see:

GFCI: Ground-Fault Circuit Interrupters

Since the early 1970s, GFCIs have been required in an increasing number of damp and wet locations, and, more recently, this requirement has extended to all receptacles in garages. Because they are safety devices, the home inspector should check every installed GFCI circuit and may advise the client of areas where they should also be fitted.

History of GFCIs

Charles Dalziel (1904-1986), a professor of electrical engineering at the University of California, invented the ground-fault circuit interrupter (GFCI) in 1961. He came to realize that a common cause of deaths was the result of ordinary household circuits malfunctioning in the ground fault. His research objective then became to create a device which would interrupt a ground-fault current before it became large enough to cause human physiological damage. The sensitivity, speed of action, reliability, small size, and cost required made the device almost impossible to design.

However, in 1965, Dalziel received a patent for a “ground-fault current interrupter” that would interrupt current before it grew to 0.005 of an ampere, and which was small, reliable and inexpensive. The device was based on a magnetic circuit plus a then newly developed semiconductor device.

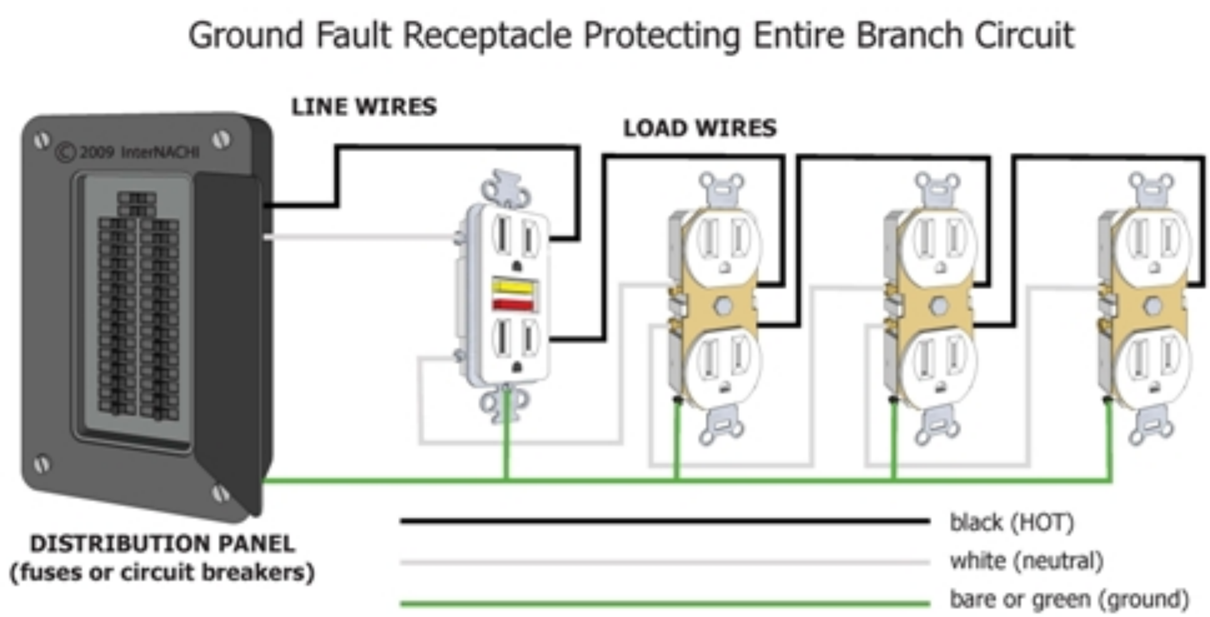
Most of the time, his invention does nothing; it just monitors the difference in the current flowing into and out of a tool or appliance. But when that difference exceeds 5 milliamps (nominal), an indication that a ground fault may be occurring, the GFCI shuts off the flow in an instant — in as little as 0.025 of a second.

How does a GFCI work?

GFCIs are designed to sense any difference in current between the supply on the ungrounded (hot) conductor in a circuit, and the grounded (neutral) conductor.

If the circuitry recognizes a differential of more than 5 milliamps (nominal) between supply and return, a solenoid trips open the circuit, causing all power to be disconnected.

For this reason, a GFCI breaker, or a correctly wired GFCI receptacle, can protect all outlets farther downstream.



The image above shows correct wiring to protect downstream outlets.

Types of GFCI Devices

There are four basic types of GFCI in common usage, and two or three of them are common in residential construction. They are:

1. GFCI breakers in the distribution panel;
2. GFCI receptacles at in-home locations;
3. stand-alone GFCIs, as sometimes used with pools; and
4. extension cords with built-in protection, primarily found on construction sites.

The image at the right shows the two most common types used in residential construction. Note the test features on all GFCI devices. These should be tested once a month, according to most manufacturers.

GFCI on 2-Wire Circuits

There is a common misconception that GFCIs work only on grounded circuits. This is not entirely the case. While there are conditions under which the GFCI will not be able to trip without a ground, the inspector should still recommend that any circuits in potentially wet or damp locations be fitted with them as a safety precaution.

GFCI Requirements

Bathroom

To protect people, ground-fault circuit interrupter (GFCI) protection should be installed in all bathrooms with 125-volt, single-phase, 15- and 20-ampere receptacles.

Laundry

To protect people, ground-fault circuit interrupter (GFCI) protection should be installed in laundry rooms with 125-volt, single-phase, 15- and 20-ampere receptacles.

Garage and Accessory Buildings

To protect people, GFCI protection should be installed at all 125-volt, single-phase, 15- or 20-ampere receptacles installed in garages and grade-level portions of unfinished accessory buildings used for storage or work areas.

Outdoor

To protect people, GFCI protection should be installed at all 125-volt, single-phase, 15- and 20-ampere receptacles installed outdoors, except for receptacles not readily accessible that are used for temporary snow-melting equipment and are on a dedicated circuit.

Crawlspace

To protect people, GFCI protection should be stalled at all 125-volt, single-phase, 15- and 20-ampere receptacles in the crawlspace when such place is at or below grade level.

Unfinished Basement

To protect people, GFCI protection should be installed at all 125-volt, single-phase, 15- and 20-ampere receptacles installed in unfinished basements. Unfinished basements are defined as portions or areas of the basement not intended as habitable rooms such as storage and work areas. The exception would be a receptacle supplying only a permanently installed fire alarm or burglar alarm system.

Kitchen

To protect people, GFCI protection should be installed at all 125-volt, single-phase, 15- and 20-ampere receptacles that serve countertop surfaces.

Sink

To protect people, GFCI protection should be installed at all 125-volt, single-phase, 15- and 20-ampere receptacles that are located within 6 feet of the outside edge of a sink, bathtub or shower. Receptacle outlets shall not be installed in a face-up position in the counter top or work surface.

Boathouse

To protect people, GFCI protection should be installed at all 125-volt, single-phase, 15- or 20-ampere receptacles installed in boathouses.

Boat Hoist

To protect people, GFCI protection should be installed for outlets supplying up to 240 volts at boat hoists.

Electrically Heated Floors

To protect people, GFCI protection should be installed at electrically heated floors in bathrooms, kitchens and in hydro-massage bathtub, spa and hot tub locations.

GFCI Locations

GFCIs should be installed in readily accessible locations.

Testing GFCI Circuits

Many common circuit testers will not be able to trip a GFCI installed on a 2-wire circuit, as most testers actually trip a GFCI by creating a partial fault to ground. Obviously, if there is no ground to energize, then the neutral will not be able to sense any voltage drop.

The manufacturers state that their equipment be tested by using the test and reset buttons on the breaker or receptacle. However, many inspectors usually check them with their receptacle tester functions. The most sophisticated testers check not only that they trip, but also measure at what voltage they trip. However, the only proper way to test a GFCI is using the button on the breaker or receptacle itself.

Equipment grounding is not necessary for a GFCI to function properly. The grounded person becomes the equipment grounding conductor, and the current going through him creates the imbalance that trips the GFCI. This is why GFCIs are allowed to replace open-ground receptacles without adding an equipment grounding conductor.

Any breaker or receptacle that fails to trip and reset properly should be written up as in need of urgent replacement.

Remember: Industry standards dictate that ALL accessible GFCI receptacles be tested.

AFCI: Arc Fault Circuit Interrupters

AFCI History

AFCIs were developed in response to a need for equipment to sense when an arc fault was occurring. AFCIs were first mentioned in the 1999 revision of the NEC. It required that bedroom receptacles were to be protected by AFCI breakers.

Studies of building fires had attributed many electrical faults to an arcing type, which were igniting flammable materials within the building structure.

The Consumer Product Safety Commission (CPSC) asked the electrical industry to look at a technical solution to the issue of preventing fires by tripping circuits which were exhibiting power fluctuations due to arc faults.

AFCIs are able to detect faults as low as 5 amps (peak) for series arcs, and for 75 amps (peak) for parallel arcs. They can also detect arcing caused by faults, such as dead-shorts due to nails and screws through conductors, and arcing due to loose connections anywhere in the circuit.

A combination type arc-fault circuit interrupter should be installed to provide protection at all branch circuits that supply 120-volt, single-phase, 15- and 20-ampere outlets installed in family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreations rooms, closets, hallways, and similar rooms or areas.

AFCI and GFCI Protection

Where branch-circuit wiring is modified, replaced, or extended, the branch circuit should be protected by one of the following:

Please refer to Section E3902 of the 2015 IRC that relates to GFCIs and AFCIs.

GFCI protection is recommended for the following:

- 15- and 20-amp kitchen countertop receptacles and outlets for dishwashers;
- 15- and 20-amp bathroom and laundry receptacles;
- 15- and 20-amp receptacles within 6 feet of the outside edge of a sink, bathtub or shower;
- electrically-heated floors in bathrooms, kitchens, and hydromassage tubs, spas, and hot tubs;
- 15- and 20-amp exterior receptacles, which must have GFCI protection, except for receptacles not readily accessible that are used for temporary snow-melting equipment and are on a dedicated circuit;
- 15- and 20-amp receptacles in garages and unfinished storage buildings;
- 15- and 20-amp receptacles in boathouses and 240-volt and less outlets at boat hoists;
- 15- and 20-amp receptacles in unfinished basements, except receptacles for fire or burglar alarms; and
- 15- and 20-amp receptacles in crawlspaces at or below ground level.

GFCIs and AFCIs must be installed in readily accessible locations because they have test buttons that should be pushed periodically. Manufacturers recommend that homeowners and inspectors test or cycle the breakers and receptacles periodically to help ensure that the electrical components are working properly.
AFCI protection is recommended at 15- and 20-amp outlets on branch circuits for bedrooms, closets, dens, dining rooms, family rooms, hallways, kitchens, laundry areas, libraries, living rooms, parlors, recreation rooms, and sun rooms.

Similar rooms or areas must be protected by any of the following:

- a combination-type AFCI installed for the entire branch circuit. The 2005 NEC required combination-type AFCIs, but before January 1, 2008, branch/feeder-type AFCIs were used.

- a branch/feeder-type AFCI breaker installed at the panel in combination with an AFCI receptacle at the first outlet box on the circuit.

- a listed supplemental arc-protection circuit breaker (which are no longer manufactured) installed at the panel in combination with an AFCI receptacle installed at the first outlet, where all of the following conditions are met:

- the wiring is continuous between the breaker and AFCI outlet;

- the maximum length of the wiring is not greater than 50 feet for 14-gauge wire, and 70 feet for 12-gauge wire; and

- the first outlet box is marked as being the first outlet.

- a listed AFCI receptacle installed at the first outlet on the circuit in combination with a listed overcurrent-protection device, where all of the following conditions are met:

- the wiring is continuous between the device and receptacle;

- the maximum length of the wiring is not greater than 50 feet for 14-gauge wire and 70 feet for 12-gauge wire;

- the first outlet is marked as being the first outlet; and

- the combination of the overcurrent-protection device and AFCI receptacle are identified as meeting the requirements for a combination-type AFCI.

- an AFCI receptacle and steel wiring method; and

- an AFCI receptacle and concrete encasement.

AFCI Recalls

Like many new technologies, the introduction of AFCIs was not trouble-free. In particular, Square D was forced to recall 700,000 breakers due to faults. (Click here to read the U.S. Consumer Product Safety Commission's announcement.) These breakers were manufactured with a blue test button.

As there are still many of these out there that have not been replaced, the home inspector should pay special attention to blue-button Square D breakers, and advise the client that they may be subject to recall.

Testing AFCIs

When testing AFCIs, as when testing GFCIs, it is recommended by the manufacturers to use the test function on the breaker. However, this only tests the internal circuit board, rather than emulates any actual fault.

Many inspectors are now purchasing specialist testers that simulates an arc fault within the tester.

Home inspectors purchase both AFCI and GFCI branch circuit testers. They are as common and easy to use for a home inspector as a flashlight.

The image at the left shows the cost-effective Ideal SureTest® with an AFCI test function.

Lighting Circuits

Lighting Requirements

All habitable spaces are required to have a source of light. What is less commonly understood is that any area used for storage must also be lit, and any area that houses mechanical equipment must have illumination, too.

General Requirements

All habitable, storage and mechanical locations require light. However, some require a fixed-wall or ceiling light, while others may have just a switched-lighting circuit to control table lamps, etc.

The inspector should also be aware of the concept of the "lit path." One should be able to walk into any home in the dark and be able to go from one room to the next in a lighted path, switching each light off behind as s/he leaves a hall or room.

This is for obvious safety reasons, and, as home inspectors are normally inspecting homes in the daylight, checking for safe light is often forgotten.

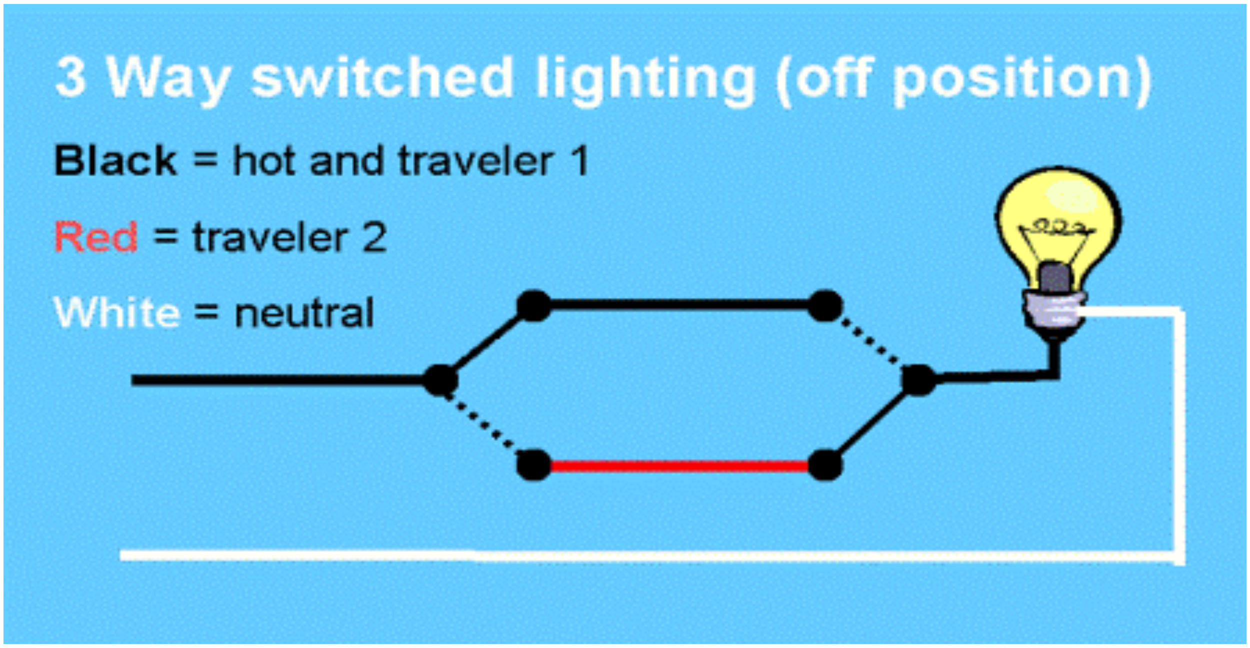
Fixed Lighting

Many locations are required to have fixed luminaires (lights). These include:

- kitchens;
- bathrooms;
- hallways;
- staircases;
- attics;
- storage spaces; and
- at exterior doors.

Images above (left to right) show a can light (courtesy of Jim Gallant), a bulb-holder spliced into Romex®, and vanity bulbs too close (or too high a wattage) against ceiling tiles.

Staircases



These should be a special consideration for the home inspector, as any staircase with six or more risers should have 3-way switches at both the top and bottom of the run.

Many people do a lot of head-scratching when trying to figure out how 3-way circuits work.

The diagram at the right shows the correct wiring schematic.

In any 3-way circuit, there are two potential supplies (travelers) to the light, with each of them switched.

When both switches are in contact with one of the travelers, the light is on, but when each switch is in contact with only one traveler, then the light is off.

Switched Receptacles

Switched receptacle circuits are allowed for all other locations:

- living rooms;
- dining rooms;
- studies;
- family rooms;
- bedrooms; and
- crawlspaces with mechanical equipment.

Switch Evaluation

All switches should be evaluated for:

- missing cover plates;
- damaged cover plates;
- missing screws;
- loose installation;
- loose or worn-out contacts; and
- any signs of arcing.

Problem Lighting

There are several potential problems with lighting to check for:

- **bathroom, bathtub and shower areas:** No parts of cord-connected luminaires, chain-, cable- or cord-suspended luminaires, lighting track, pendants, or ceiling-suspended (paddle) fans shall be located within a zone measured 3 feet horizontally and 8 feet vertically from the top of the bathtub rim or shower stall threshold.

- **bathroom luminaires:** Unless recessed and listed for a damp and/or wet location, no luminaire is allowed to be within 3 feet of the sides, or within 8 feet above any tub or shower enclosure.

- **ceiling fans:** Many times we will see a ceiling fan wobbling around on its mount, or doing a helicopter impression as it flies around its axis, because it's been installed on a standard ceiling box. Remember that fixtures under 35 pounds must be mounted to a box rated for fan-support, and fixtures over 35 pounds cannot be supported by the electrical box at all.

Bathroom:

Lighting tracks, hanging light fixtures, and ceiling fans are not allowed with the tub or shower space, which is a zone 3 feet horizontal by 8 feet vertical above the threshold of a shower or the rim of a bathtub. Recessed or surface mounted lighting fixtures are allowed in this zone if they are labeled for use in damp locations. If the fixtures might get wet from shower spray, they must be marked for use in a wet location.

A switch must not be installed within a wet location in a tub or shower space, unless it is installed as part of a listed tub or shower assembly.A surface-mounted switch located in a damp or wet location must be enclosed in a weatherproof enclosure. A flush-mounted switch in a damp or wet location must be equipped with a weatherproof cover.

Cord-connected luminaires, chain-, cable-, or cord-suspended-luminaires, lighting track, pendants, and ceiling-suspended (paddle) fans must not have any parts located within a the tub and shower zone, which is an area measured 3 feet horizontally and 8 feet vertically from the top of a bathtub rim or shower stall threshold. This area is all-encompassing. It includes the space directly over the tub or shower.

Luminaires within the actual outside dimension of the bathtub or shower to a height of 8 feet vertically from the top of the bathtub rim or shower threshold must be marked for damp locations. If the luminaire is subject to the spray of a shower, it must be marked for wet locations.

A receptacle installed within or directly over a bathtub or shower stall is not permitted. That is a defect and safety hazard.

Recessed Lights:

Lights in contact with insulation should be IC-rated. If not, they should have 3 inches of clearance away from insulation or any other combustible surface or material.

The image at the right (courtesy of B. Kelly) shows a "pot" light in direct contact with vermiculite insulation.

This light is not rated for this application.

Closet Lights:

Open incandescent lamps or bulbs are a bad idea near storage shelving, as the heat generated can easily start a fire.

- Protected incandescent bulbs should be no closer than 12 inches to the shelf space.
- Fluorescent or recessed lights should be no closer than 6 inches to the shelves.

The image at the right *(by Jeff Pope)* shows an incandescent bulb illuminating a closet space which is installed too near a shelf with clothing stacked on it.

These bulbs put out enough heat to set fire to cotton and other materials.

This is a hazardous situation.

Quiz on Distribution (Part I)

Which of the following would the inspector require a specialist?

- single-strand aluminum wiring
- aluminum wiring
- copper-clad aluminum wiring

The first kind of residential wiring is called _________.

- knob-and-tube
- button-and-sleeve
- knob-and-sleeve
- button-and-tube

The ______________ copper wiring size carrying 120 volts should be 14 awg.

- minimum
- maximum

A _________ conductor should be connected to a 15-amp fuse or breaker.

- 14 awg
- 10 awg
- 6 awg
- 2 awg

"Romex" cable that is not actually of the brand Romex is more properly called _______.

- type-NM cable
- type-UL cable
- type-BX cable
- type-AC cable

What color will plastic conduit be if it is for electrical use?

- gray
- red
- white

Electric water heaters should be fed with 10-awg _______________ copper conductors.

- minimum
- maximum

Several grounded conductors _____ terminate on the same lug.

- should not
- are permitted to

The inspector should not report all _______________ electrical splices as improper.

- in-panel
- dead front
- neither

Wiring within 1-1/4 inches to the front of a __________ requires protection.

- stud
- door
- breaker
- conduit

___________ electrical wiring in an attic should not be within 6 feet of the entrance opening.

- Unprotected
- Protected

_____________ cable assemblies should not be in crawlspaces.

- Unsupported
- Supported

Are horizontally mounted face-up countertop receptacles allowed?

- No
- Yes

What circuits should bathroom outlets be on?

- 20-amp, GFCI-protected
- 15-amp, GFCI-protected
- 20-amp, AFCI-protected
- 15-amp, AFCI-protected

Which of the following is the inspector not required to test for on electrical receptacles?

- voltage drop
- open ground
- reversed polarity
- open hot

In a false grounded receptacle, the ground wire is connected to _________.

- the grounded conductor
- the ungrounded wire
- the grounding wire
- the receptacle box

On a standard 120-volt outlet, what is the smaller slot?

- ungrounded conductor
- grounding conductor
- grounded conductor
- bonding conductor

The home inspector is required to test ________.

- a representative number of receptacles
- all available receptacles
- all receptacles

COPALUM is the only approved repair to _____________ wire terminations?

- aluminum
- copper
- iron
- plastic

Most circuits in North America are wired with _______________ cable type.

- non-metallic
- aluminum
- faux-metal

Quiz on Distribution (Part II)

In ____________ the 4-wire, 240 volt circuit was required.

- 1996
- 1986
- 1976
- 1966

A 4-wire, 240V cable assembly has _____________ hot, one neutral, one ground conductors.

- two
- three
- five

What is the minimum circuit for stoves?

- 40 amps
- 20 amps
- 80 amps
- 50 amps

How many amps are electric clothes dryers?

- 30-amp
- 60-amp
- 50-amp
- 40-amp

Exterior receptacles require ____________ protection.

- GFCI
- circuit surge
- extra wire
- no
- AFI

GFCI receptacles _________ only on 3-wire circuits.

- do not work
- work

GFCI receptacles can protect ____________ receptacles, if properly wired.

- downstream
- upstream
- all receptacles on the circuit

AFCIs are required to protect _________ circuits.

- bedroom
- bathroom
- kitchen

Which of the following locations require fixed lighting?

- kitchens
- living rooms
- all crawlspaces
- bedrooms

A staircase with six or more risers requires a light switch at ____ of the staircase.

- both the top and the bottom
- the top
- the bottom

Recessed ceiling lights should be rated ____ if installed against insulation.

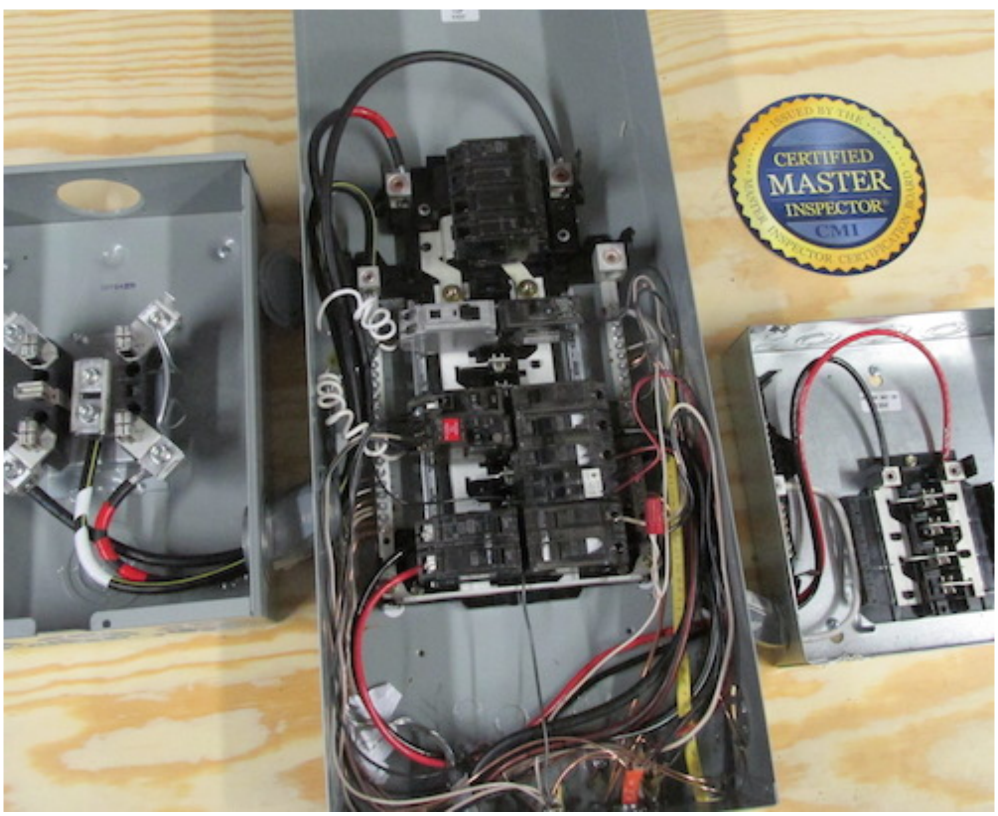
- IC
- EC
- GC
- CC

Electrical Wall Video

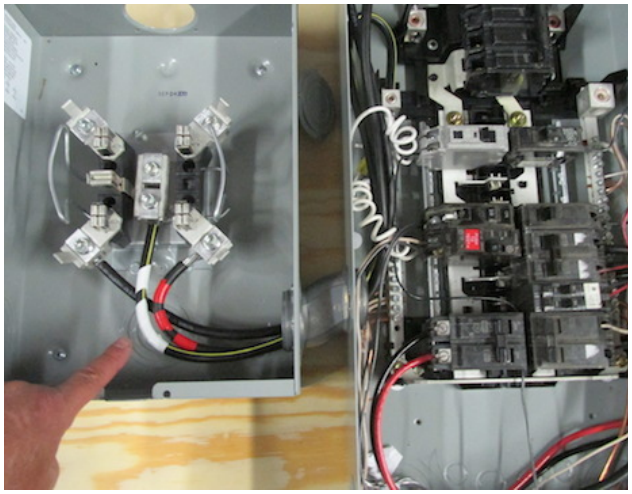
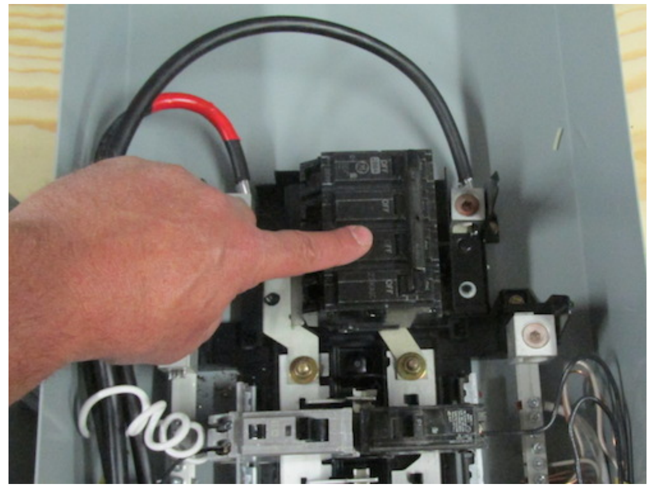
Optional Video

You will not be assessed on the content of the following video. It is optional to play and watch this video.

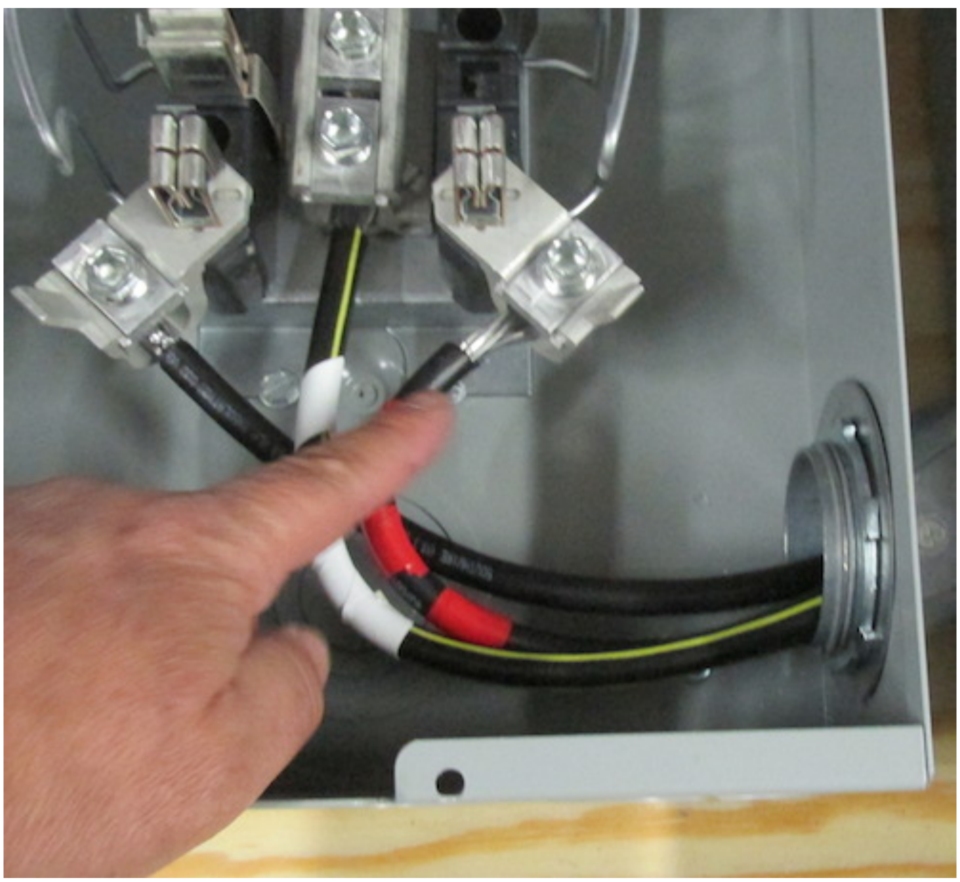
Electrical Panel Defects



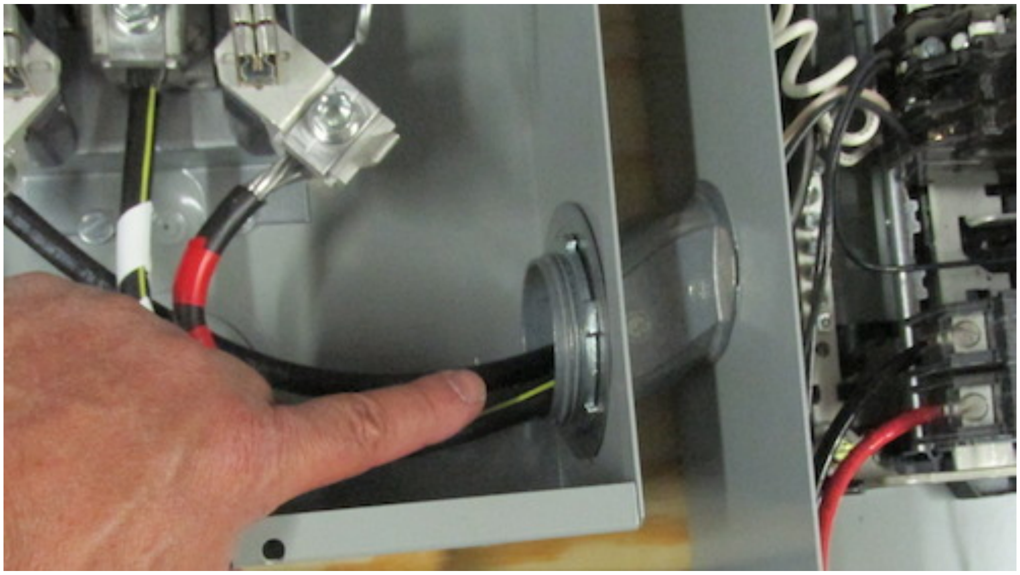
Meter socket, load center, and auxiliary panel.

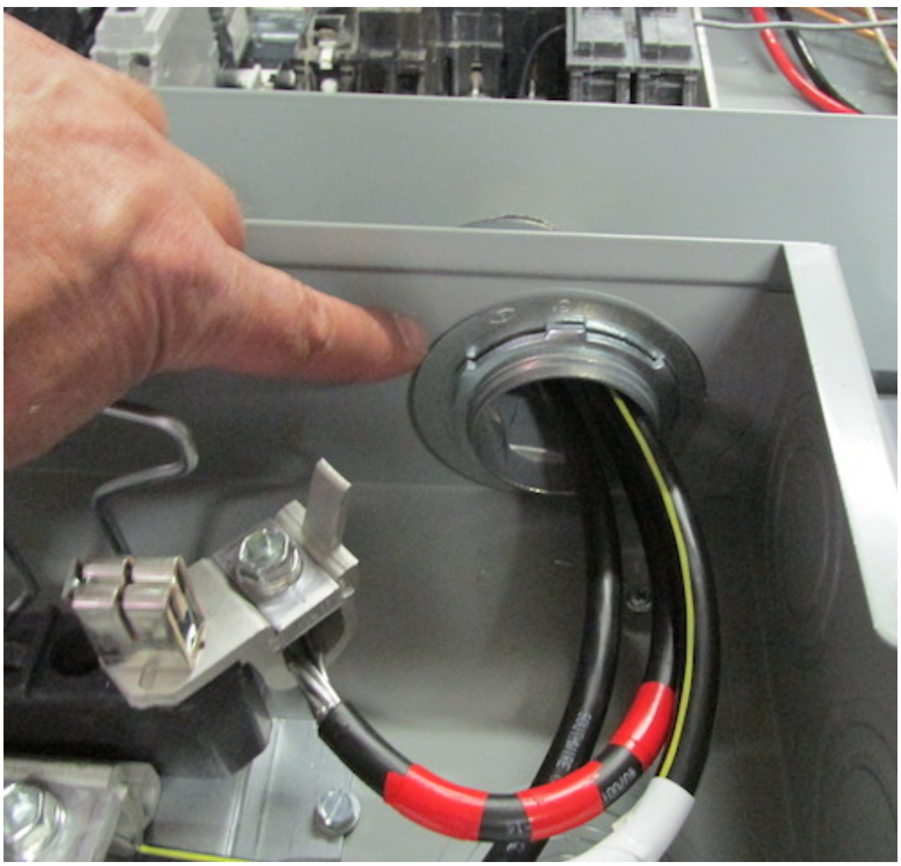
Undersized service conductors. 200 Amp service disconnect with #2 aluminum conductors. Should be 4-0.



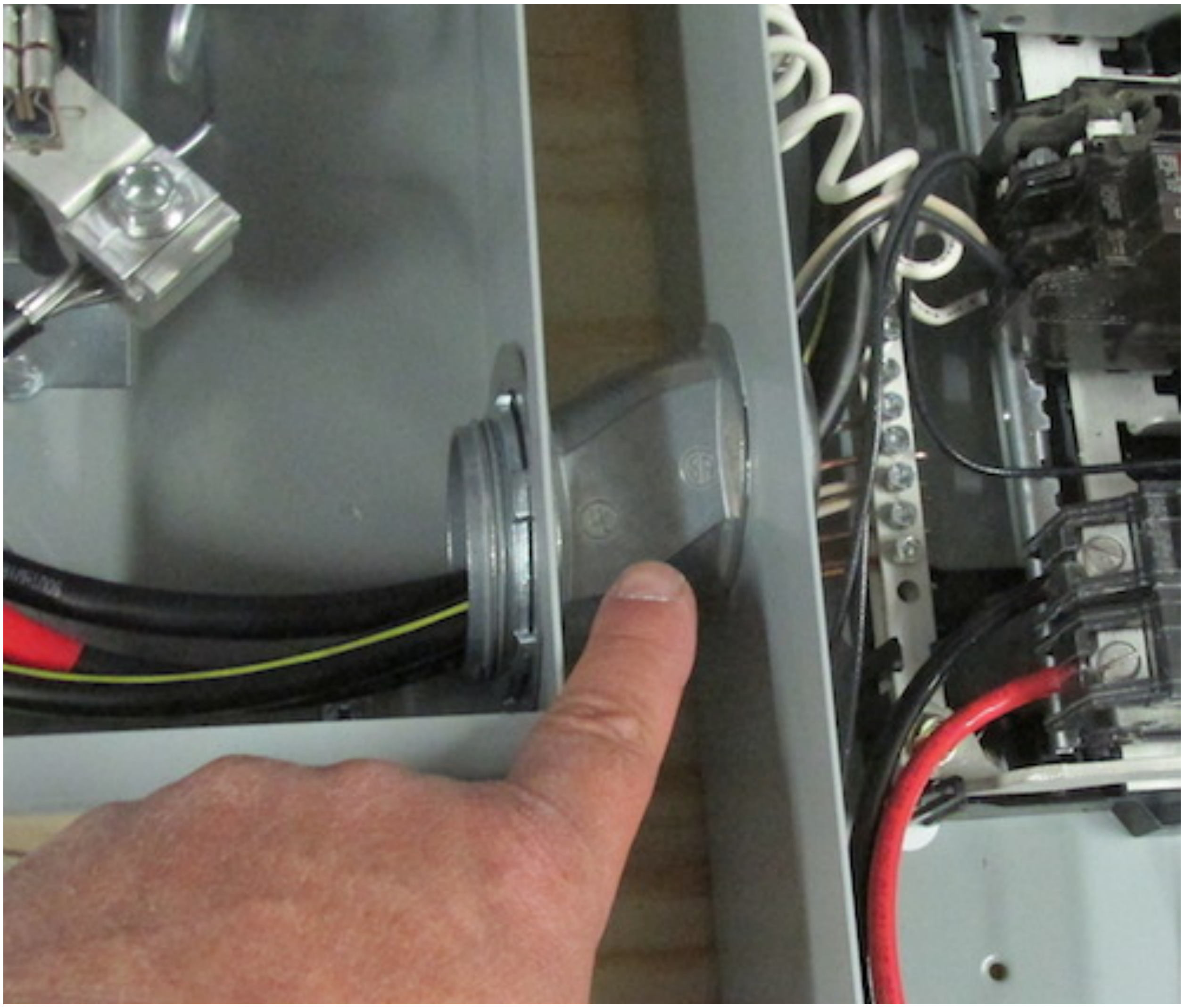
- Over stripped conductor.
- Nicked conductors
- No Anti-oxidation paste on current-carrying aluminum conductor

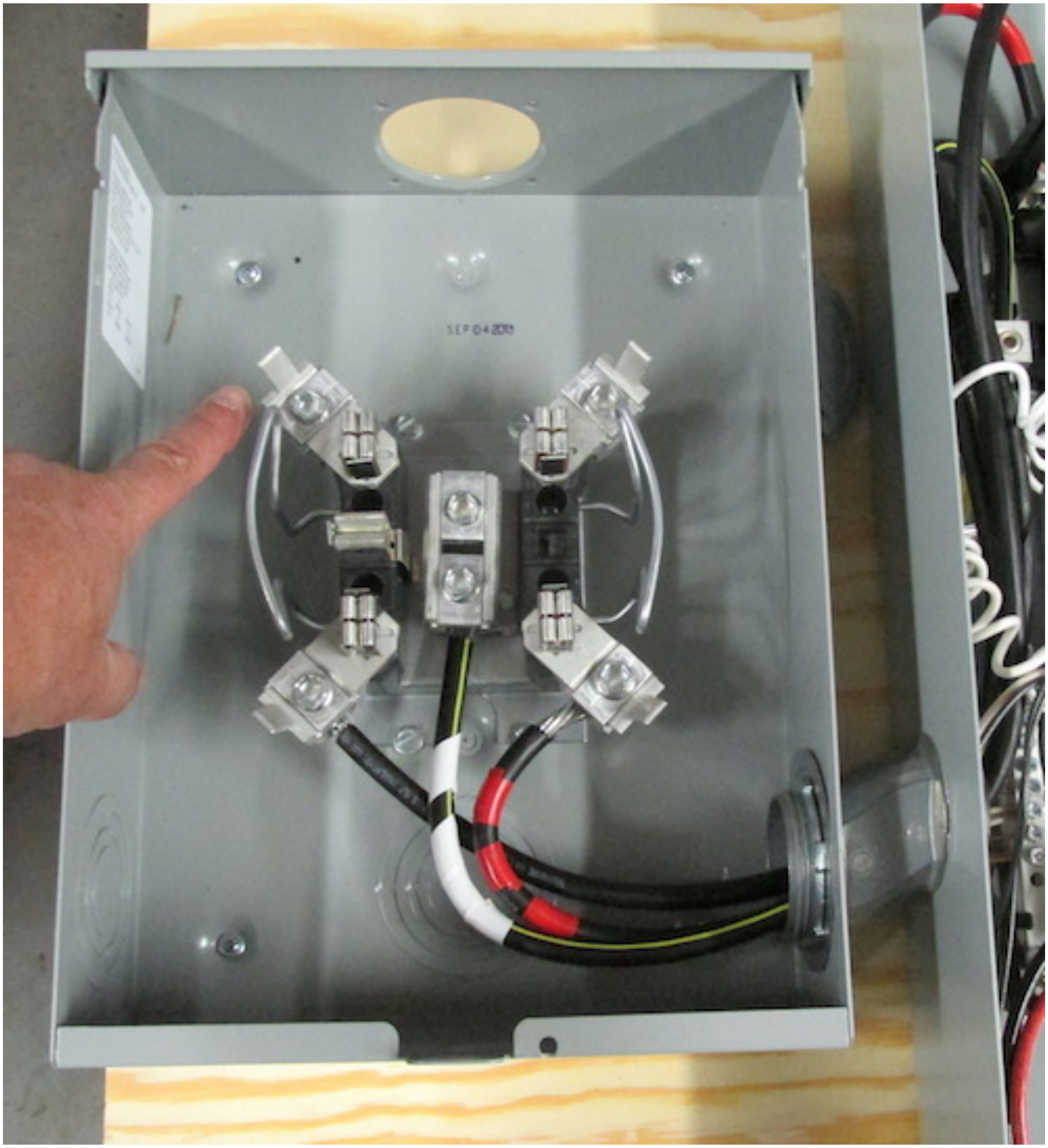


Lack of nylon bushing for service entrance conductors going through offset. Required when conductors are over AWG 4.

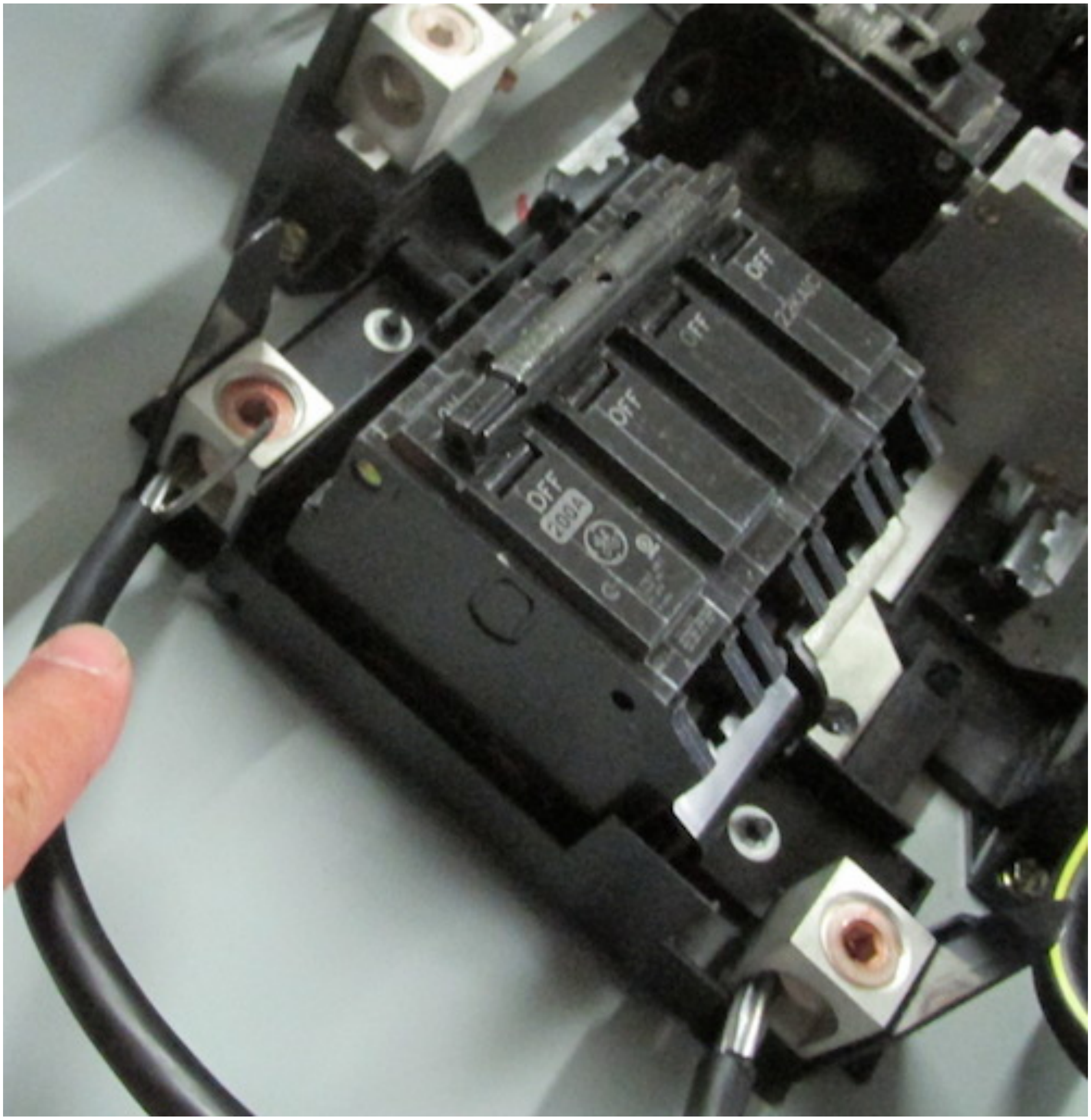


Reducing washer used on concentral knock-outs of ungrounded meter base. Does not meet service bonding requirements.

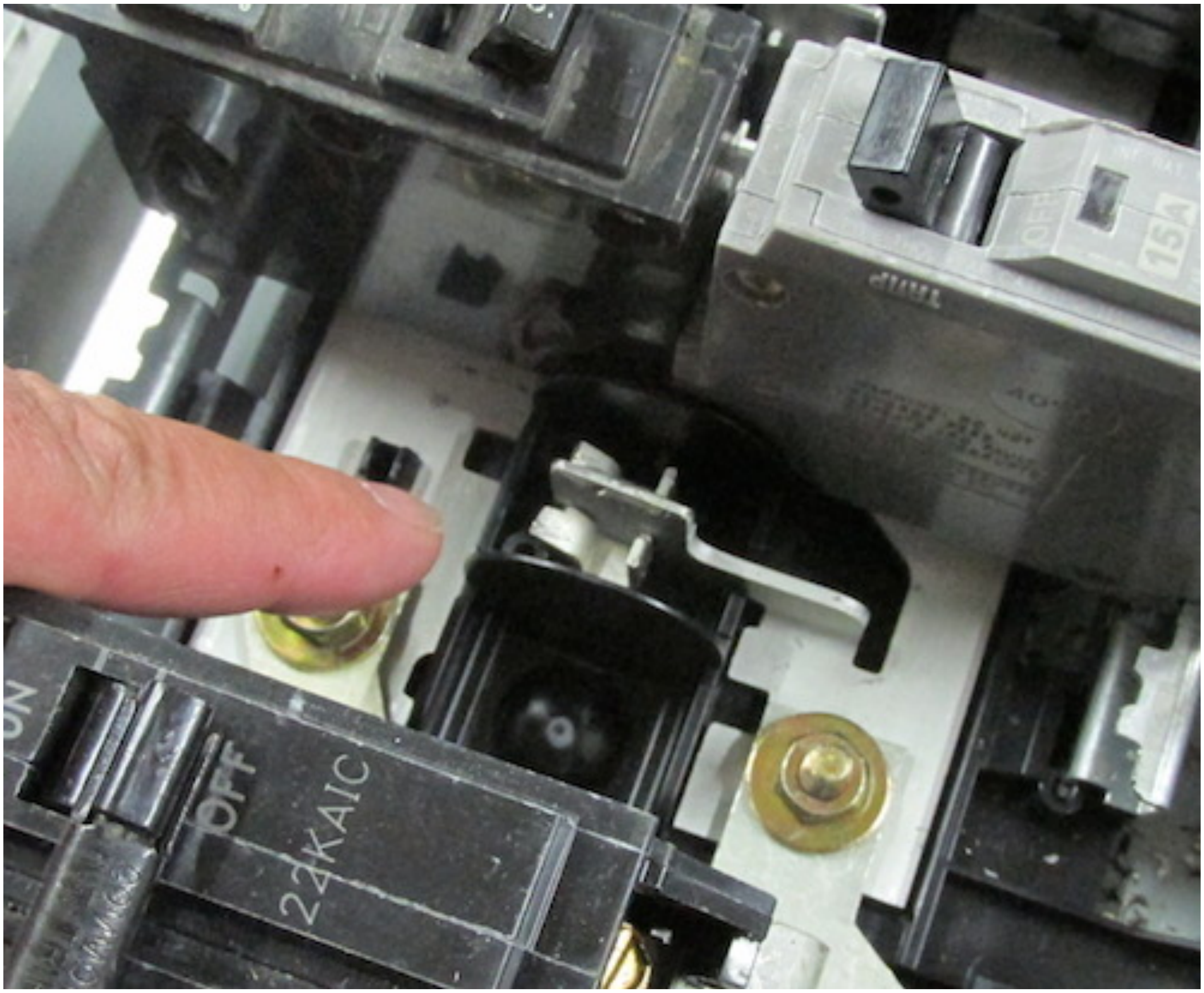

Non-wet location fitting used when entering panel above energized bus.



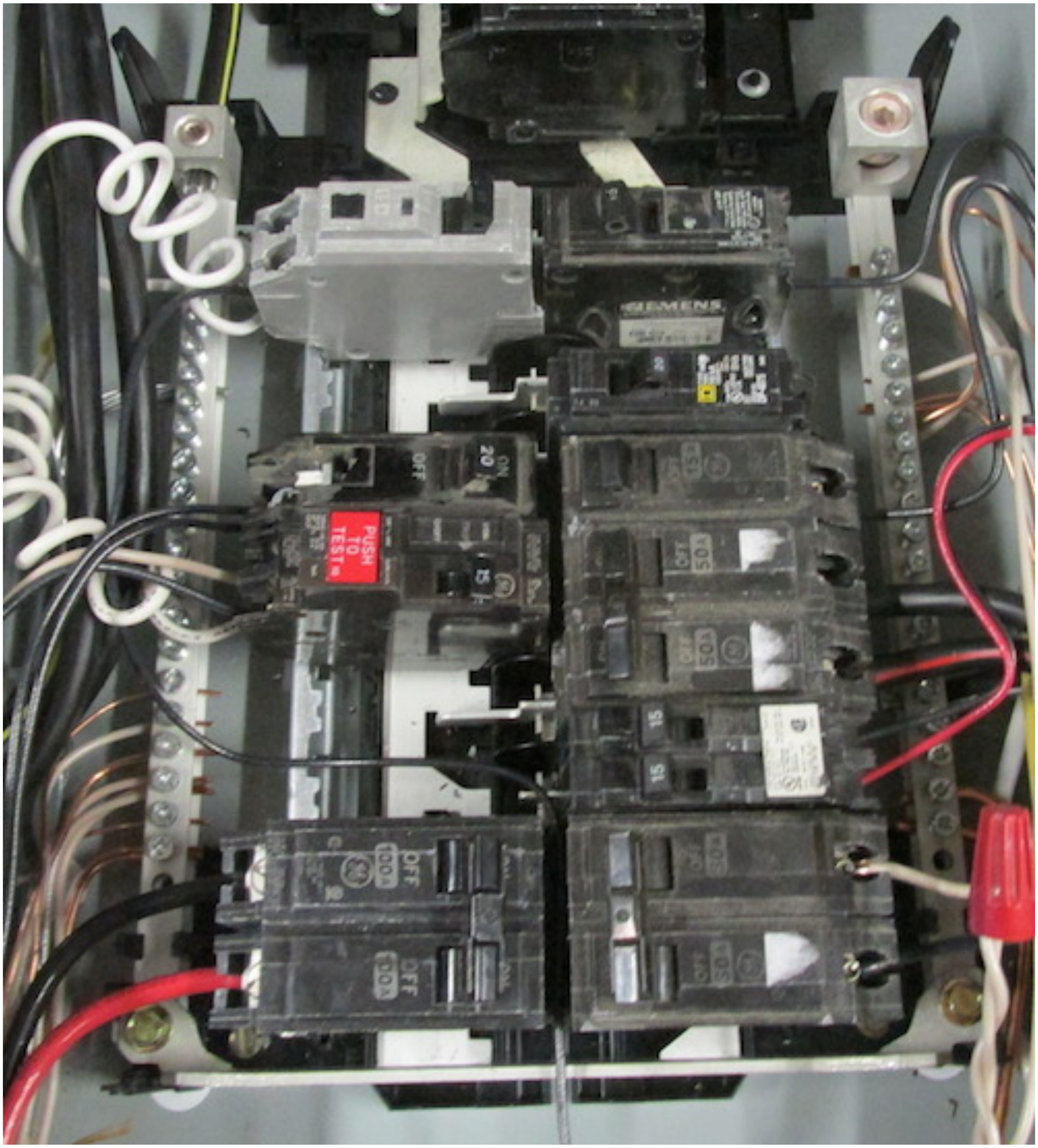
Horn bypass meter installed as opposed to lever bypass. For new construction, all PUDs and MUDs have adopted the new lever bypass meter. The lever bypass meters provide meter maids with a safe-to-use lever so that they don't need to install a jumper or shut off the electricity to the house.



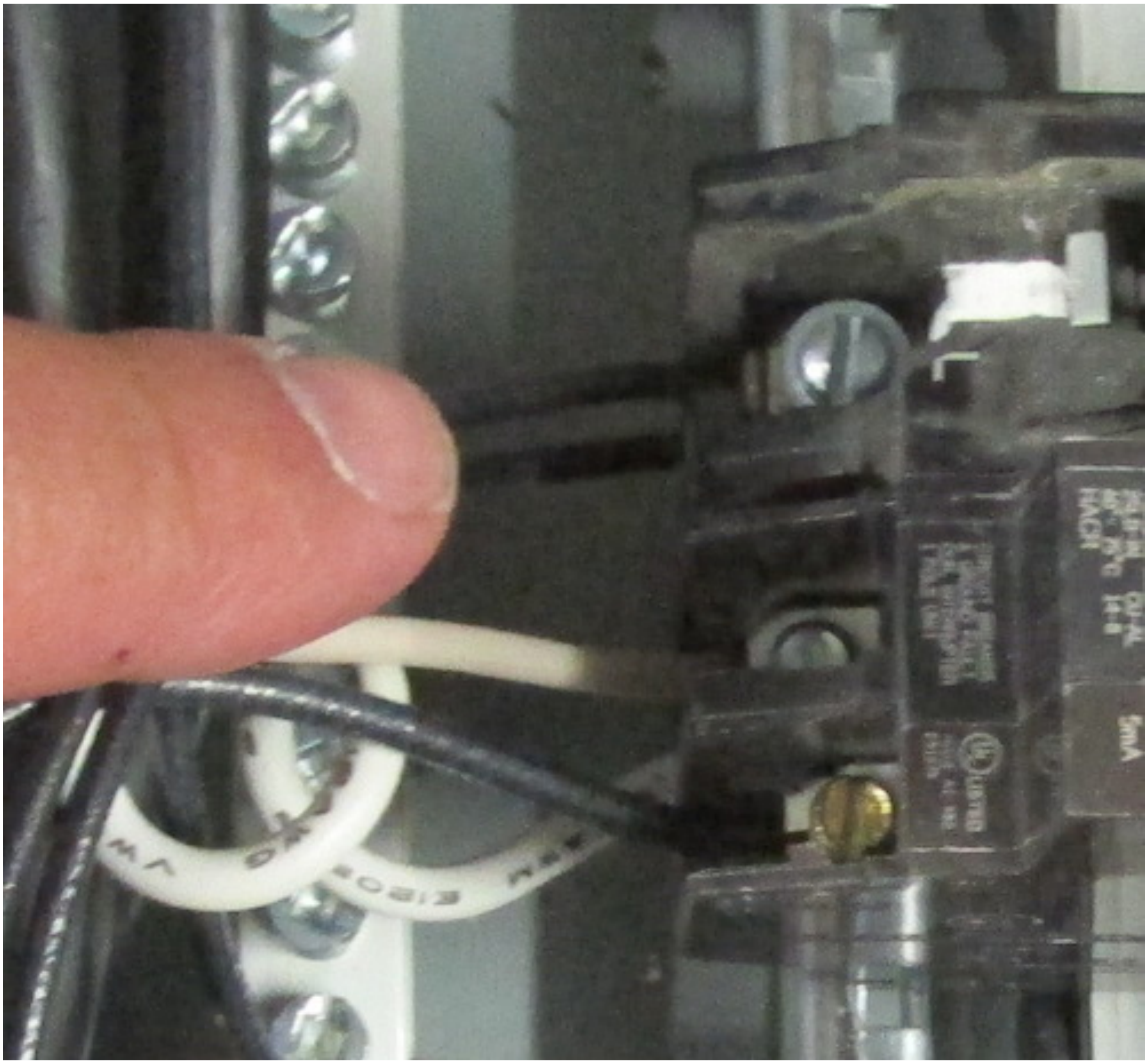
Not all strands are under set screw of lug.



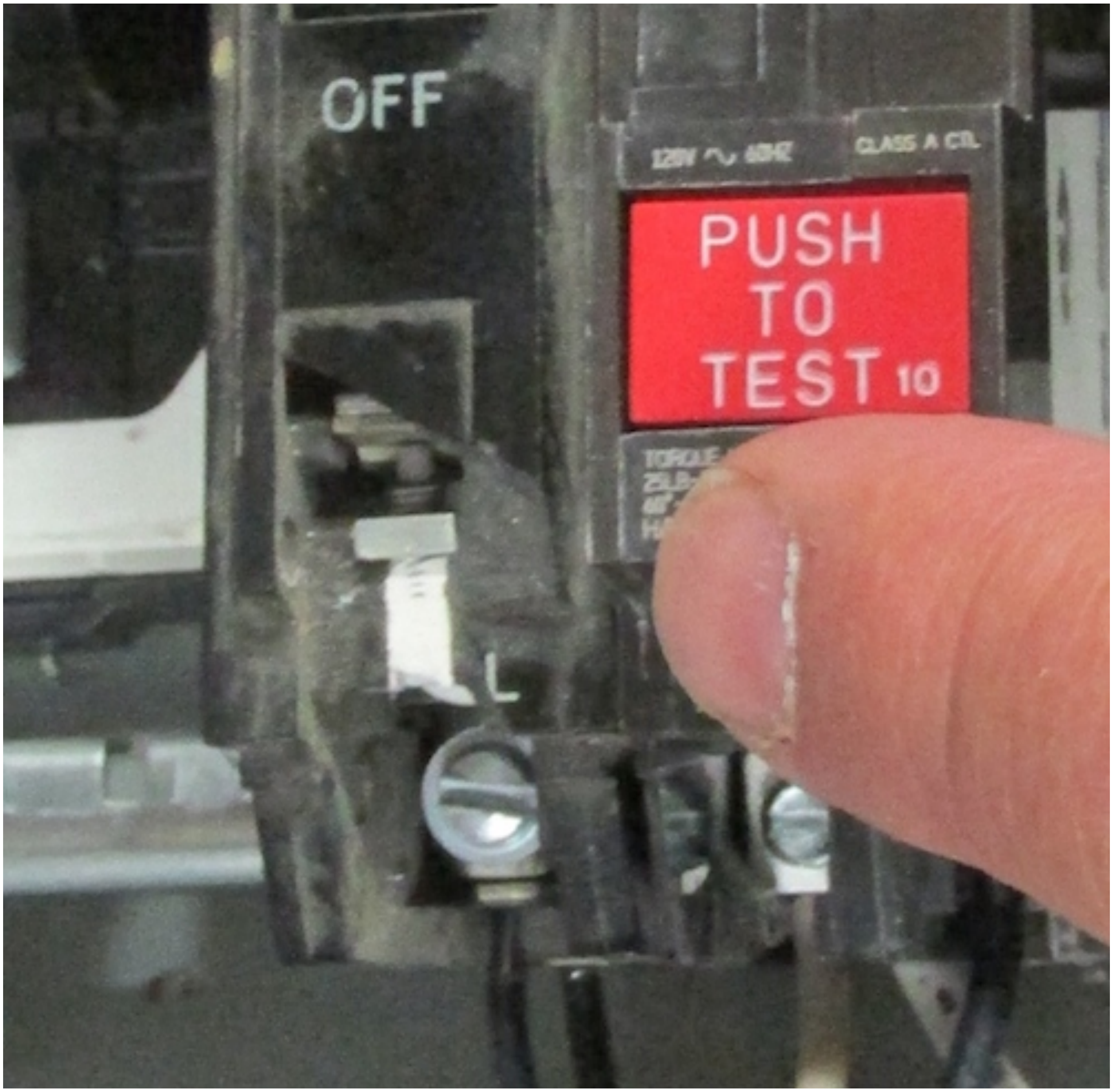
Modified or damaged bus. Often found when someone tries to install a breaker that doesn't belong in the panel.



Breakers not listed for the panel. Various brands of breakers.



Double lugged (tapped) breaker.



Damaged breaker.

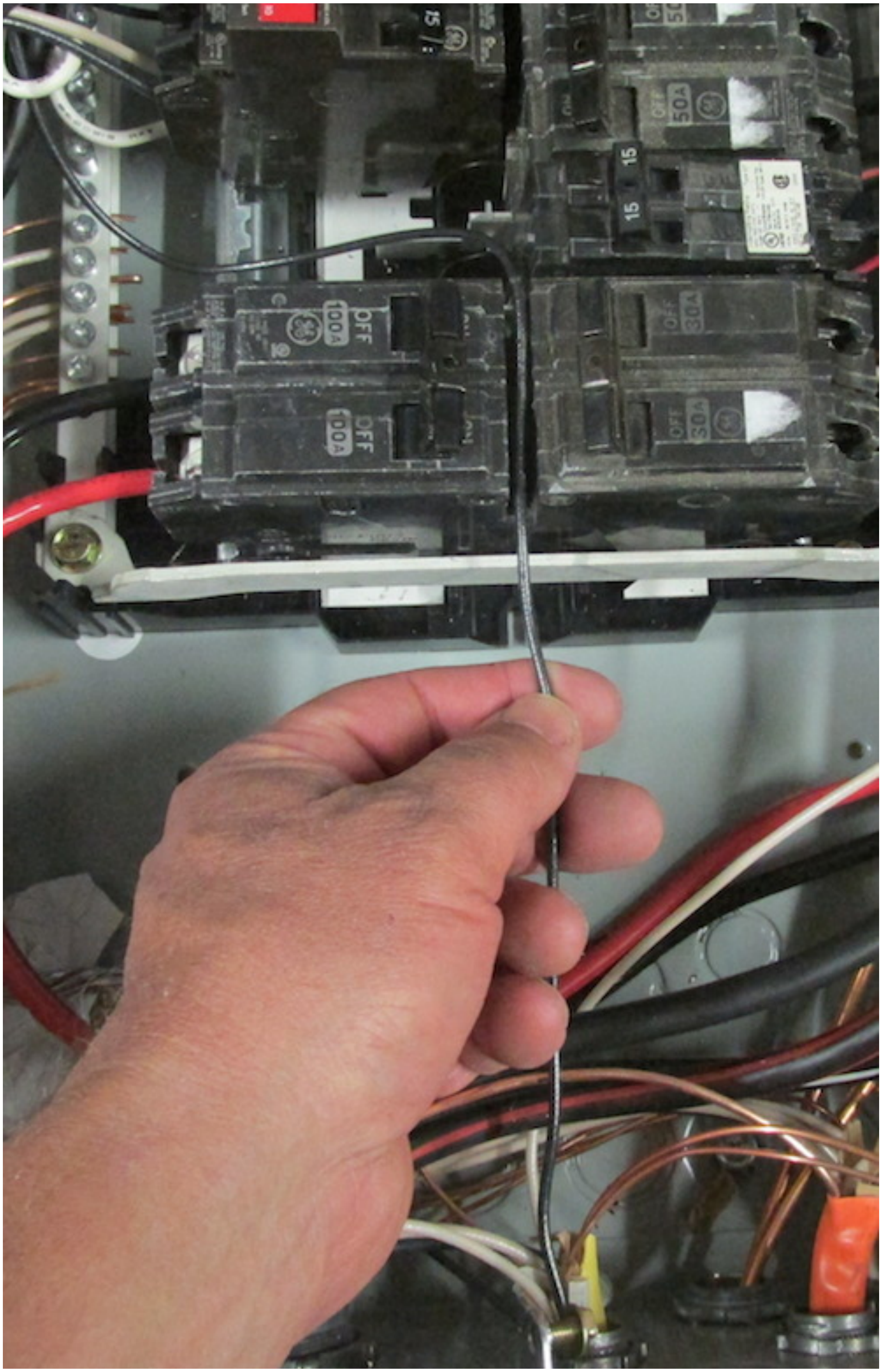

ON
20
OFF
PUSH
TO
TEST 10
5mA

Over-fused conductor. 20 amp breaker protecting 14 gauge conductor.

Neutral and ground bus bar not bonded to panel:

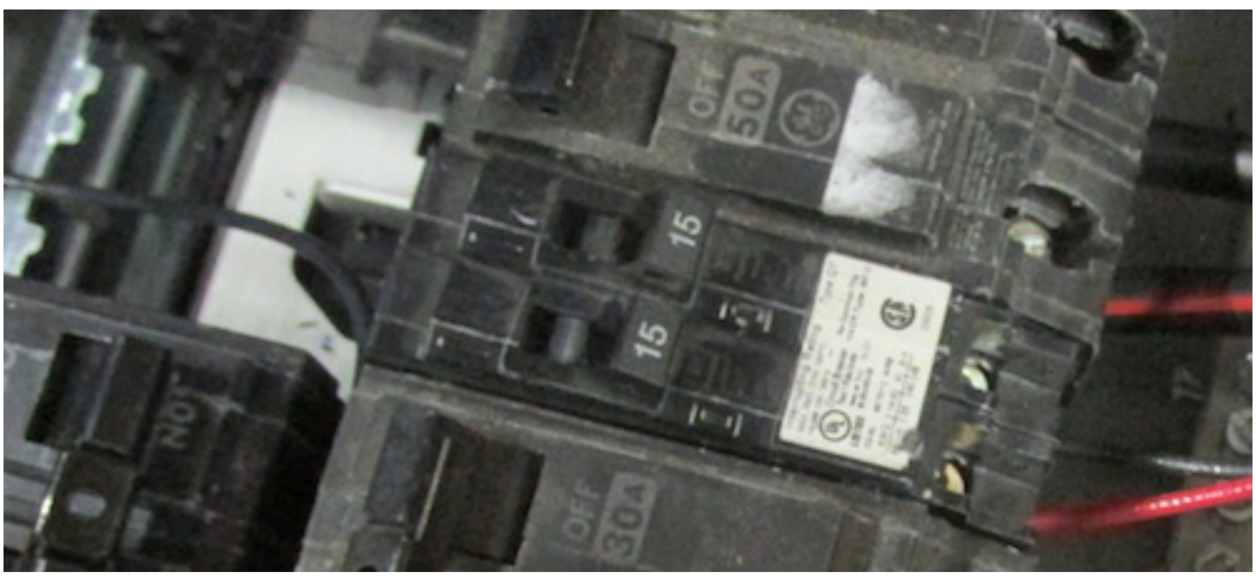
- No green screw
- No copper bond strap
- No #4 conductor bonded to panel

Debris in bottom of panel.



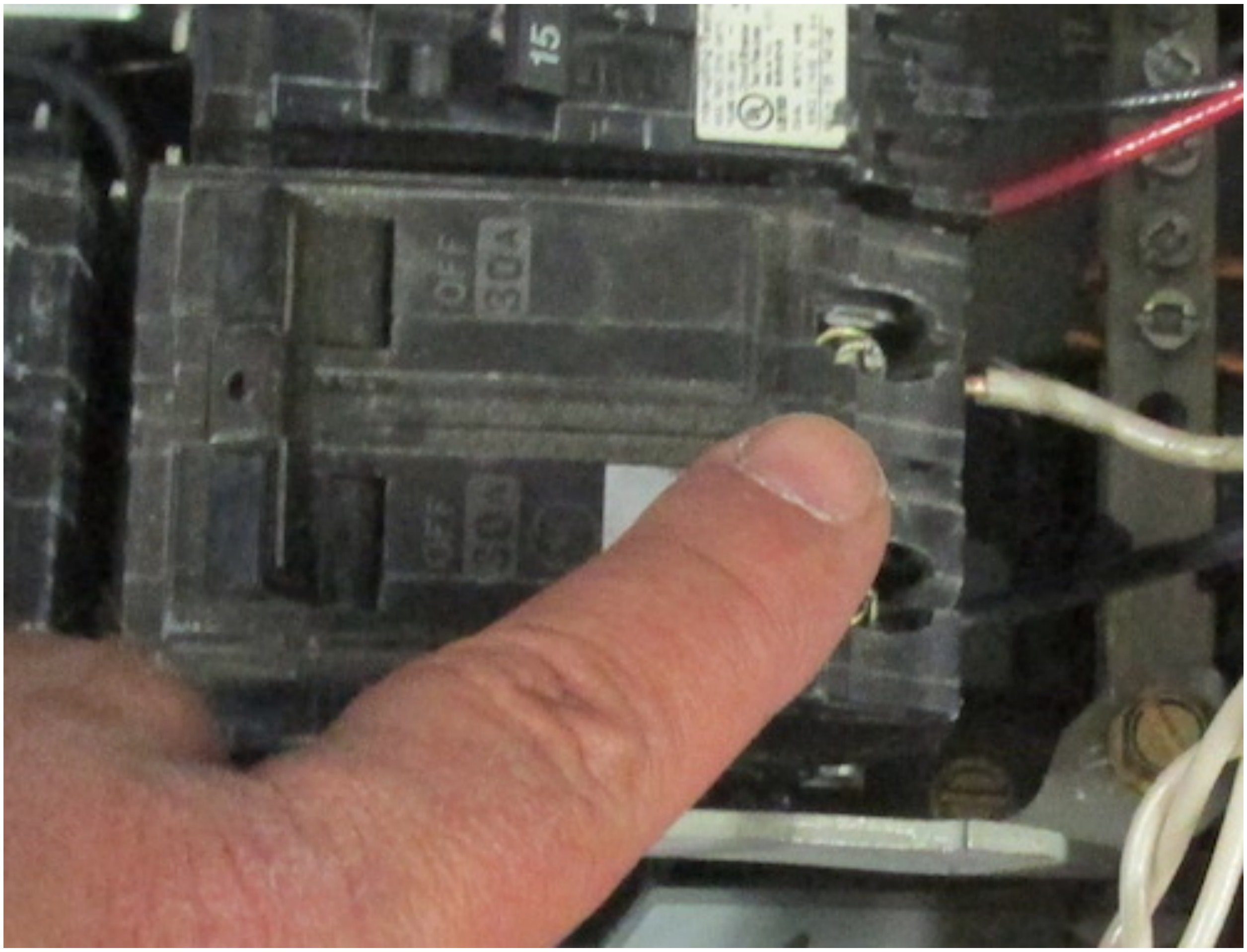
Conductor runs over energized bus.

Loose conductor at breaker.

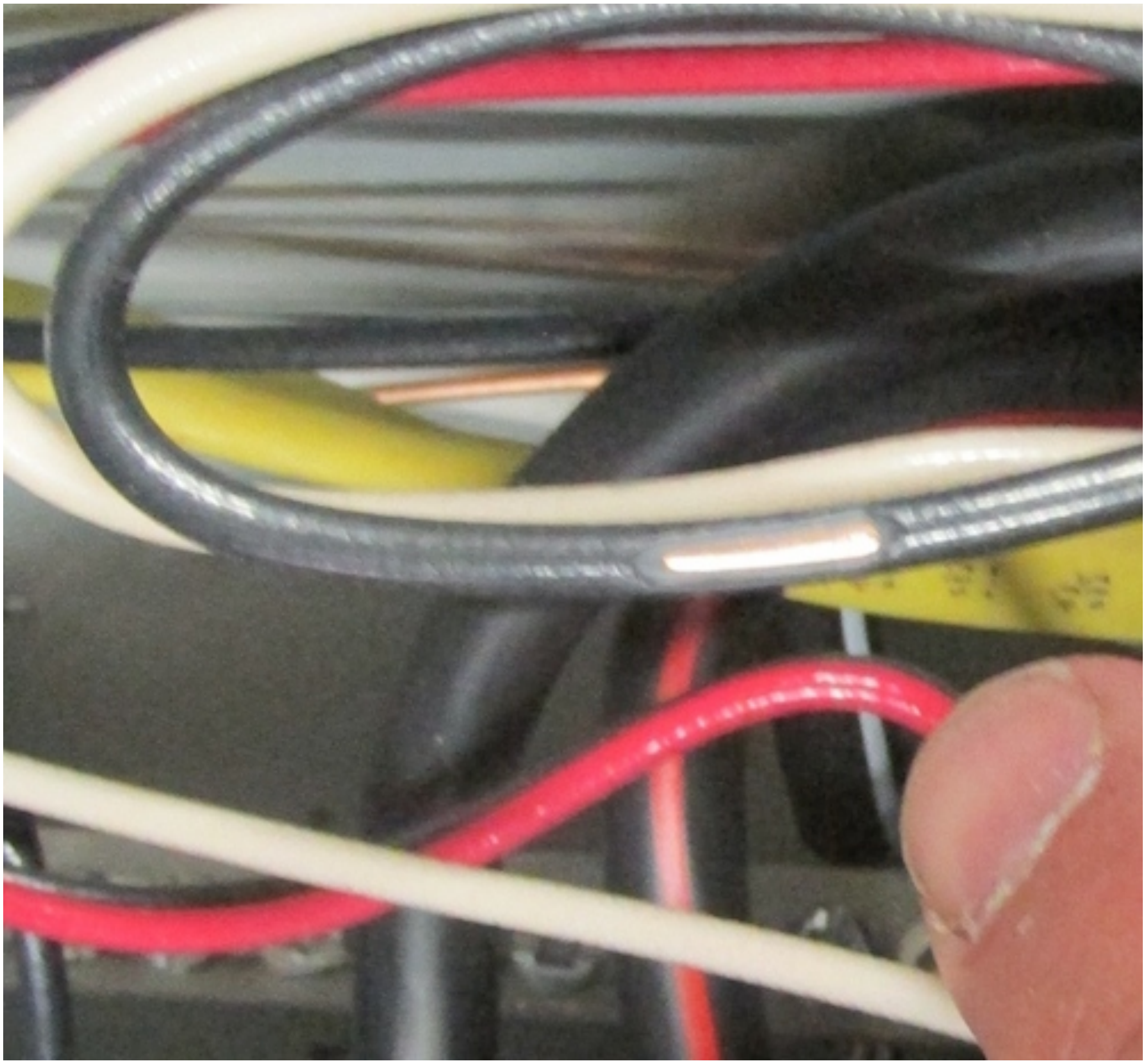


Multi-wire branch circuit issues:

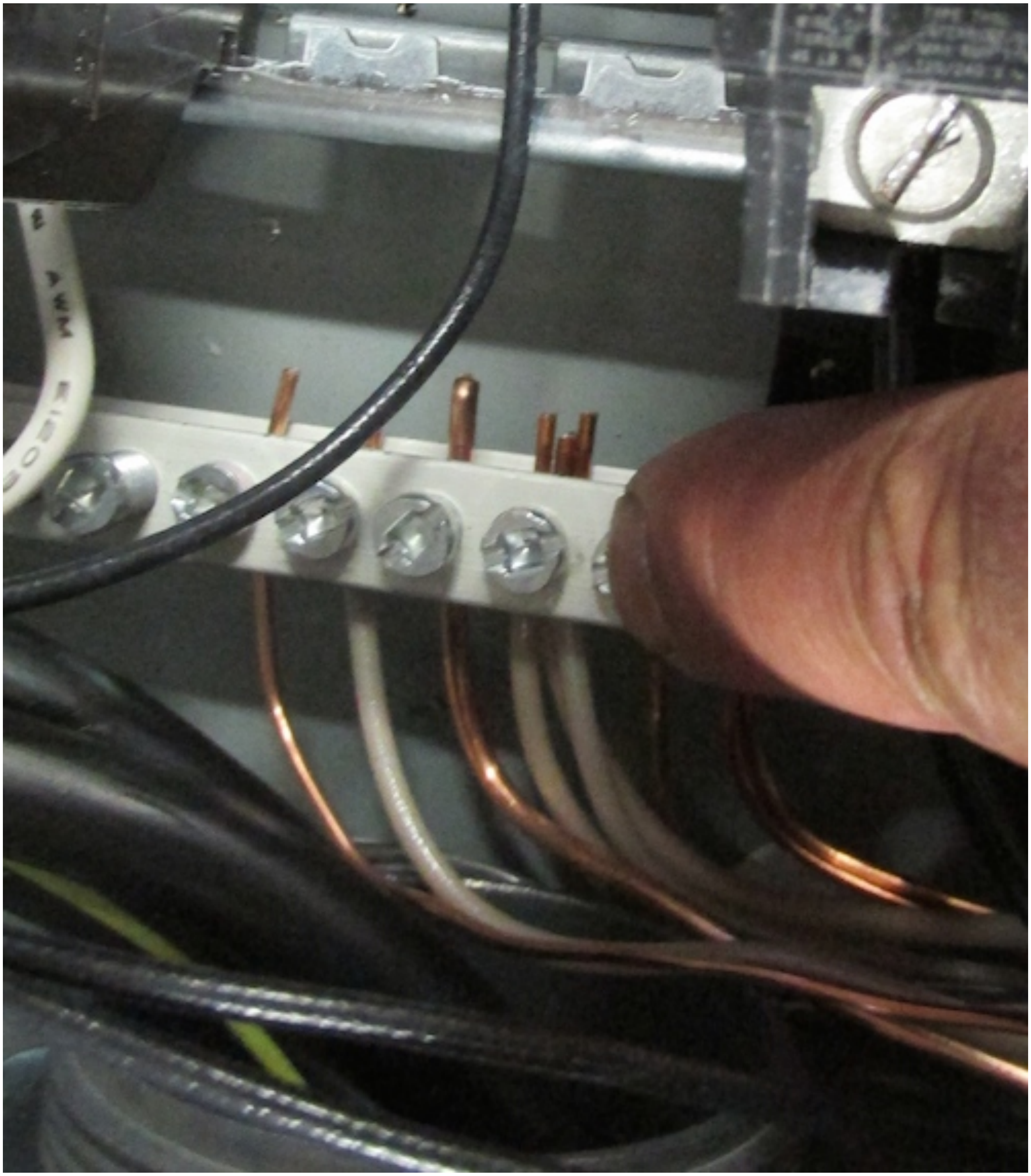
- Mismatched tandem breaker on single phase of bus
- Multi-wire branch circuit wires not grouped or zip tied



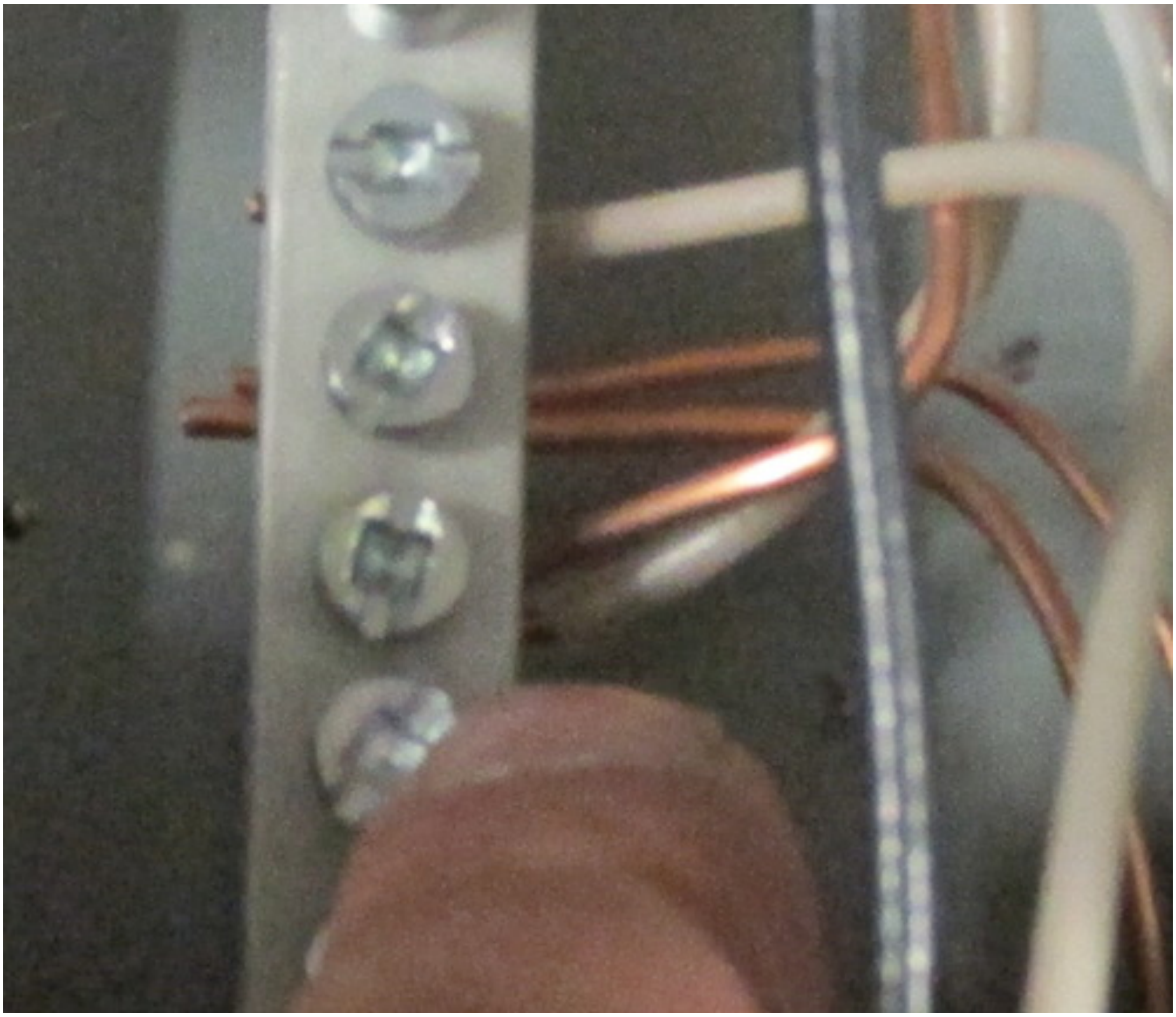
Phase conductor not identified. Should be taped, typically with red tape (anything but white or green).
10-2 (2 conductor) cable used for dryer circuit requiring 4 conductors.



Nicked (exposed) conductor.



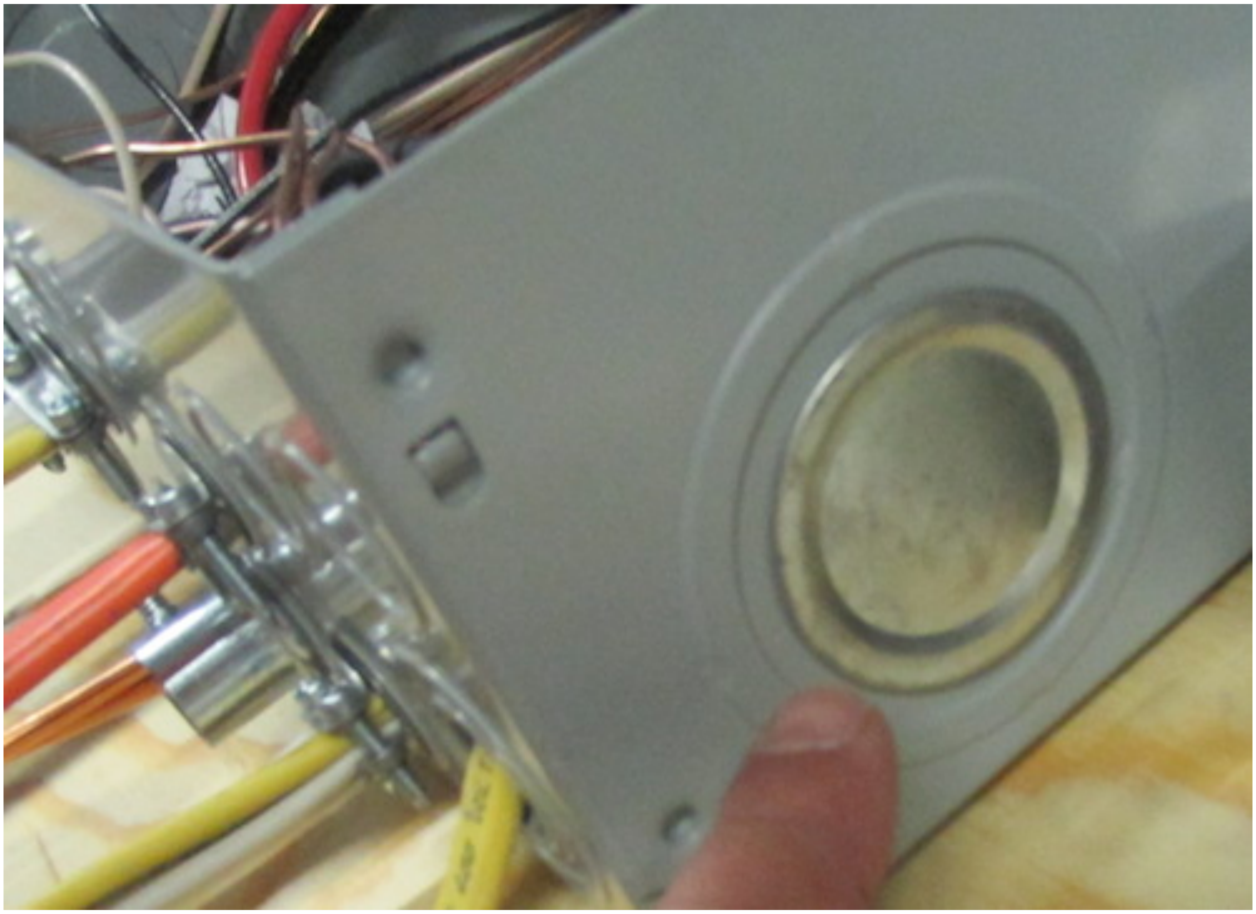
Three neutral conductors on one lug (only one allowed).


Ground and neutral conductor sharing same lug.

Yellow jacket not removed.

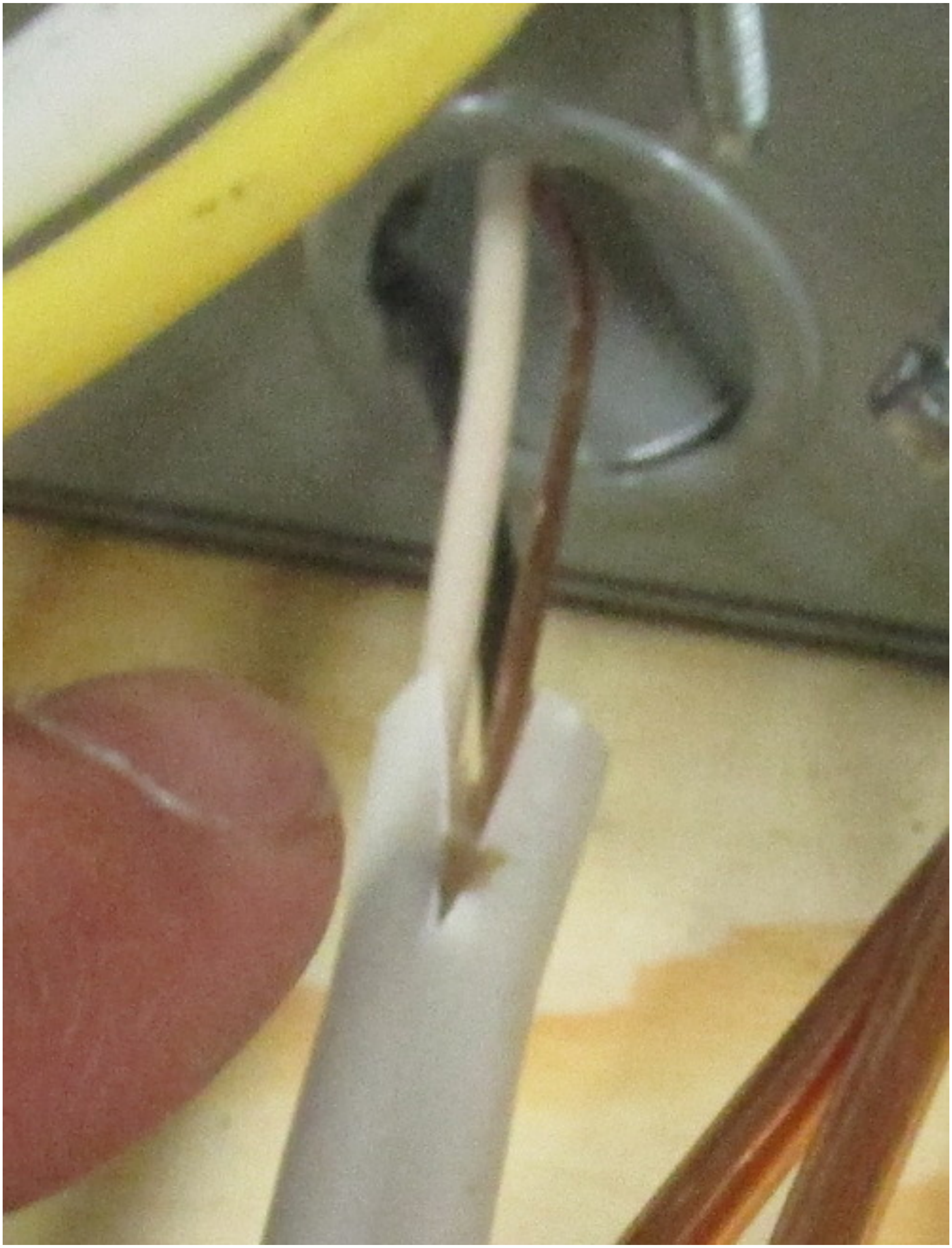
Cable entering panel without strain relief or bushing.

Three cables entering panel through one strain-relief fitting.

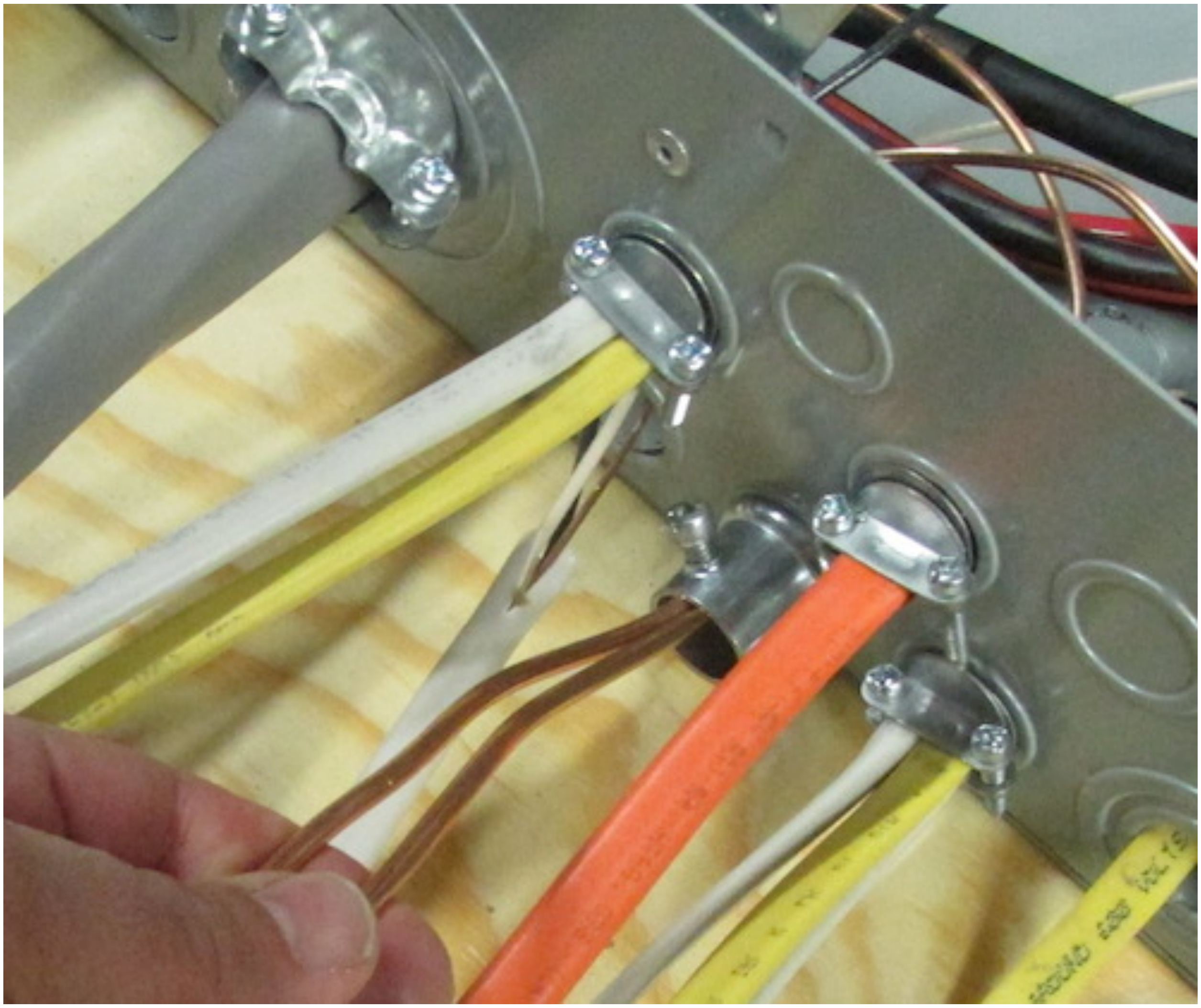


Non weather-tight twist-out (knockout) cover used on side of panel. Bottom of panel would have been O.K.

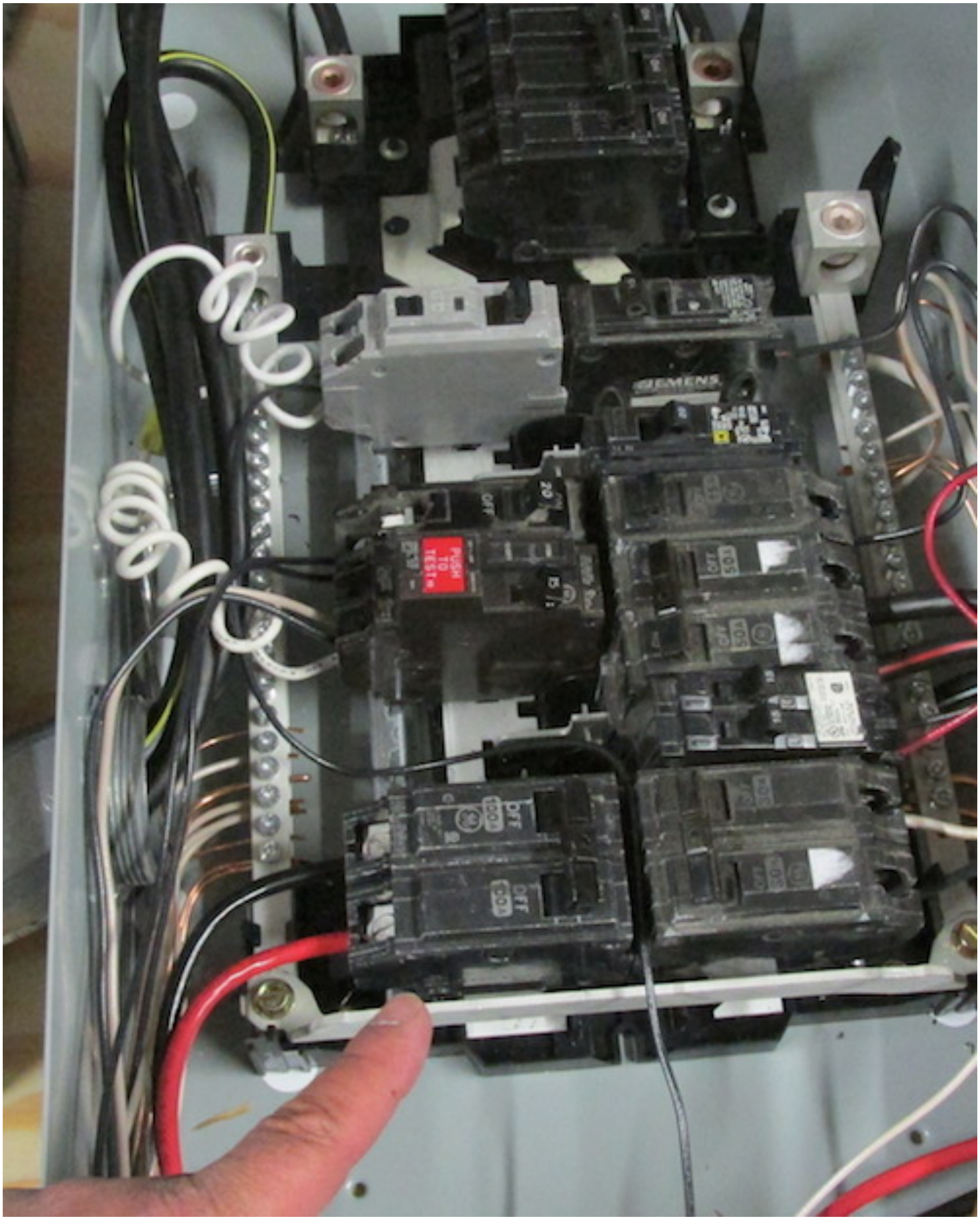

Open twist-out (knockout) in panel.



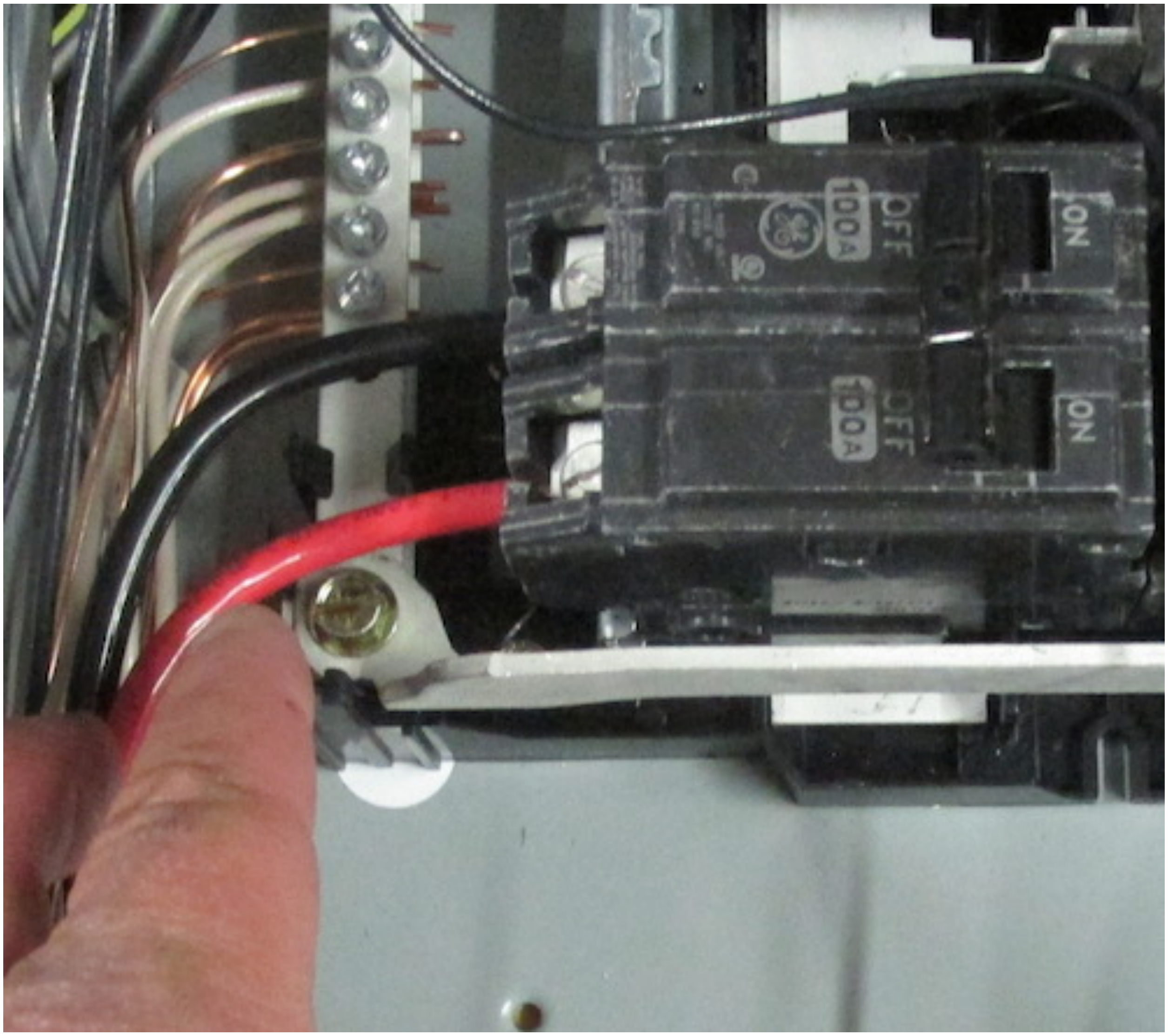
Cable entering panel without strain relief or jacket. Cable jacket is stripped beyond entry.



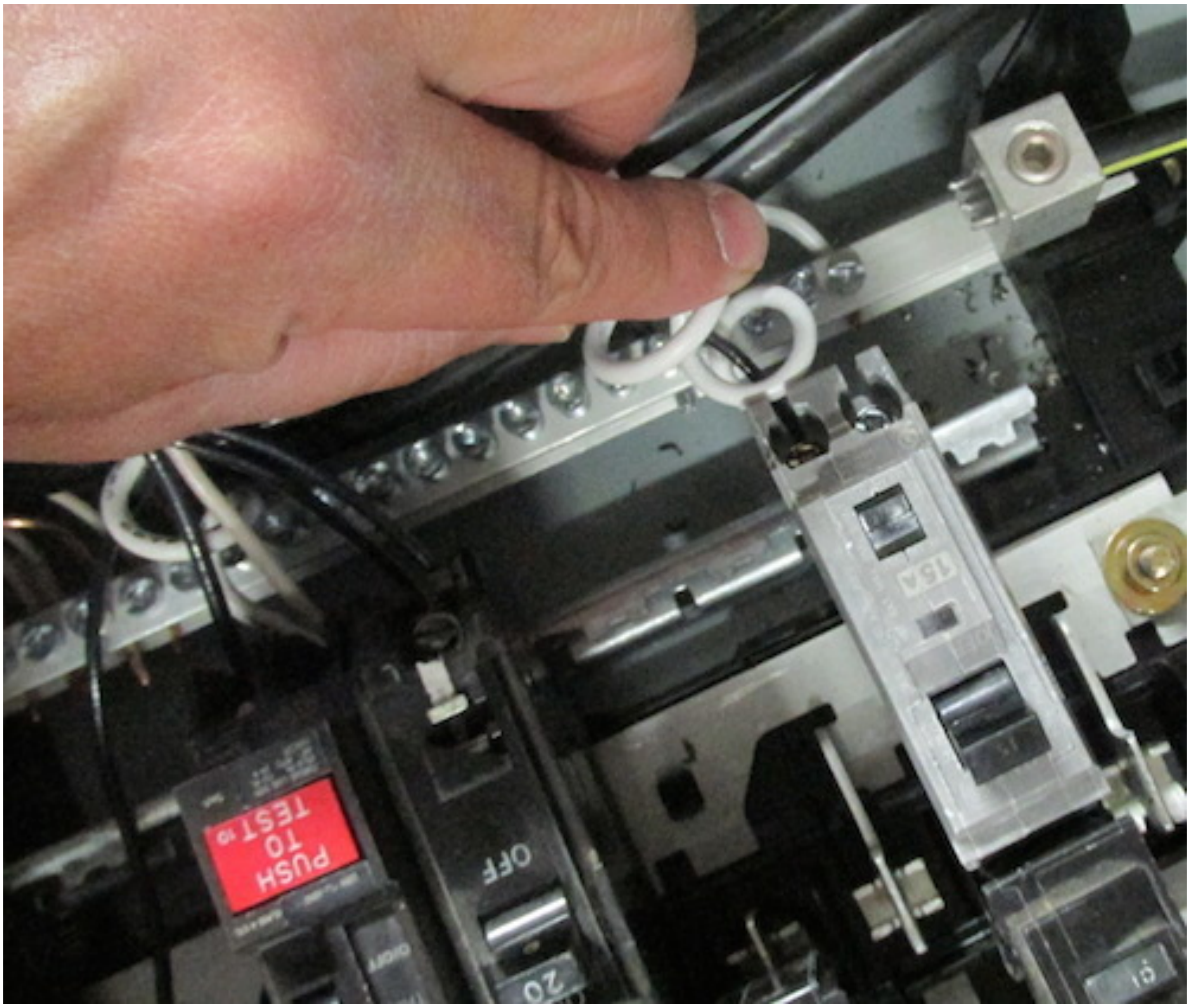
Both forms of grounding are undersized. Should be #4 instead of #6.



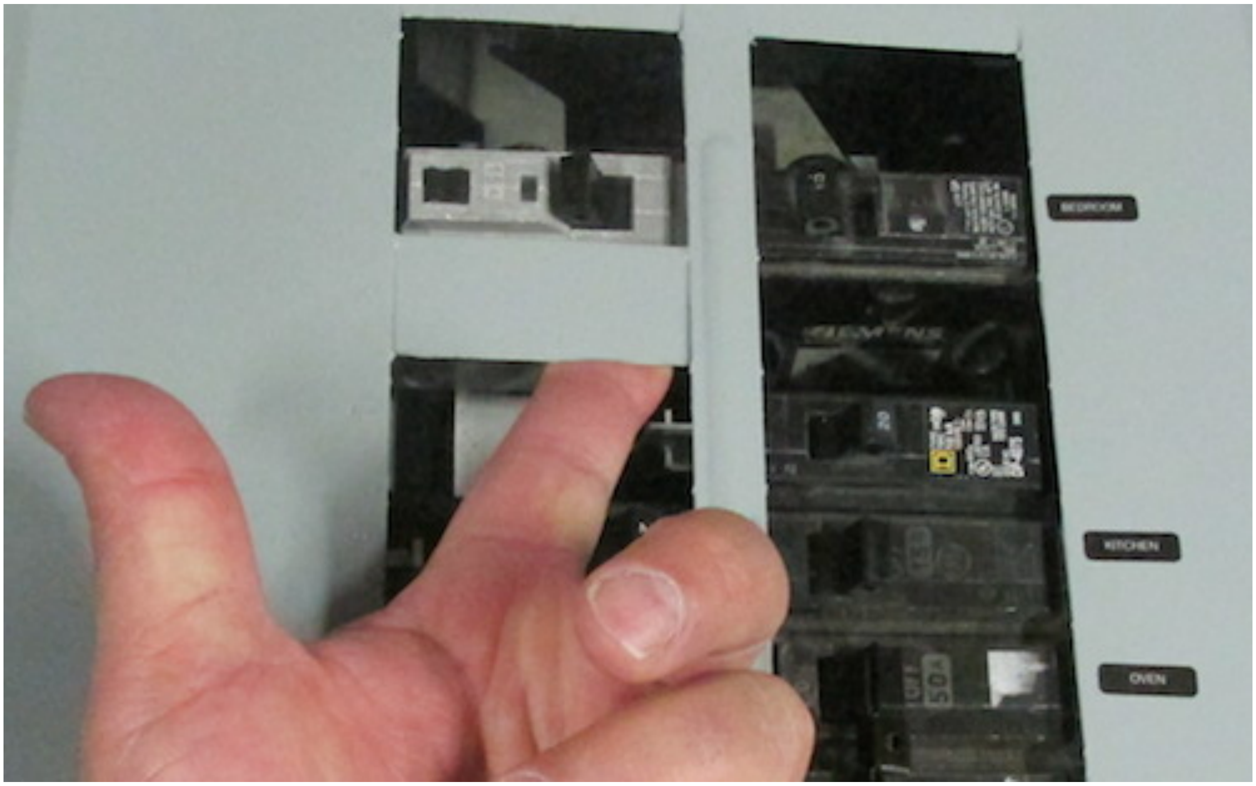
100 amp subpanel feed located at bottom of bus assembly. Best practice would be to locate near top of bus to dissipate heat on bus.



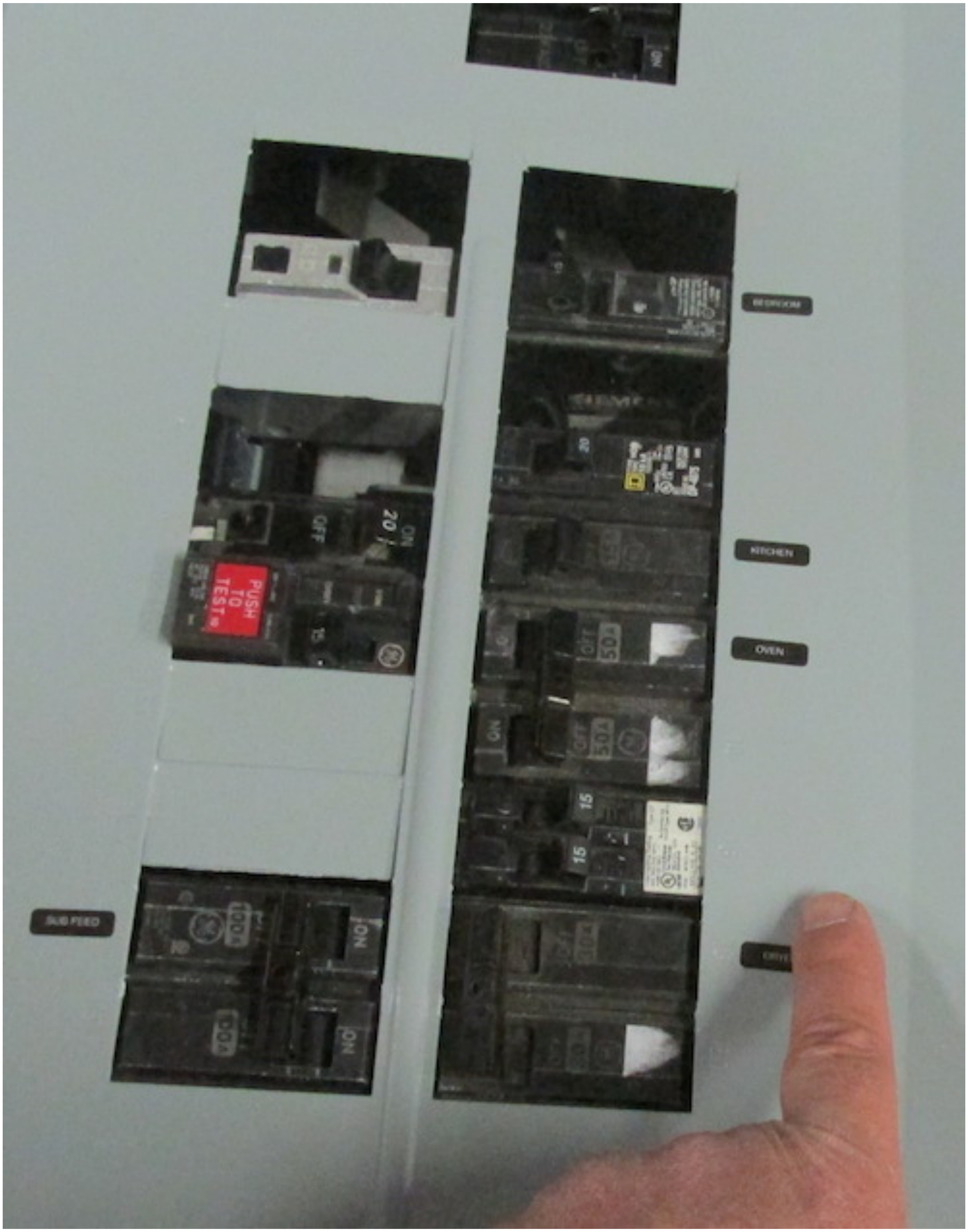
100 amp feeder breaker to subpanel protecting #6 conductor.



Branch circuit neutral conductor attached to neutral bus rather than AFCI neutral lug.



Breaker knockouts missing. Requires filler plates (blanks).



Improper labeling. Every breaker should be labeled.

Missing panel cover screw.

Missing utility tag. Removing is considered meter tampering.

PIC of the creating of the display of electrical components with defects.

If you need more pages, use these here: