



Consulting, Resource, Education, Training, and Support Services for Home Inspectors
"A candle loses no light when it lights another candle."

ASHI® Ohio Chapter

2012 SPRING CONFERENCE



Consulting, Resource, Education, Training, and Support Services for Home Inspectors
A candle loses no light when it lights another candle.

Electrical System Grounding and Bonding

It's Everyone's Fault

Presented by Kevin O'Hornett, ASHI® Retired

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REVIEW OF THE ASHI® STANDARDS

WHAT'S REQUIRED WHEN
CONDUCTING AN INSPECTION
OF AN ELECTRICAL SYSTEM IN
ACCORDANCE WITH THE ASHI®
STANDARDS?



ASHI® SoP requires inspectors to report systems and components which, in their professional judgment, are:

- not functioning properly
- significantly deficient
- unsafe
- near the end of their service lives



ASHI® SoP requires inspectors to report:

- reasoning or explanation as to the nature of the deficiencies reported in 2.2.C.1, that **are not self-evident**.

This means that an inspector must report the potential implications of adverse conditions if they are not obvious to a lay person.



A general implications statement which is simple and easy for customers to understand:

Failure to address ADVERSE CONDITIONS for which IMMEDIATE ACTION is recommended increases the potential for damage, accelerated deterioration, catastrophic failure, and/or personal injury.

If specific implications statements are used, it's suggested that they pertain to systems rather than individual components.

Failure to address electrical SYSTEM ADVERSE CONDITIONS for which IMMEDIATE ATTENTION is recommended increases the potential for overheating, fire, shock, and/or electrocution.

ASHI® SoP requires inspection of the following electrical system components:

1. service drop
2. service entrance conductors, cables, and raceways.
3. service equipment and main disconnects
4. service grounding
5. interior *components* of service panels and sub panels
6. conductors
7. overcurrent protection devices
8. *a representative number of installed* lighting fixtures, switches, and receptacles
9. ground fault circuit interrupters



ASHI® SoP requires documentation of the following :

1. amperage and voltage rating of the service
2. the location of main disconnect(s) and sub panels
3. presence of solid conductor aluminum branch circuit wiring
4. presence or absence of smoke detectors.
5. wiring methods



Important Terms

- GROUNDING
- BONDING
- GROUNDED/NEUTRAL CONDUCTOR
- EQUIPMENT GROUNDING CONDUCTOR
- UNGROUNDED CONDUCTOR
- GROUNDING ELECTRODE
- GROUNDING ELECTRODE CONDUCTOR
- FEEDER(S)
- MAIN BONDING JUMPER
- BONDING JUMPER - BONDING CONDUCTOR



**BOTH GROUNDING AND BONDING
ARE FUNDAMENTALLY NECESSARY
FOR ELECTRICAL SAFETY.**

**PROPER BONDING AND GROUNDING
REDUCE THE POTENTIAL FOR
ELECTROCUTION AND FIRE.**



Grounding

- The process of joining all non-current carrying conductors in the electrical system and making a low-resistance connection between them and the earth (a reservoir of charge) or some conducting body that serves in place of the earth.
- For practical electrical circuits, the earth or ground potential (voltage) is usually taken to be zero and everything is referenced to the earth.



The purpose of grounding is:

- To stabilize voltage in relation to the earth or to another body that serves in place of the earth.
- To assure that the voltage measured between an **ungrounded conductor** (also referred to as the **hot, live, or phase conductor**) and a grounded object is always at the same potential.
- **That potential is zero.**



The conductivity of the grounding electrode/grounding electrode system

- It is relatively low.
- Its resistance is relatively high, as much as 25 ohms, (that translates as 5 amperes at 120 volts), it is not enough to trip a 15 amp breaker.
- Therefore, it is not intended to be involved in causing a breaker to trip and clear a fault when a hot to-ground, hot-to-hot, or hot-to-neutral short circuit occurs on individual circuit wiring.

So, what is involved?



System Grounding and Bonding

- Fault current flows through the equipment grounding conductor to the service panel
- Where it joins the neutral path through the main neutral back to the center-tap of the service transformer
- There it becomes part of the overall current flow driven by the service transformer
- This produces a high enough fault current to trip the breaker

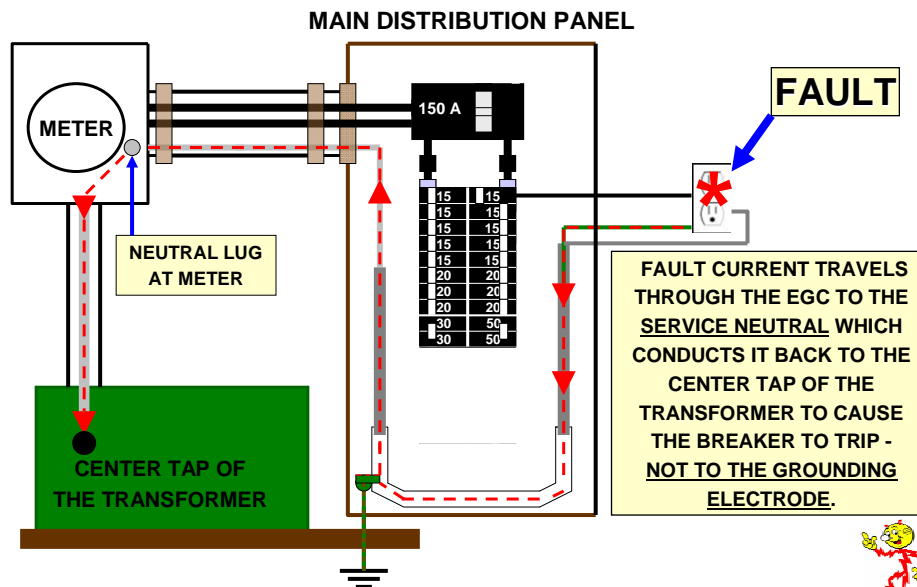


System Grounding and Bonding

- Tying the ground wire back to the neutral of the transformer is called *bonding*.
- Both grounding and bonding are necessary for electrical safety.



The path of fault current



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System Grounding:

- Allows detection of current from an unwanted, unintended, or accidental connection between system conductors and ground.
- Is intended to cause the operation of automatic devices such as fuses or circuit breakers to remove the source of voltage.
- Reduces the potential of shock or electrocution to a person who might come in contact with live conductors.



Electrically Grounded

- Refers to an accidental or intentional connection between electrical equipment or an electrical circuit and the earth.

Effectively Grounded

- Refers to an electrical system that is intentionally connected to the earth.



Grounding

- Provides an intentional permanent low impedance path to carry fault current
- Provides the capacity to carry ground fault current
- Returns fault current to its source – not the earth
- Is connected to earth for system reference
- Is used to allow operation of over-current protection devices



Bonding

(also referred to as *equipotential bonding*)

- The permanent joining of metallic parts to form an electrically conductive path that ensures both electrical continuity and the capacity to safely conduct any current likely to be imposed on such metallic parts.



- Properly bonded systems are at the same electrical potential as the grounding portion of the electrical system - ZERO
- That's why it's referred to as "equipotential" bonding.
- Bonded systems are neither designed nor intended to carry current as part of the electrical system.
- However, they must be able to safely carry current and conduct it to ground in the event that current is imposed on them.



Electrical potential

- It's the difference in electrical charge (+ or -) between two points in a circuit.
- Electrical potential is expressed in volts.
- Keeping the electrical potential (voltage) at zero on the components of conductive systems such as water piping and fuel gas piping reduces the potential for shock or electrocution for anyone who comes into contact with such components.



Amperage chart

- A 2½ watt light bulb in a 120 v circuit draws 0.2083 amps.
- It only takes 65mA to cause heart fibrillation.
- A GFCI trips at 3 to 5 mA.

CURRENT (milliamperes)	HUMAN REACTION (at 60 Hertz)
1.1	PERCEPTION: A slight tingling sensation.
10.0	CAN'T LET GO: Arm and hand muscles close involuntarily: A 120-pound person.
16.0	A 175-pound person.
18.0	CAN'T BREATHE: PARALYSIS OF THE CHEST MUSCLES.
65.0	HEART FIBRILLATION: Rapid, irregular contractions of the heart muscles. Could be fatal.

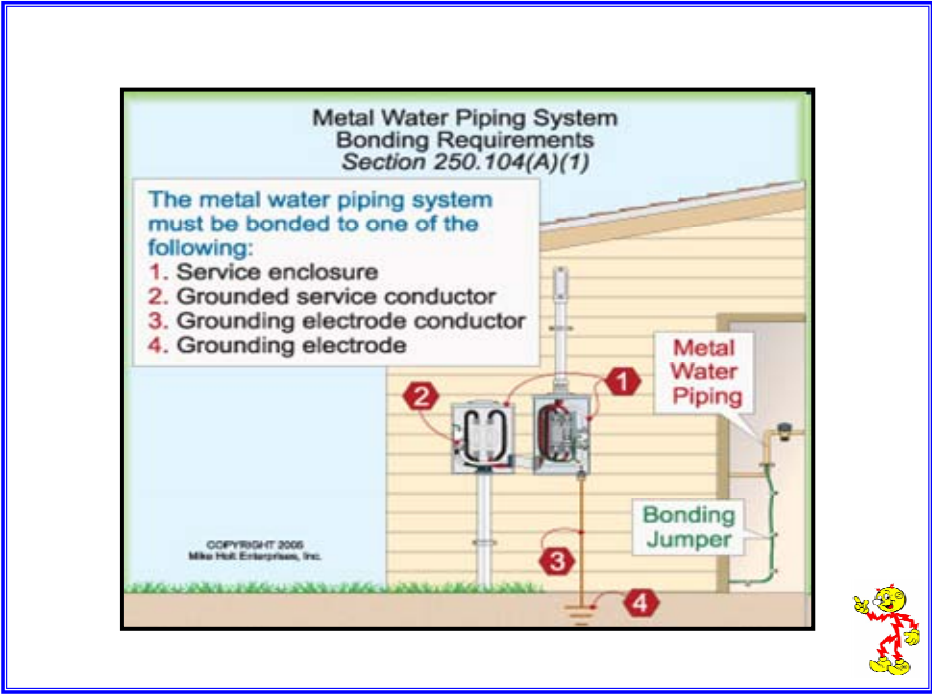


- **Think of bonding as physically attaching the parts of a non-current carrying metallic system both to each other and to the electrical grounding system.**
- **Bonding conductive systems minimizes the voltage differential between the different components in the bonded system under both normal and atypical operating conditions.**



- **All metallic piping and ducting systems which are likely to become energized must be bonded to an effective ground-fault current path.**
- **The equipment grounding conductor for any circuit which may energize ducting systems and gas piping systems can be used to bond such systems to the electrical grounding system.**
- **However, the bonding conductor for interior water piping must be properly sized (equal to the largest ungrounded service conductor).**





Common systems and components to be bonded



- **Metallic hot and cold piping on water heaters where the rest of the potable water distribution piping is metallic. The bonding jumper must be attached upstream of any flexible metallic pipe connectors.**
- **Fuel gas and fuel oil piping including CSST**
- **Metallic chimney liners metallic appliance vents**
- **Metallic pneumatic piping**
- **Metallic landscape irrigation system piping**



- **Metallic fire suppression sprinkler system piping**
- **Metallic water softener piping (bonding jumper)**
- **Swimming pool pump motors and some hydromassage tub pump motors**
- **Metallic components such as diving boards, ladders, fences, exposed metal structural framing, and patio roof support columns within five (5) feet of the edge of a pool.**
- **Metallic ducting**



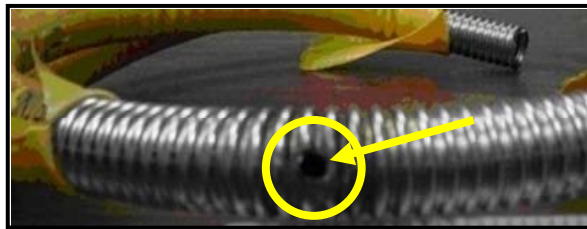
Gas Pipe Bonding

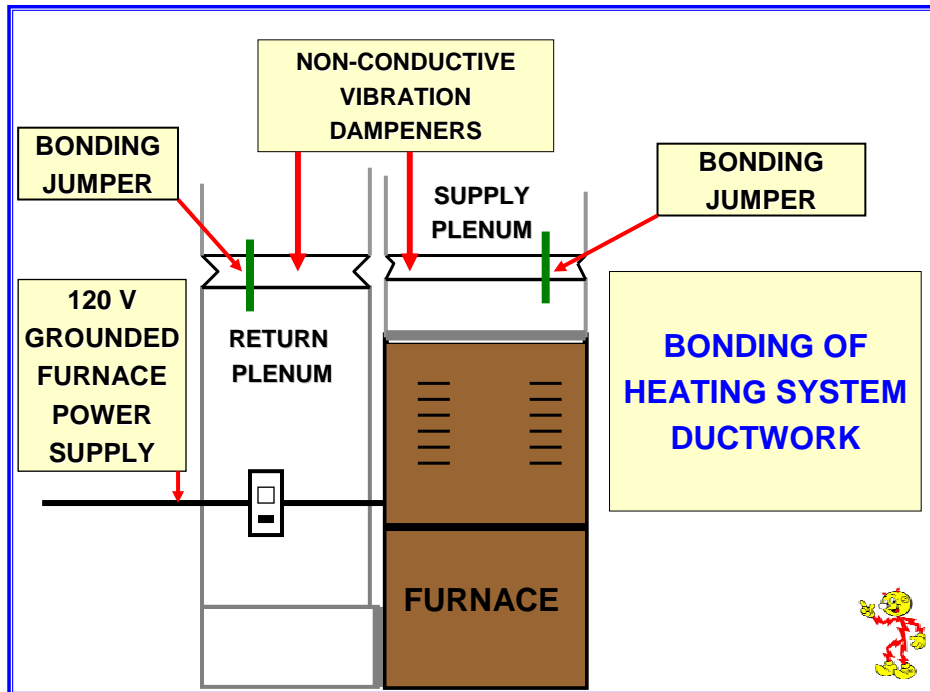


Photograph© Courtesy of the International Association of Electrical Inspectors
www.iaei.org



CSST and Lightning





A non-conductive, non-metallic piping system in which a short piece of metal pipe or other conductive material is installed is still considered a non-conductive system and the short piece of metal pipe does not have to be bonded.





The two handles are not electrically continuous because the fiberglass rungs are not conductive. If one ladder socket is bonded but the other is not, the possibility exists for creating a non-equipotential condition between the two ladder handles.

If current were imposed on the non-bonded handle, a person grabbing both handles would act as a path to ground for the current.

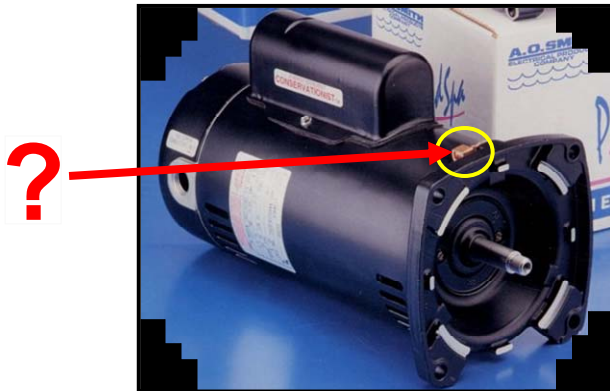
Fiberglass (non-conductive) ladder rungs

Ladder sockets

Photo© courtesy www.ozpools.com.au



Hydromassage tub or spa motor

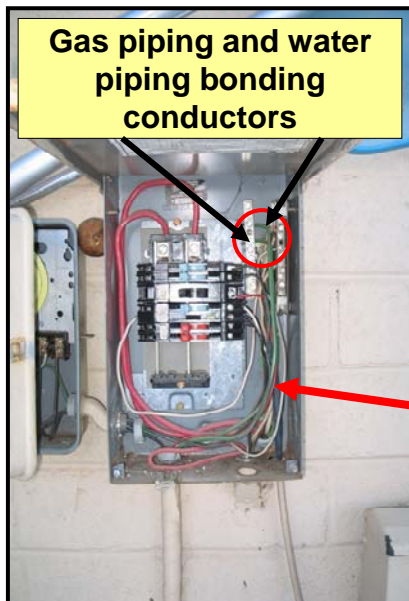


Bonding is required only if the motor is attached to metal/conductive piping for the tub.



BONDING CONDUCTOR

- Connects a bonded system to the grounded part of the electrical system.
- Typically large gauge solid conductor or large multi-strand conductor
- Often found connected to the cold water pipe at a water heater or a pipe at a hose bib when bonding the potable water piping system or connected to metal gas pipe near the gas meter or near a gas fired appliance when bonding the fuel gas piping system.
- Like all electrical connections, bonding conductor and bonding jumper connections can't be concealed behind components or materials of construction and must be readily accessible.



Gas piping and water piping bonding conductors

Bonding Conductors

Grounding electrode conductor

Photo© courtesy of ProSpex – www.prospex.us



GROUNDING/NEUTRAL CONDUCTOR

- Has become accepted as interchangeable with the term **grounded conductor**.
- Defined in the *NEC* as a wire *intended to carry current under normal operation*.
- Therefore, in this presentation, the term **neutral** appears after the term **grounded** in the term **grounded/neutral conductor**.



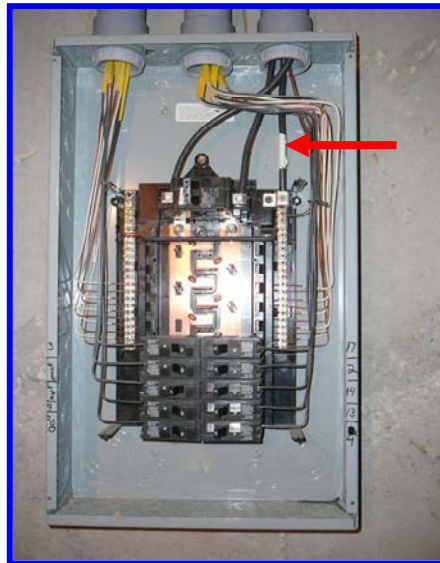
- A grounded/neutral conductor is a **system** wire or circuit wire that is **intentionally grounded**.
- Equipment grounding conductors and bonding conductors **ARE NOT system conductors** because they **DO NOT** have to be present for the electrical system to function or operate.
- They only need to be present to make the system operate more safely.



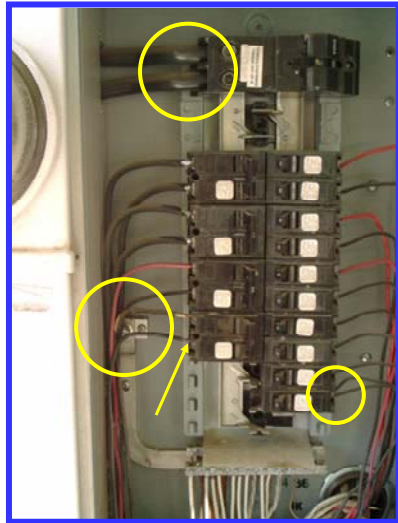
- **ONLY** a grounded/neutral service conductor and an ungrounded (hot) service conductor are required in order to have an operational system.
- Since the grounded/neutral service conductor serves as the effective path for ground-fault current, it has to be sized large enough to safely carry the maximum fault current that is likely to be imposed on it.



Grounded/neutral service conductor



Grounded/neutral service conductor



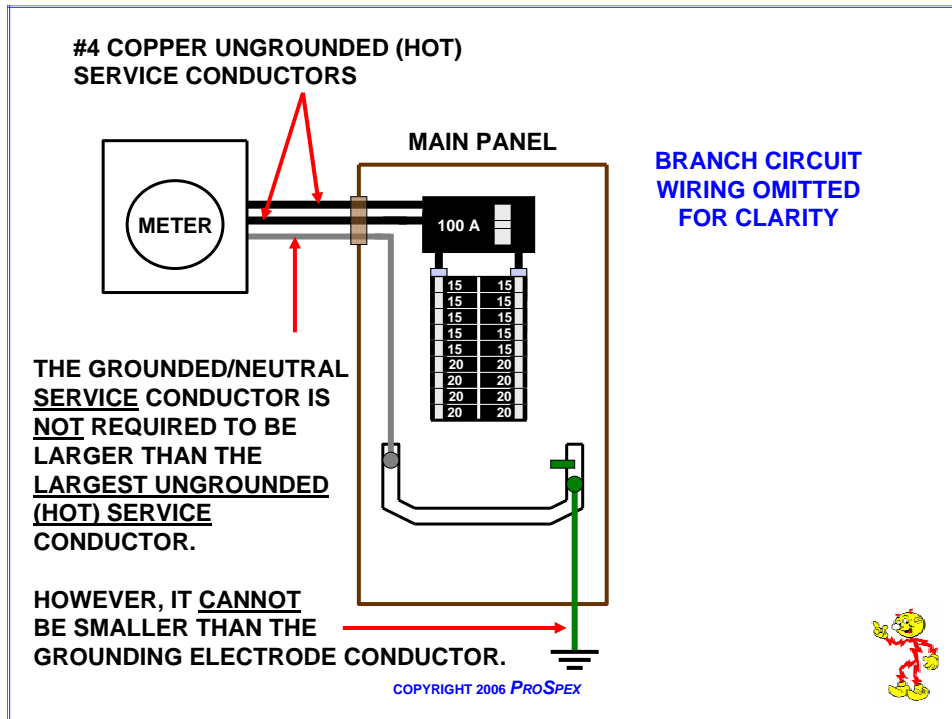
Where is the grounded/
neutral service conductor
from the meter to the
main panel?



The grounded/neutral service conductor:

- **CANNOT** be sized smaller than the required grounding electrode conductor.
- Is not required to be larger than the largest ungrounded (hot) service-entrance conductor.
- Individual branch circuit grounded/neutral conductors carry the unbalanced neutral current in a 240 volt circuit. Therefore, they have to be sized large enough to handle the maximum unbalanced neutral current that they may be required to carry.
- Insulation on grounded/neutral conductors is to be white or gray.





- NOTE -

- Neutral conductors are typically the grounded conductors, but not all grounded conductors are neutral conductors.
- In a typical single-phase, 120v/240v (nominal) residential system with both 120v and 240v circuits, only the white or gray insulated conductor in a 240v circuit (such as the circuit for an electric clothes dryer, electric water heater, or electric range) will function as a true neutral conductor.
- It will carry the difference in current between the two 120v ungrounded (hot) conductors.
- If one 120v ungrounded (hot) conductor is carrying 25 amps and the other is carrying 21 amps, the 4 amp difference will run on the neutral conductor.

EQUIPMENT GROUNDING CONDUCTOR

- A wire which connects non-current-carrying metal parts such as raceways, enclosures, and the metal frames of equipment, appliances, motors, etc. back to the [main bonding jumper](#).

MAIN BONDING JUMPER

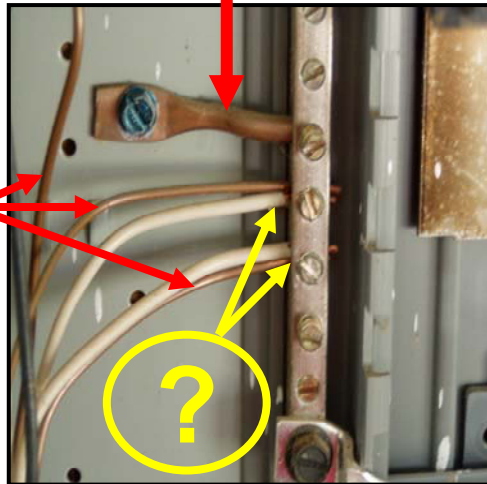
Connects the grounded/neutral conductor to the:

- Distribution panel enclosure
- Equipment grounding conductors
- Grounded/neutral conductor coming from the incoming service provider's wiring



MAIN BONDING JUMPER

EQUIPMENT
GROUNDING
CONDUCTORS

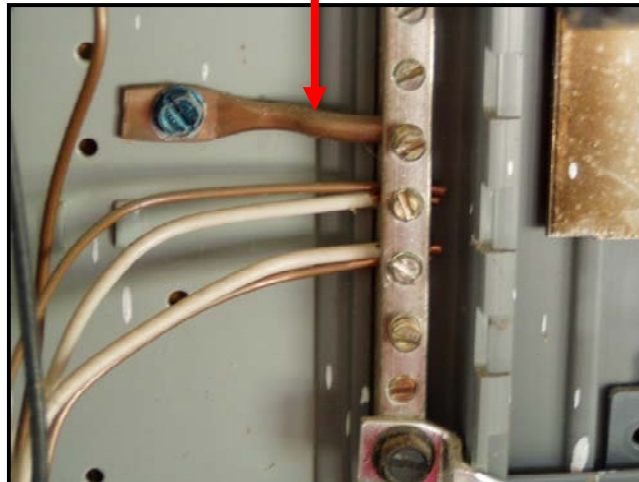


THE MAIN BONDING JUMPER:

- Is located at the electrical service.
- Is the connection between the grounded/neutral circuit conductor and the equipment grounding conductor at the service.
- Connects equipment grounding conductor(s) and the enclosure in which the service disconnect device is located to the grounded/neutral conductor within the service disconnect enclosure for each disconnect.



MAIN BONDING JUMPER



The main bonding jumper:

- Is a critical path for ground-fault current.
- Must be copper or other corrosion-resistant material.
- Is not allowed to be spliced.

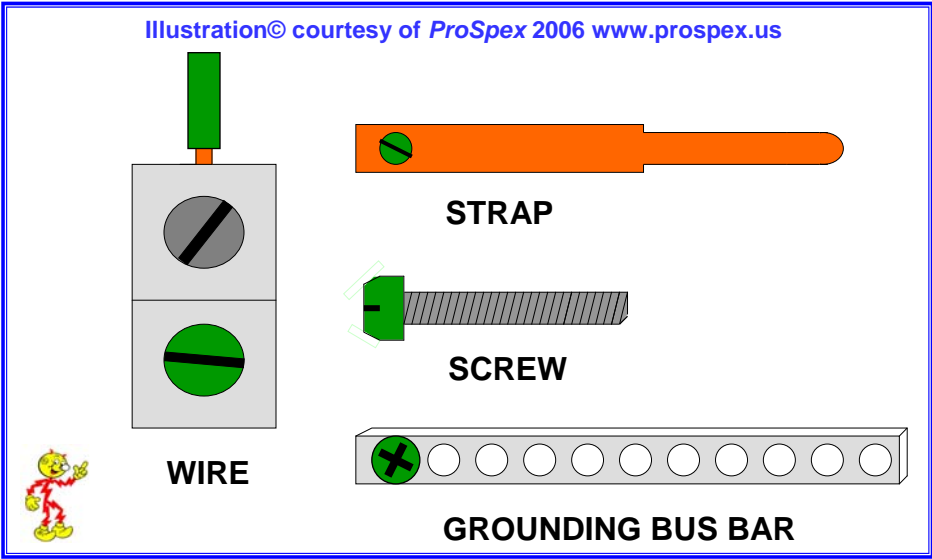


The purpose of the main bonding jumper is:

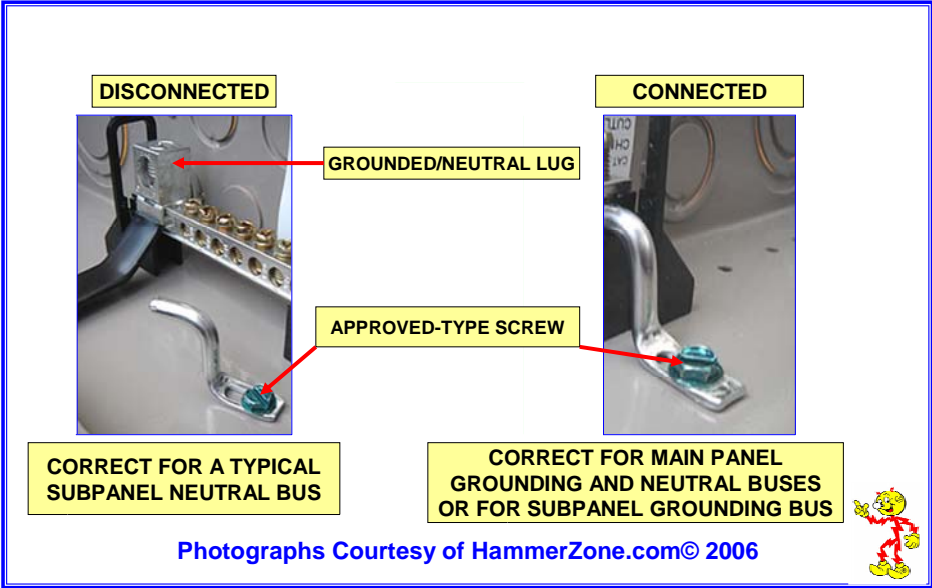
- To provide a path for a ground-fault back to the source of supply to the service.
- The grounded/neutral conductor of the system may also serve as the neutral for some applications and may carry neutral currents as well as transmit any fault current back to the utility company transformer or other source of power.



The main bonding jumper can be a wire, screw, terminal bus, or other suitable conductor.



Main Bonding Jumper



- Depending on the impedance of the system, fault current levels can often be hundreds of thousands of amps as compared to the much lower normal current in the circuit.
- Therefore, both the main bonding jumper on the supply (line) side of any overcurrent protection device and the grounded/neutral service conductor (from the electrical service provider) must be large enough to conduct this potentially high fault current.
- Since the main bonding jumper is connected in series with the grounded/neutral service conductor and is subject to the same amount of fault current, it must be similarly sized to the grounded/neutral service conductor.



An equipment grounding conductor:

- Doesn't normally carry current when the electrical system is functioning properly.
- Is designed and intended to provide an effective, low impedance ground-fault current path from the point of a ground-fault on the wiring system to the electrical supply source in order to cause the overcurrent protection device to open the circuit and to clear the fault.
- May be uninsulated or, if it's insulated, the insulation is to be green or green with yellow stripes.

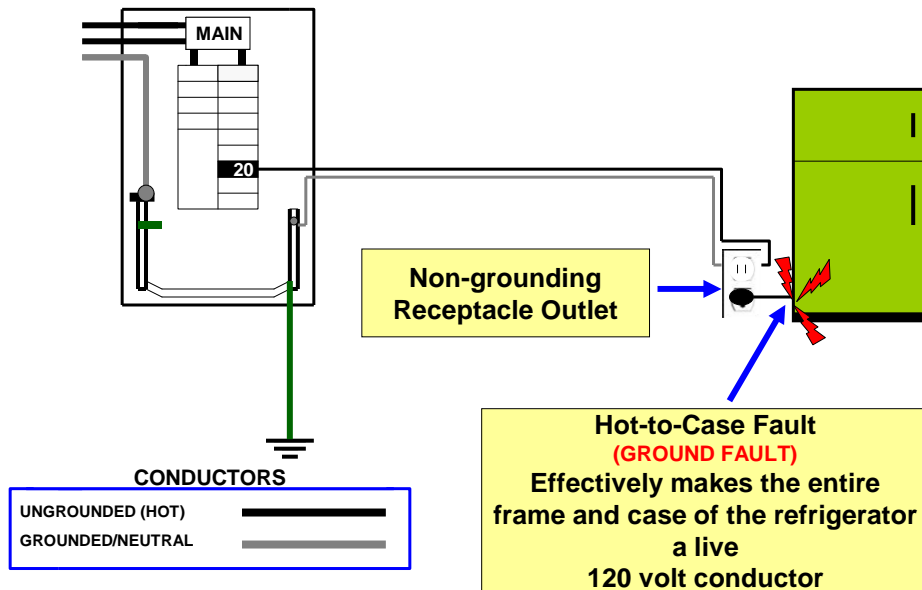


In older electrical system circuits without equipment grounding conductors:

- Hot-to-case fault current (such as that imposed when the hot conductor comes into contact with the chassis of a refrigerator) has no path to ground through the grounded/neutral service conductor to the center tap (ground) of the service transformer.
- Therefore, there is no means of causing an overcurrent protection device (a fuse or circuit breaker) to operate and to clear the fault.



Hot-to-Case Fault in a two wire 120v circuit



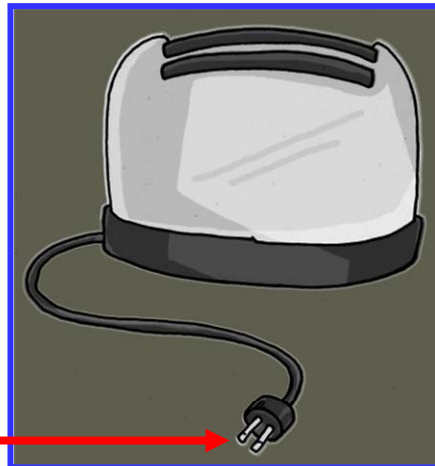
- All of the metal parts of the refrigerator in contact with the refrigerator chassis become the equivalent of an exposed, live 120 volt wire.
- Anyone grounded by touching a metal plumbing system component or through their feet and touching the refrigerator would become part of a path to ground for the fault current.
- The result would be shock or electrocution.

However, some appliances such as toasters, fans, and lamps still have two-wire cords and two pin plug ends – why?

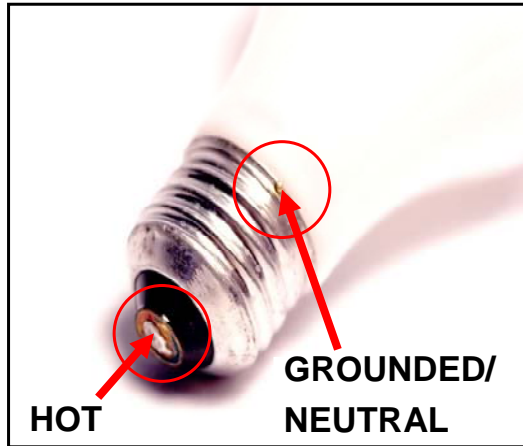


SOME APPLIANCES AND EQUIPMENT ARE INTENTIONALLY NOT GROUNDED.

IF THE METAL BODY OF THE TOASTER WERE GROUNDED BY AN EQUIPMENT GROUNDING CONDUCTOR, ANYONE TRYING TO FREE A STUCK BAGEL BY HOLDING ONTO THE BODY OF THE TOASTER WHILE STICKING A KNIFE INTO IT WOULD PROVIDE A PATH TO GROUND IF THE KNIFE CONTACTED THE HEATING ELEMENT OR THE CONNECTION OF THE HOT WIRING TO THE ELEMENT.

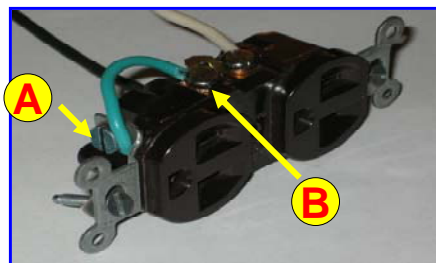


TWO-PIN PLUG END



If the lamp body were metal and were grounded, if the polarity was reversed, and if you were holding on to the lamp and touching the screw base of the bulb while screwing it into the socket, current would pass through your body.

In some older two-wire electrical systems, two slot, ungrounded receptacle outlets have been replaced with grounding-type receptacle outlets and the equipment grounding conductor terminal "A" has been jumpered to the receptacle grounded/neutral conductor terminal "B" as shown creating what is sometimes referred to as a false ground.



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False Ground

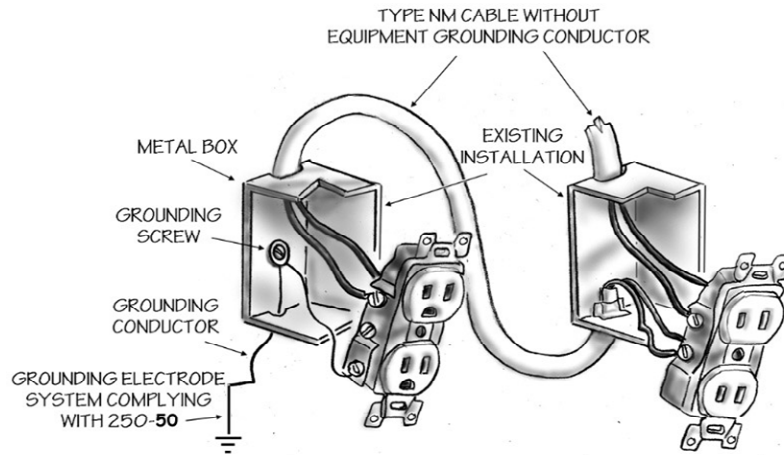
- **Makes the EGC in the cord becomes a parallel path with the neutral which, in turn, makes the metal frame or housing of the equipment part of that path.**
- **Any contact between the frame of the appliance and a grounded object can result in current flow.**
- **If the contact is through a person, there is the potential for electrocution.**



- **Such a receptacle outlet may test as correctly wired with some testers; however, it clearly is not correctly wired.**
- **While it exceeds generally established home inspection standards, inspectors who don't use an electrical tester capable of detecting false ground may want to consider removing some receptacle outlet cover plates to visually examine the wiring if they know or suspect that two-wire receptacle outlets have been replaced with grounding-type receptacles.**



Correct two-wire circuit receptacle outlet wiring



Illustration© from "Code Check"© courtesy of Taunton Press
www.taunton.com



UNGROUNDING CONDUCTOR

(also referred to as a "hot," "power," or "phase" conductor)

- Supplies power or which carries current from a source of power to a device which uses power (a load).
- Insulation must be finished to be clearly distinguishable from both grounded/neutral conductors and equipment grounding conductors.



GROUNDING ELECTRODE

- An electrically conductive solid rod, plate, or ring (of approved materials and whose size and surface area are sufficient to permit adequate contact with the earth in which it is buried or driven.
- In the case of a concrete-encased electrode (**Ufer ground**), it is steel rebar of sufficient size, length, and embedment in concrete foundation components which are themselves, in sufficient and substantial contact with the earth.
- It is connected to the frame of the main disconnection device enclosure by a wire called the **grounding electrode conductor**.



- Once jurisdictional building authorities both permitted and encouraged the use of metal potable water supply piping as the grounding electrode because it was embedded in the earth outside of the building.
- Prior to 1978, the National Electrical Code (NEC) specified the metal potable water supply pipe as the first choice for use as a grounding electrode and *other electrodes* and *made electrodes* were acceptable only “*where a water system (electrode)...is not available.*”



In the past...

If a minimum of ten (10) feet of a metal potable water pipe to a building were buried in the ground, then that water pipe had to be used as the grounding electrode and no other electrical system electrode was required.

With the growing use of non-conductive components in such piping systems, their ability to provide an electrically continuous and reliable electrical system ground came into question.



Non-conductive components in a main water supply line



Today, buried metal potable water supply piping:

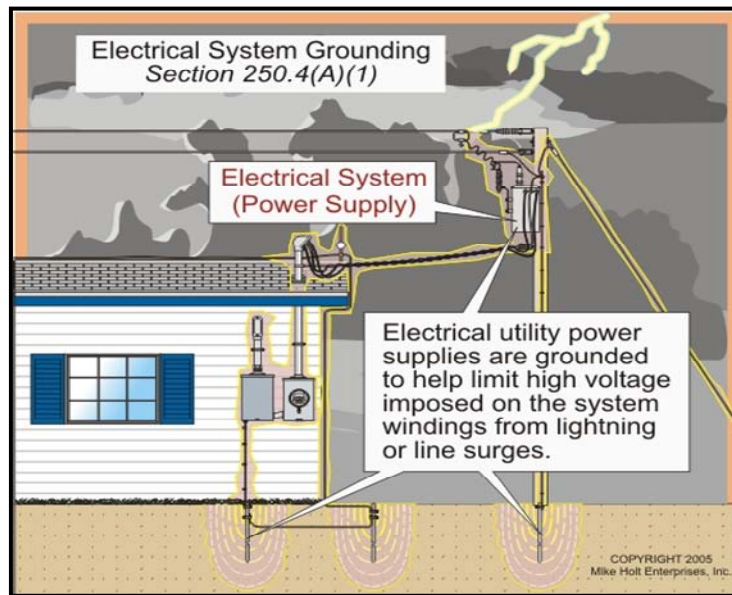
- Is considered by the NEC to be the least acceptable grounding electrode.
- Is the only grounding electrode that may never be used as the sole grounding electrode.
- Must be supplemented by at least one additional approved grounding electrode.
- Metal fuel gas piping is to be bonded to the electrical system but it is never to be used as a grounding electrode.



The grounding electrode/grounding electrode conductor system:

- Is not intended to conduct much current under normal circumstances.
- Its primary purpose is to conduct the currents generated by lightning strikes and other extremely short duration electrical events.





Illustration© Courtesy of Mike Holt Enterprises, Inc.
www.mikeholt.com

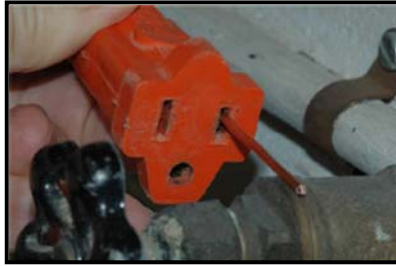


The conductivity of the grounding electrode/grounding electrode system

- It is relatively low.
- Its resistance is relatively high, as much as 25 ohms, (that translates as 5 amperes at 120 volts), it is not enough to trip a 15 amp breaker.
- Therefore, it is not intended to be involved in causing a breaker to trip and clear a fault when a hot to-ground, hot-to-hot, or hot-to-neutral short circuit occurs on individual circuit wiring.



Don't try this at home.



A bare, 12 gauge copper wire was inserted into the hot wire side and the voltage was confirmed by meter to be 120 volts. It was touched directly to a cold water pipe valve and did not trip the breaker. This valve is attached to a copper pipe that extends, without interruption, directly out into the earth.

Photo© and Text© Courtesy of <http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.htm>



Different grounding electrodes

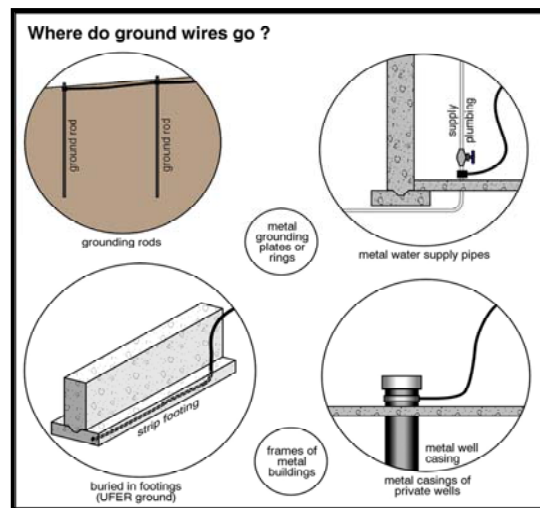
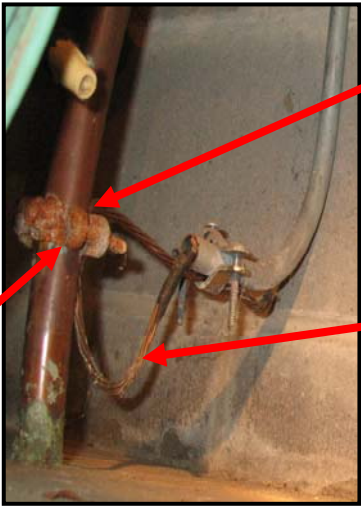


Illustration © [The Illustrated Home](http://www.dearbornhomeinspection.com) Dearborn Home Inspection Education
www.dearbornhomeinspection.com



Main Water Supply Pipe Grounding Electrode




NOTE THE CORROSION OF THE GALVANIZED STEEL CLAMP

NOTE THE IMPROPER PLACEMENT OF THE GROUNDING ELECTRODE CONDUCTOR

GROUNDING ELECTRODE CONDUCTOR

Photo© Courtesy of Roger Hankey www.hankeyandbrown.com

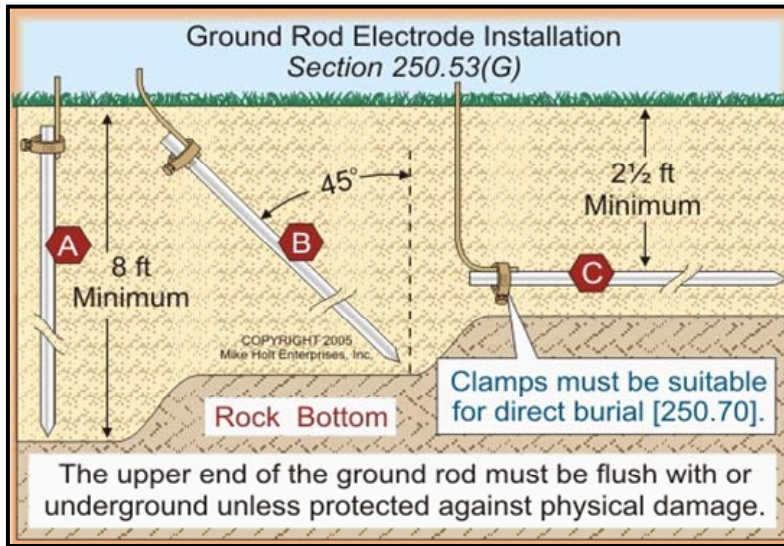


Water well casing grounding electrode and grounding electrode conductor



Photo© Courtesy of Roger Hankey www.hankeyandbrown.com





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Grounding Electrode - Not Fully Driven



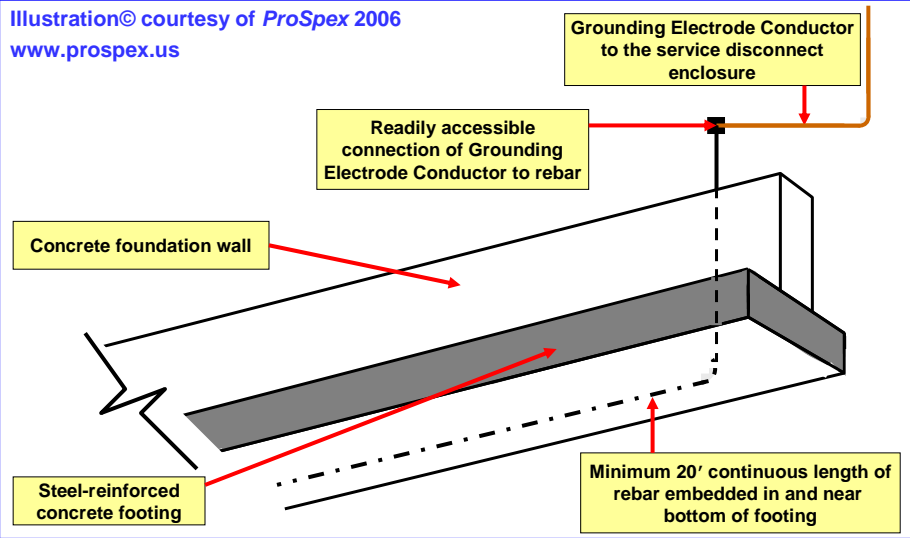
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Concrete-Encased Electrode System (Ufer Ground)

Illustration© courtesy of ProSpex 2006

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Examples of grounding electrode conductors attached to concrete-encased grounding electrodes.



A GROUNDING ELECTRODE CONDUCTOR:

- Connects equipment or the grounded circuit of a wiring system to a grounding electrode.
- Must be a continuous conductor from its point of attachment at the grounding electrode to its point of attachment at the service.
- If cut and reconnected or if lengthened, it must be spliced by exothermic welding or by using an irreversible compression type connector listed for grounding.
- Together, the grounding electrode and the grounding electrode conductor comprise the grounding electrode system.



WHAT IS THE ADVERSE CONDITION?



The conductor (yellow arrow) is installed on the wrong side of the clamp. It should be installed at the point indicated by the red arrow.

Photo Courtesy of Roger Hankey www.hankeyandbrown.com

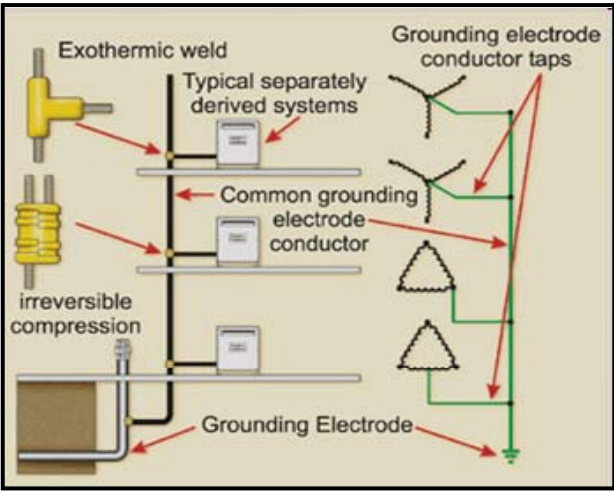
The grounding electrode conductor may be protected and not visible



Photo© courtesy of Home Wiring USA
www.selfhelpandmore.com



Approved splicing methods



www.iaei.org



Spliced grounding electrode conductors

INCORRECT (split bolt)



Photo Courtesy of Roger Hankey
www.hankeyandbrown.com ©



CORRECT



FEEDERS

- Any circuit conductor between the service equipment and the final branch circuit overcurrent device.
- To be identified in accordance with the requirements of the *NEC* and can be any color other other than those reserved for other conductors.

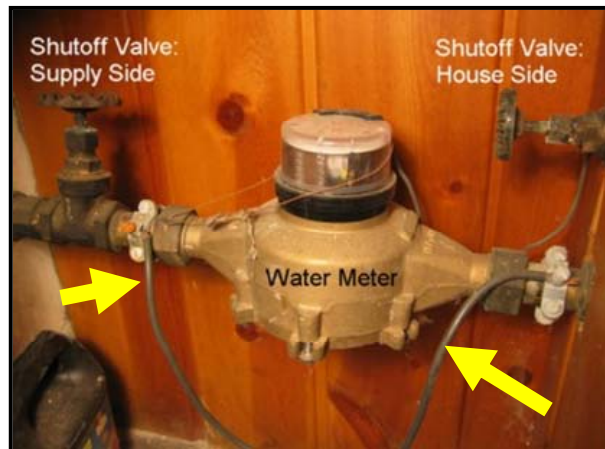


A BONDING JUMPER:

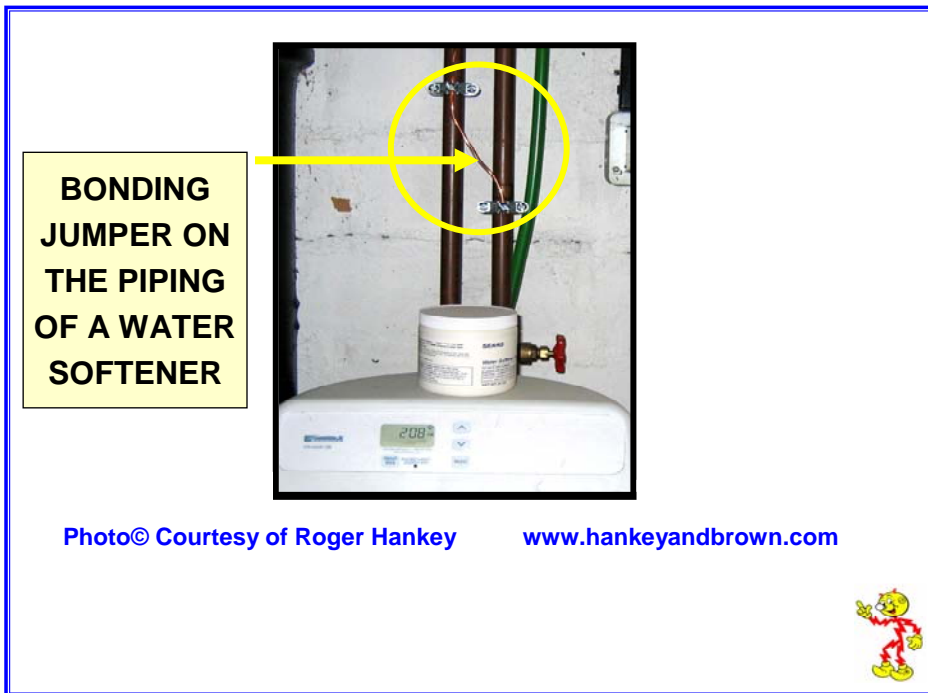
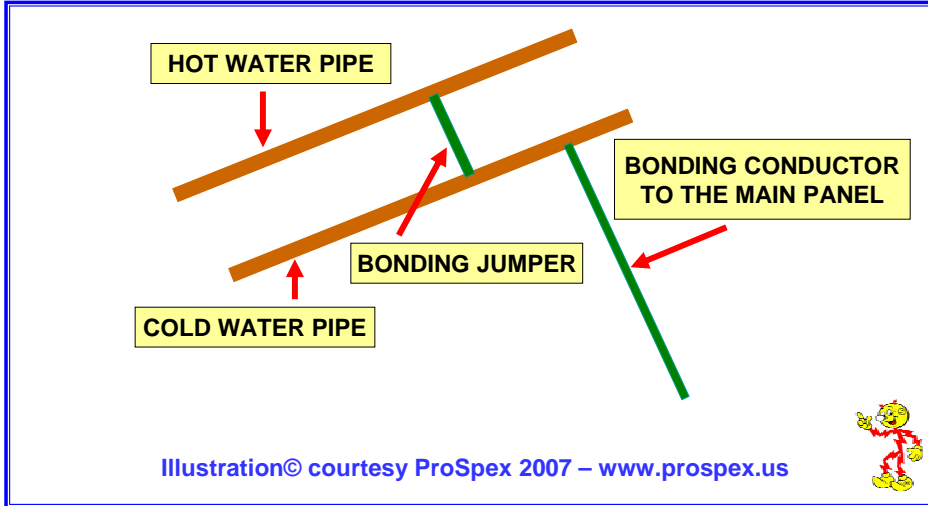
- Used where small sections of non-conductive components such as water meters and other non-conductive components are installed in potable water piping, fuel gas piping, and other systems composed primarily of conductive metal materials.
- Connects the sections of metal pipe on either side of such non-conductive components.
- Helps ensure that electrical conductivity and continuity are maintained throughout the system.

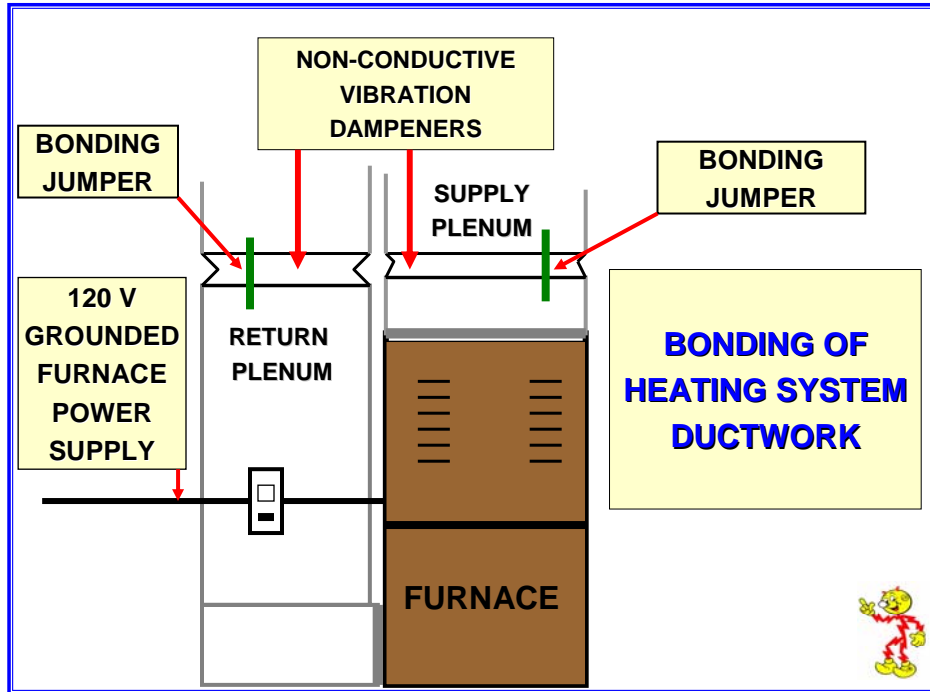


Water meter bonding jumper

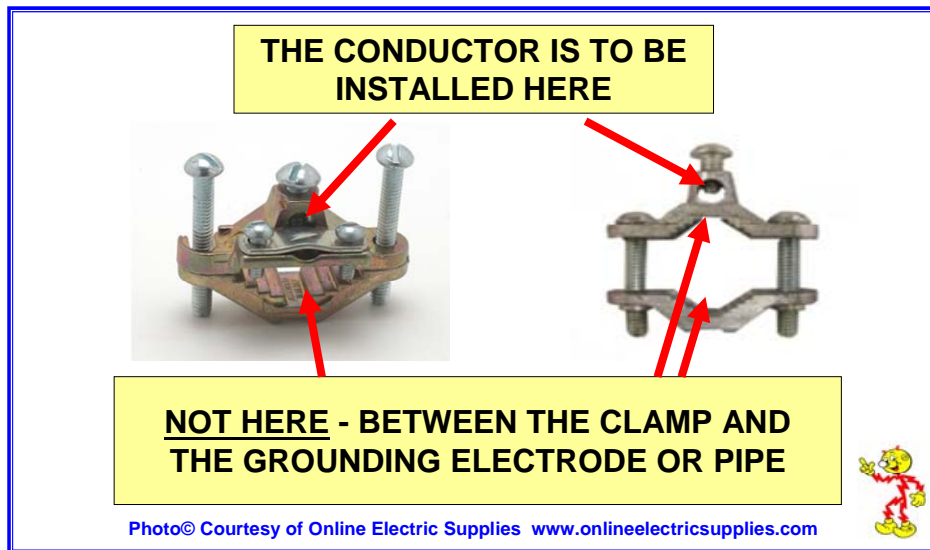


The bonding jumper both physically and electrically connects the hot water pipe to the cold water pipe. The bonding conductor connects both pipes to the main panel enclosure.

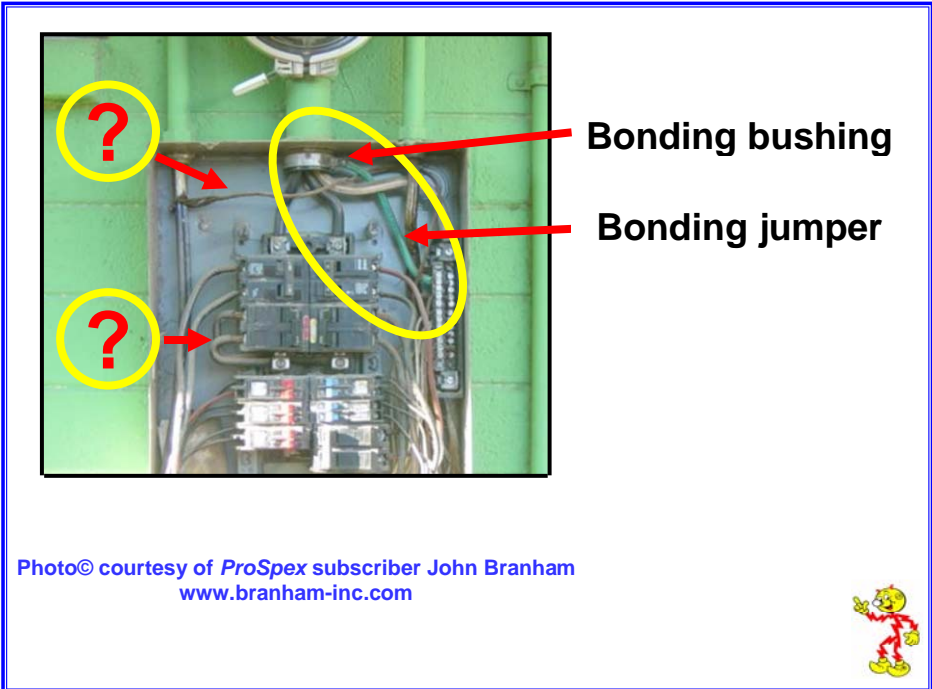




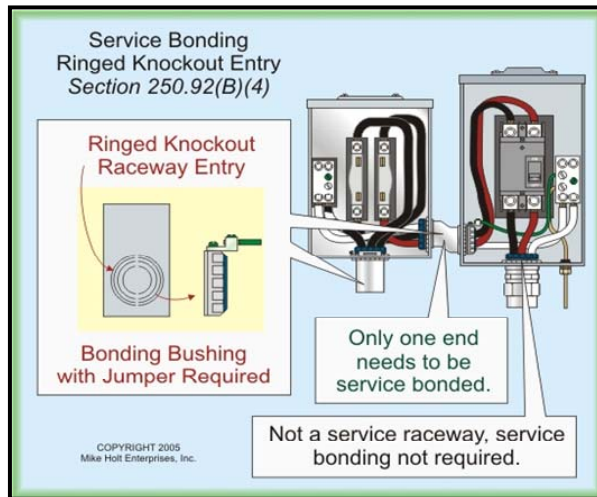
Grounding Electrode Conductor and Bonding Conductor Clamps



Correct installation of bonding conductors



Bonding Bushings



Illustration© Courtesy of Mike Holt Enterprises, Inc.
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OVERCURRENT CONDITION

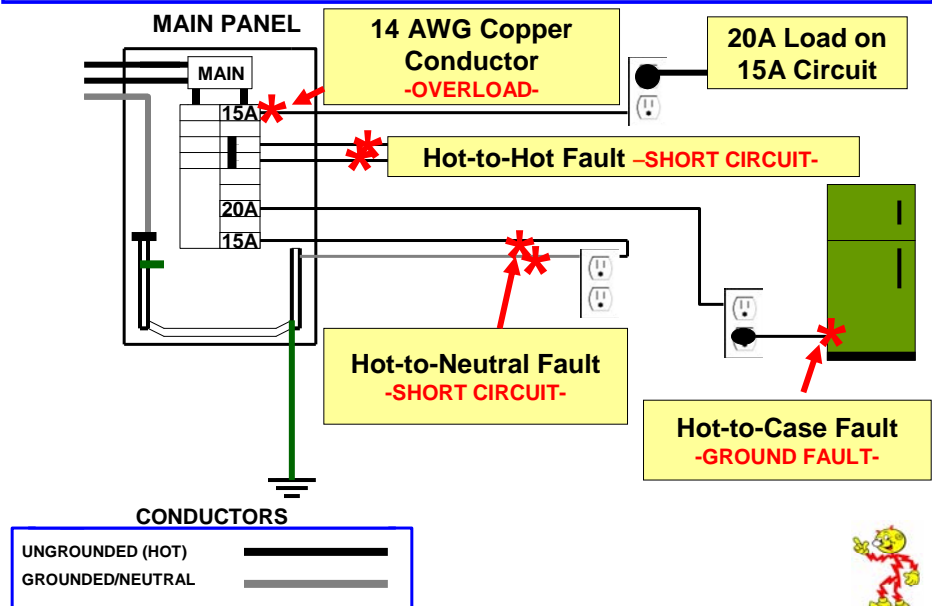
- Any current in excess of the rated current of equipment or materials

CAUSES OF OVERCURRENT ARE:

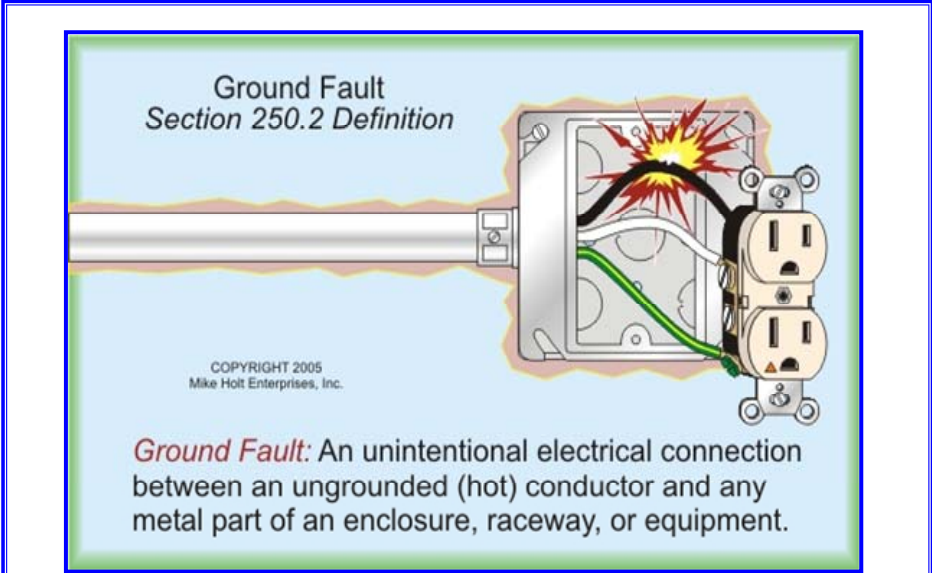
- Overloads
- Short circuits
- Ground Faults



OVERCURRENT



Illustration© 2007 Courtesy of ProSpex www.prospex.us



Illustration© Courtesy of Mike Holt Enterprises, Inc. www.mikeholt.com

SHORT CIRCUIT

- An accidental path of low resistance which passes an abnormally high amount of current.
- It exists whenever there is a low resistance connection between the conductors supplying electrical power to any circuit.
- If there is no overcurrent protection device (circuit breaker or fuse) installed in the circuit, a short circuit can cause the power source to be destroyed.



Photo Courtesy of Dr. Ray Franco, PhD., PE r.a.franco@ieee.org



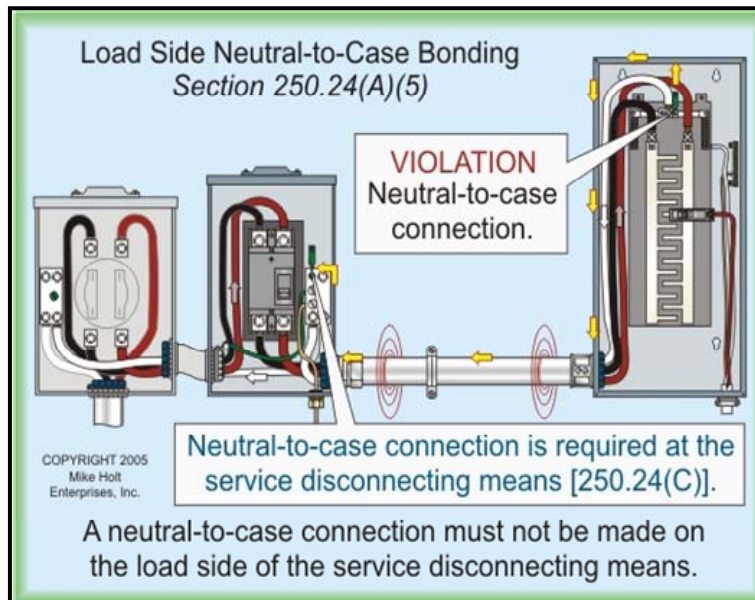
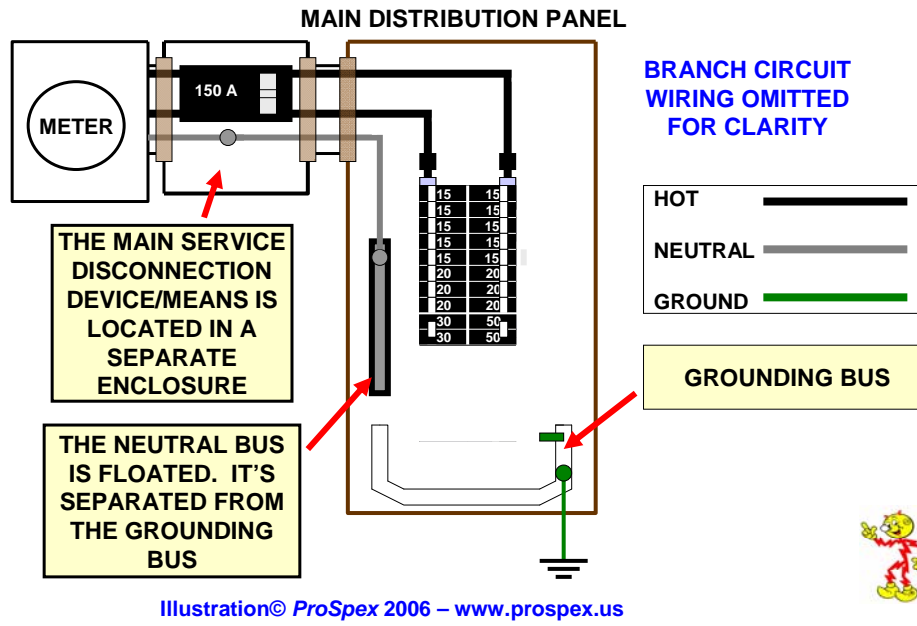
- **Opening a circuit and clearing a short circuit in the electrical system relies on the manner in which equipment grounding conductors (when present) and grounded/neutral conductors are installed and how they function in the electrical system.**
- **Equipment grounding conductors and grounded/neutral conductors terminate at the grounded/neutral conductor bus in the main distribution panel as long as the main disconnection means is located in the panel enclosure.**



- **Short circuit current will be conducted down the equipment grounding conductor or down the grounded/neutral conductor to the point of connection with the grounded/neutral service conductor in the Service Entrance Section (SES).**
- **From there, it will travel back to the center tap (ground) of the service transformer causing the overcurrent device (circuit breaker or fuse) to clear the fault by opening the circuit.**
- **Equipment grounding conductors, grounded/neutral conductors, and the grounded/neutral conductor from the electrical service provider terminate at the grounded/neutral conductor bus in the main distribution panel when the main service disconnection means is located in the panel enclosure.**

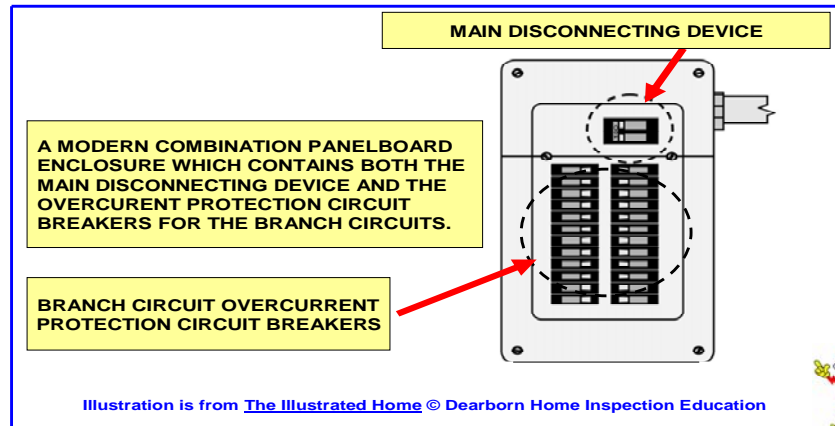


Condos, apartments, and some rural properties



In most modern single family residential electrical systems the main disconnecting device is located in the same enclosure as the main distribution panelboard as illustrated below.

Modern combination main panel



In a split bus panel with six single throw, double pole 240v breakers (multi wire circuits), in the upper bus:

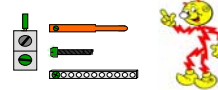
- The grounded/neutral conductors for each of those six circuits must be bonded to the enclosure by one of the approved methods for doing so.
- Typically, this would be by connecting them to a terminal bus bar that is bonded to the metal body of the enclosure.



It is in the enclosure containing the main service disconnecting device, and only in this enclosure, that 4 (four) specific conductors must all be connected and bonded to the body of the enclosure.

These conductors are the:

- GROUNDED/NEUTRAL CONDUCTOR
- GROUNDING ELECTRODE CONDUCTOR
- EQUIPMENT GROUNDING CONDUCTOR
- MAIN BONDING JUMPER



UNDERSTANDING LINE AND LOAD

-WHOSE SIDE ARE YOU ON?-



Line and Load (give and take)

- From the transformer to the final point of use on a branch circuit, every electrical component, fixture, appliance, etc. is on the **load** side of every electrical device that is **upstream** of it and is on the **line** side of every electrical device that is **downstream** of it.
- The meter is on the **load** side of the transformer and on the **line** side of the main service disconnection device.
- The service disconnection device is on the **load** side of the meter and on the **line** side of the branch circuit overcurrent protection devices.



Line and Load

- Devices or equipment that receive/use power are on the **load** side or **downstream** of devices or equipment from or through which the power comes.
- Devices or equipment through which the power comes are on the **line** or upstream side of the devices or equipment that receive power (that are **downstream**).



**EQUIPMENT GROUNDING CONDUCTORS
AND GROUNDED/NEUTRAL CONDUCTORS
ON THE LOAD SIDE OF THE MAIN SERVICE
DISCONNECT DEVICE ENCLOSURE**

**WHY IS CONNECTING THE GROUNDING
CONDUCTORS TO THE GROUNDED/NEUTRAL
CONDUCTORS ANYWHERE ON THE LOAD SIDE
OF THE MAIN SERVICE DISCONNECT
ENCLOSURE A PROHIBITED PRACTICE?**



**If a grounded/neutral circuit conductor
becomes disconnected:**

- Neutral current will travel on the equipment grounding conductors.
- This will energize the chassis of any grounded equipment or appliances that are served by circuits located anywhere downstream of where such a grounding conductor and a grounded/neutral conductor connection is made on the load side of the main disconnect device enclosure.



Neutral-ground bonds on the load side of the main service disconnect device allow any neutral current to flow on conductive metal parts of electrical equipment that are connected to the electrical system by equipment grounding conductors.

This is because current doesn't take the path of least resistance to ground; it takes every available path to ground.

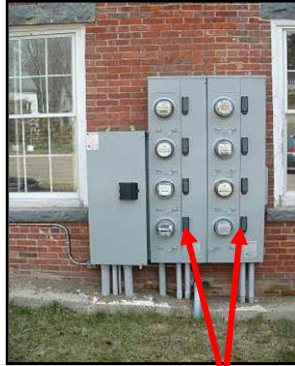


This includes installations such as those commonly found in townhouses and condominiums where:

- **Each unit is individually and separately metered**
- **The main service disconnect means or device for each unit is located in its own separate enclosure on the line side (upstream) of the main distribution panel enclosure**
- **Main distribution panel enclosures are located in each unit**



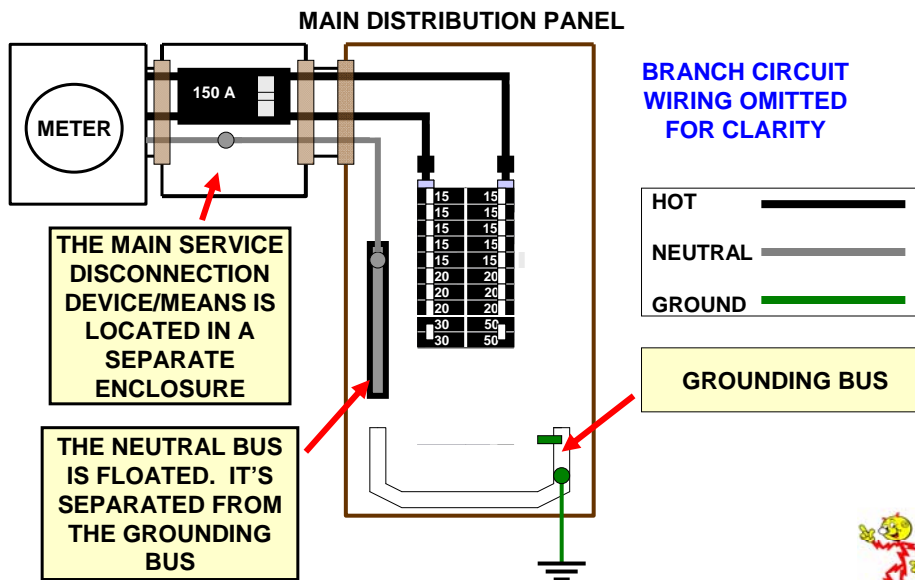
A bank of electric meters with individual single throw service disconnect devices



The main disconnect devices are located at the meters and not in the same enclosures as the branch circuit overcurrent devices.



Condos, apartments, and some rural properties



Illustration© ProSpex 2006 – www.prospex.us



Neutral currents can:

- Cause lethal electric shock
- Increase the potential for:
 - arcing and flashovers
 - overheating of equipment
 - other problems stemming from electricity being where it doesn't belong.
- The idea behind proper bonding is to reduce the potential for these conditions to occur.



The only place in the electrical system that the grounded/neutral conductors and the equipment grounding conductors should come together is in the enclosure in which the main service disconnect device is located.

At all other points throughout the electrical system, there should be no connection between the bare or green insulated equipment grounding conductor and the white or gray grounded/neutral conductor.



Remember, current doesn't take the path of least resistance to ground; it takes every available path to ground. The idea behind bonding is to reduce the potential for a person to become part of that path.

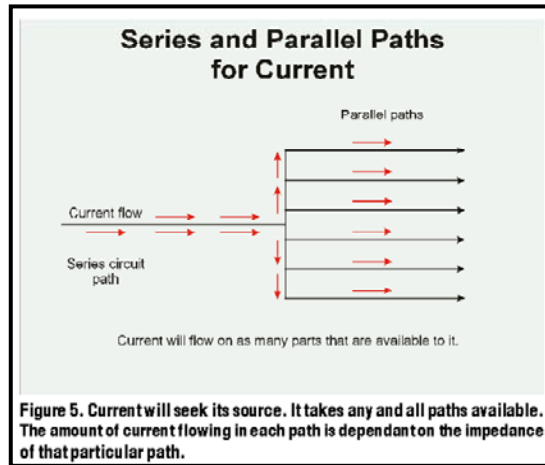


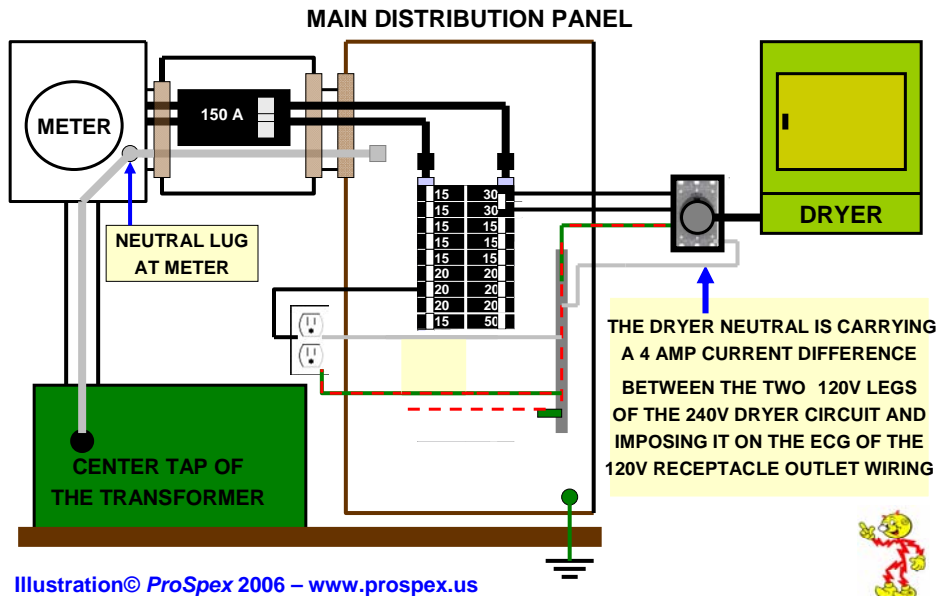
Illustration © Courtesy of the International Association of Electrical Inspectors
www.iaei.org



- **Bonding of the neutral terminal to the enclosure case of a panelboard which is not part of service equipment or a separately derived system creates a parallel path for return neutral current.**
- **The result is neutral current (net current) flowing on the metal parts of electrical equipment as well as the grounding and bonding conductors.**



Fault current path with a missing floating neutral bus



**JUST WHEN
YOU THOUGHT YOU
WERE FINALLY
STARTING TO GET IT...
THE EXCEPTIONS**



There are specific installations in which neutral to ground bonding is permitted on the load side of the main service disconnect enclosure. These are:

1. Separately derived systems when the requirements of 250.30(A)(1) of the NEC are followed
2. Separate buildings when the requirements of 250.32(B)(2) of the NEC are followed.

It's number 2 above which is of concern to home inspectors.



It is not uncommon for home inspectors to examine a detached garage in which there is a subpanel supplied from the main panel at the house.

After removing the cover from the subpanel in the detached building, carefully examine the subpanel to determine if ALL of the conditions outlined in the following slide are present...



- An equipment grounding conductor **HAS NOT** been run with the feeder/supply wiring coming from the main panel,
- There are **NO** shared electrically continuous and metallic systems that are bonded to the grounding system for the main panel such as conduit between the main and subpanels or plumbing piping or gas piping from the house to the separate building, **AND**
- Ground-fault protection of equipment **HAS NOT** been installed on the common alternating current service.

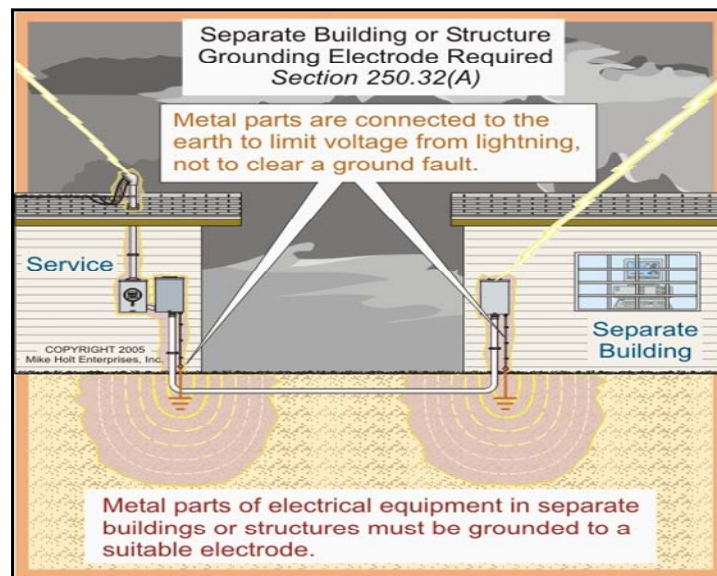


- **IF ALL** of these conditions are present, **THEN** the grounded/neutral conductor which has been run with the feeder/supply wiring to the separate building **must** be connected to the detached building disconnecting means **and** to a **separate** grounding electrode/grounding electrode conductor system.
- The separate grounding electrode/grounding electrode conductor system bonded to both the grounding bus and to the subpanel enclosure in the separate building is necessary to create a completely separate and independent path to ground.



If **NO** separate grounding electrode/grounding electrode conductor system is installed:

- The grounded/neutral **feeder** conductor would provide the **only** path for hot-to-case faults back to the service transformer center tap (ground) if system current were imposed on the subpanel system
- And it would provide the **only** path to the main panel grounding electrode/grounding electrode conductor system in the event of a high current, short duration event such as a lightning strike.



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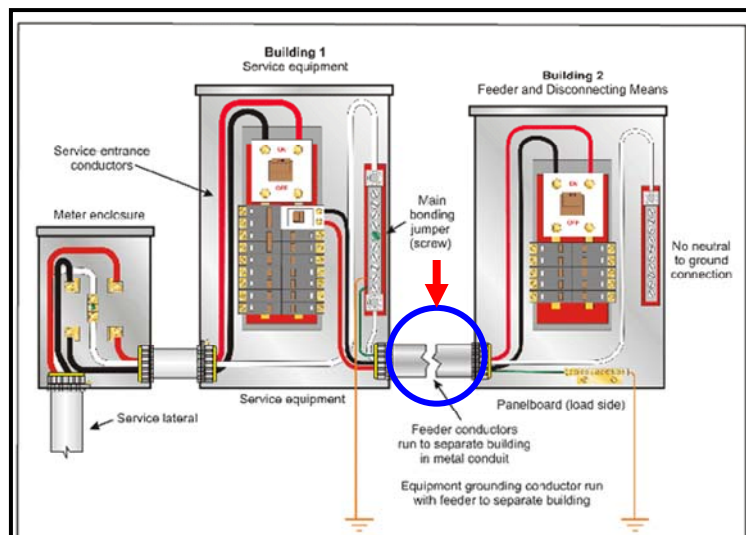


When there is no equipment grounding conductor from the main panel and there are no shared electrically continuous systems that bond the main panel to the subpanel, the subpanel becomes a separate SES.

- This makes all applicable main panel bonding and grounding requirements apply to the subpanel.
- It is important to understand this particular situation to reduce the potential for misidentifying non-floated grounded/neutral conductors as an ADVERSE CONDITION if all of the specific conditions outlined are present.



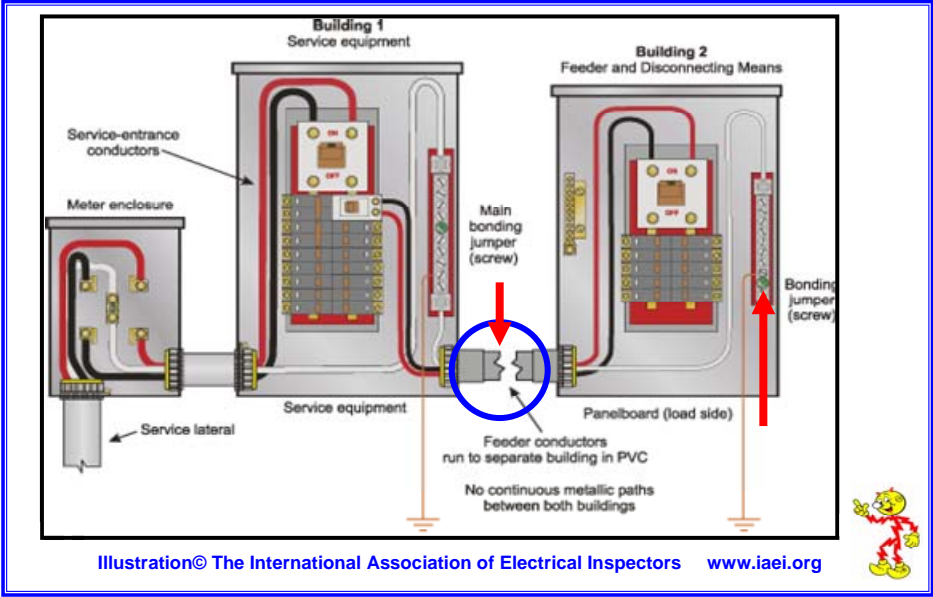
Bonded metallic conduit between the buildings



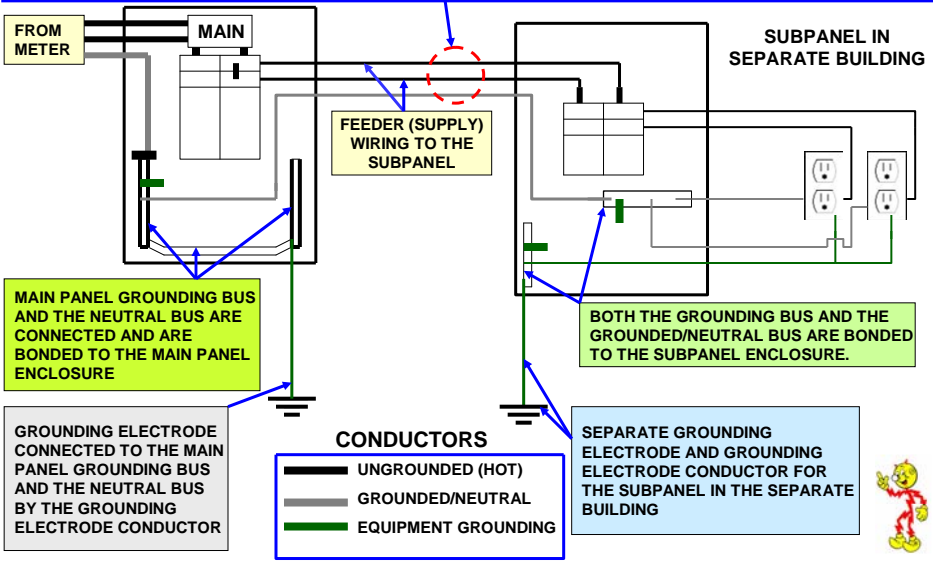
Illustration© Courtesy of the International Association of Electrical Inspectors www.iaei.org



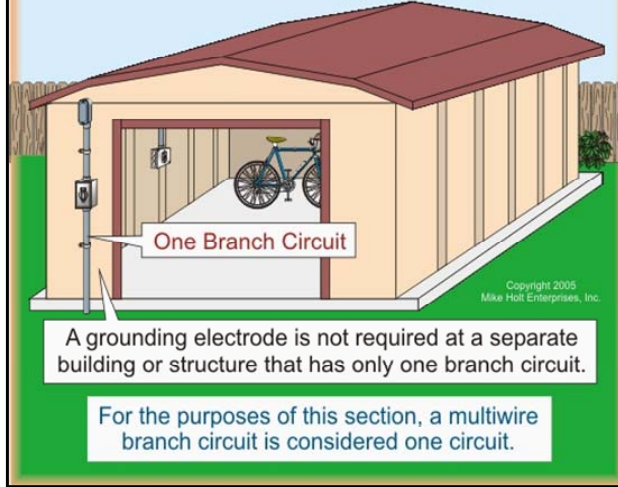
No continuous metallic path between buildings



NO EGC RUNS WITH THE WIRING BETWEEN THE MAIN PANEL AND THE SUBPANEL IN THE SEPARATE BUILDING. THERE ARE NO CONDUCTIVE/METALLIC PATHS BONDED TO THE ELECTRICAL SYSTEMS IN BOTH BUILDINGS. THERE IS NO GFCI PROTECTION ON THE COMMON SERVICE.



Grounding Electrode at Separate Building or Structure
Section 250.32(A) Ex



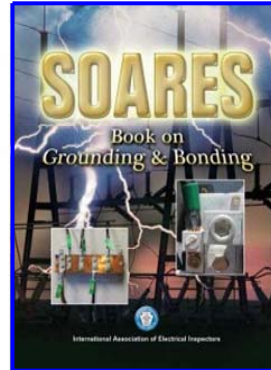
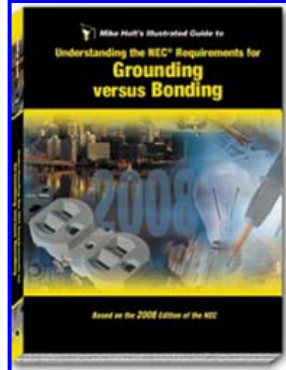
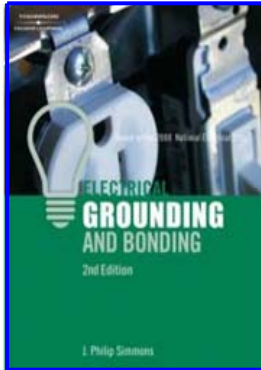
A grounding electrode is not required at a separate building or structure that has only one branch circuit.

For the purposes of this section, a multiwire branch circuit is considered one circuit.

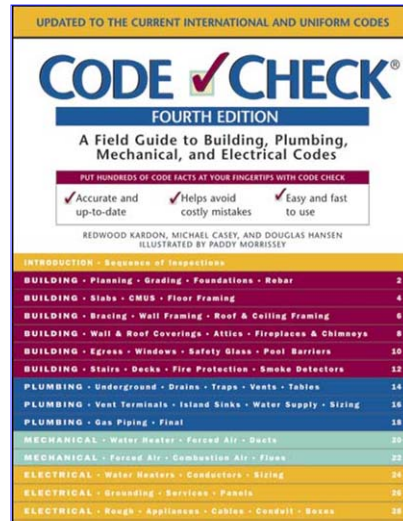
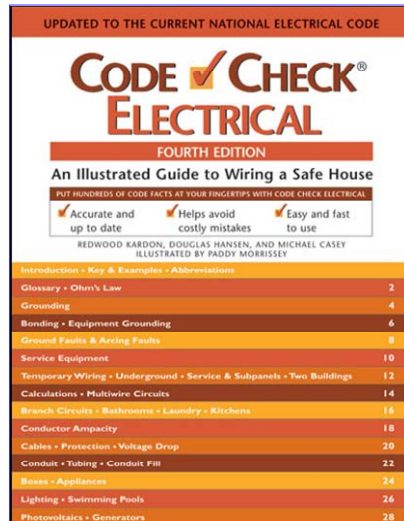
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HELPFUL RESOURCES



HELPFUL RESOURCES



Be sure to visit these useful sites

- Mike Holt Enterprises, Inc. (He has one of the best forums going) www.mikeholt.com
- Dearborn Home Inspector Education and Carson and Dunlop Associates www.dearbornhomeinspection.com
- The Taunton Press and "Code Check" and "Code Check Electrical" www.taunton.com
- The National Fire Protection Association and The National Electrical Code 2008 www.nfpa.org
- The International Association of Electrical Inspectors www.iaea.org
- HammerZone www.thehammerzone.com
- The Electrical Contractor Network (Great photos and information) www.electrical-contractor.net

-THANK YOU-

AND EVERYONE WHO HAS HELPED MAKE THIS
CONFERENCE A SUCCESS.



Consulting, Resource, Education, Training, and Support Services for Home Inspectors
"A candle loses no light when it lights another candle."

On the web at: www.prospex.us

Email: prospex@prospex.us

303-517-1980