Understanding Electrical Hazards

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www.nietc.org
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Objectives

- *Part 1*
- *Electrical Theory*
- *Terminology*
- *Units of Measurement*
- *Electrical System Design*
- *Overcurrent Protection*
- *GFCI / GFI Protection*

Objectives

- *Part 2*
- *Electrical Hazards*
- *Shock*
  - *burns and reaction injuries*
- *Arc Flash / Blast*
  - *terminology - hazard assessment*
- *Fire*

Objectives

- *Part 3*
- *Q & A regarding typical citations and workplace conditions*

Objectives

- *Part 4*
- *Working Energized*
  - *who, when, why and how*
    - *NFPA Standards - 70 and 70E*
    - *OSHA Standards - 1910 and 1926*

Is electricity magic?

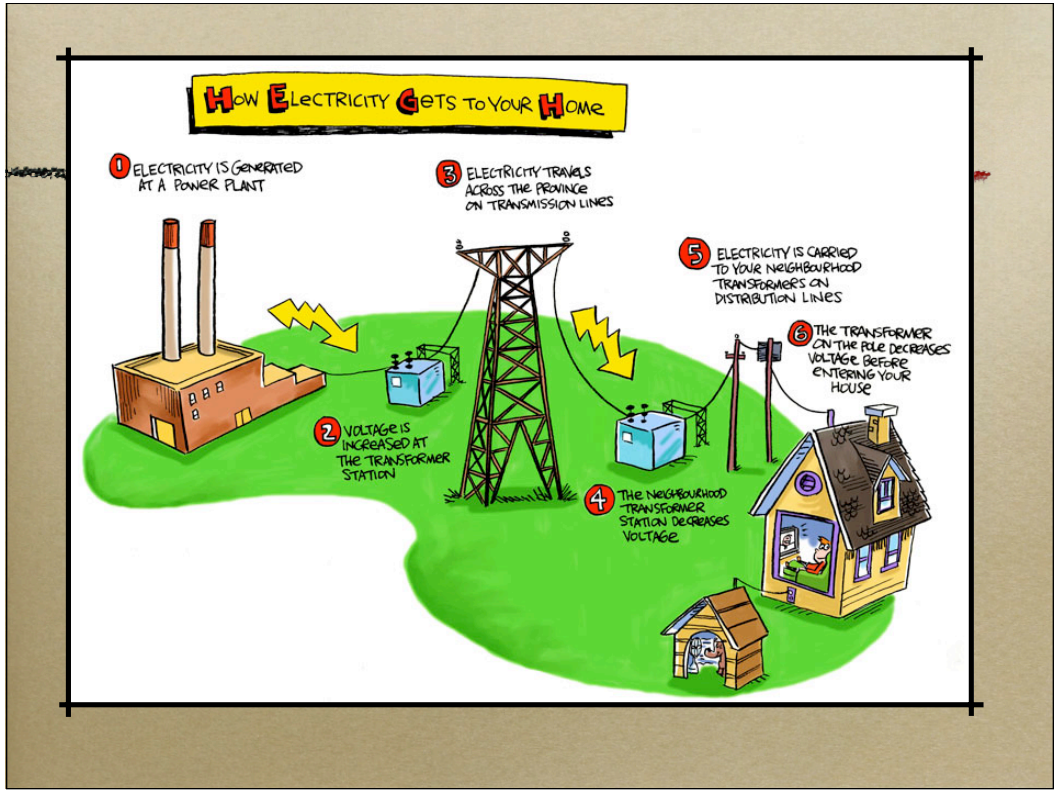
- *Volunteer*
- *Pure aluminum pipe (conductor)*
- *Rare earth magnet*
- *PPE*
- *Gravity*

Explaining Magic Trick

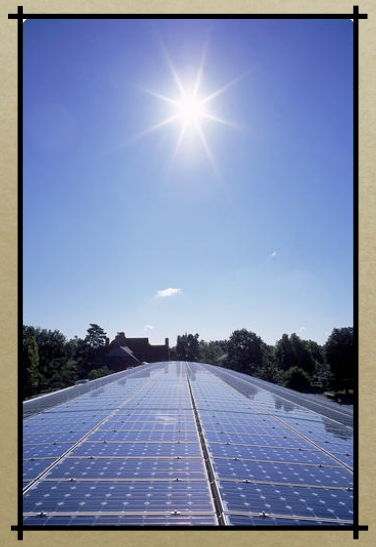
- *More interesting to watch*
- *Simplified concepts*
- *Advanced concepts*

Key electrical concepts

- *magnetic field*
- *conductor*
- *motion*
- *= birth of an induced voltage*
- *THINK GENERATING STATIONS*


How Electricity Gets to Your Home
1 Electricity is generated at a power plant
2 Voltage is increased at the transformer station
3 Electricity travels across the province on transmission lines
4 The neighbourhood transformer station decreases voltage
5 Electricity is carried to your neighbourhood transformers on distribution lines
6 The transformer on the pole decreases voltage before entering your house

Generation



Creates “Voltage”

- *a.k.a. electrical pressure or electromotive force (EMF)*
- *It is the “push” that forces electrons through a “circuit” (lack of complete circuit = no movement of energy)*
- *Measured in Volts (V) or (E)*
  - *difference of potential*

Current - Amps - Amperes

- *Simplified = amount of electrical energy moving past a point in one second - Intensity*
- *Complex = one volt of pressure causing one coulomb (6.25×10^{18}) of electrons past a point in one second = 1 amp*
- *Measured in amperes (A)*

Current - Amps - Amperes

- *Very important for proper ratings of wire size, electrical equipment and overcurrent devices*
- *Higher amps = larger wires*
  - *14 guage*
  - *5oo Kcmils*

Resistance or Impedance

- *opposition to current flow - resistance (R) for DC circuit & impedance (Z) for AC circuit*
- *Measured in ohms*
- *Consideration for voltage drop, line losses etc.*

Wire and Resistance

- *14 guage*
  - *CU = 3 ohms - AL = 5 ohms*
  - *15 amp capacity*
- *12 guage*
  - *CU = 2 ohms - AL = 3.25 ohms*
  - *20 amp capacity*

Basic circuit concepts

- *water pump, hose diameter and volume example*
- *larger diameter hose or pipe = more volume or capacity of water*

Basic circuit concepts

- *set nominal voltage - i.e. 120 V*
  - *110, 115, 120, 125, 130*
  - *208, 240, 277, 480*
- *amount of R or Z in ohms*
  - *conductor plus load*
- *establishes amount of current (amps)*

circuit

- *web def - A closed, conducting path or route through which an electrical current travels*
- *“Closed” is a very important concept*
- *an Open circuit will not function as intended*

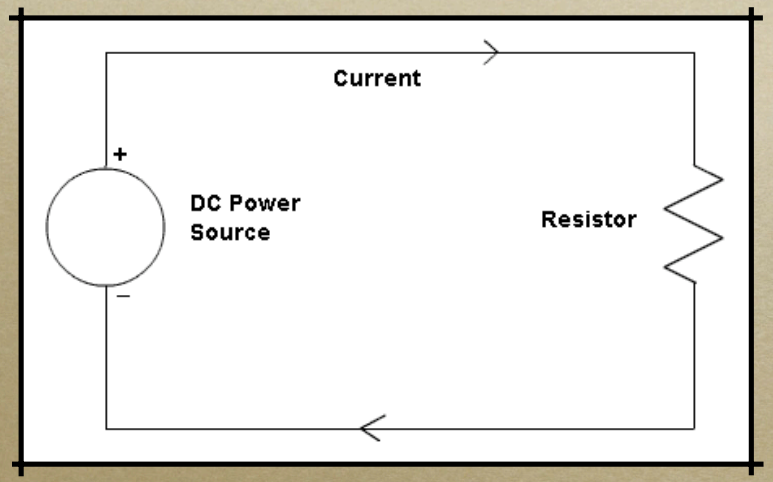
focus on “closed”

- *keep current flowing only on intended path*
- *electricity will seek the path of _____ resistance*

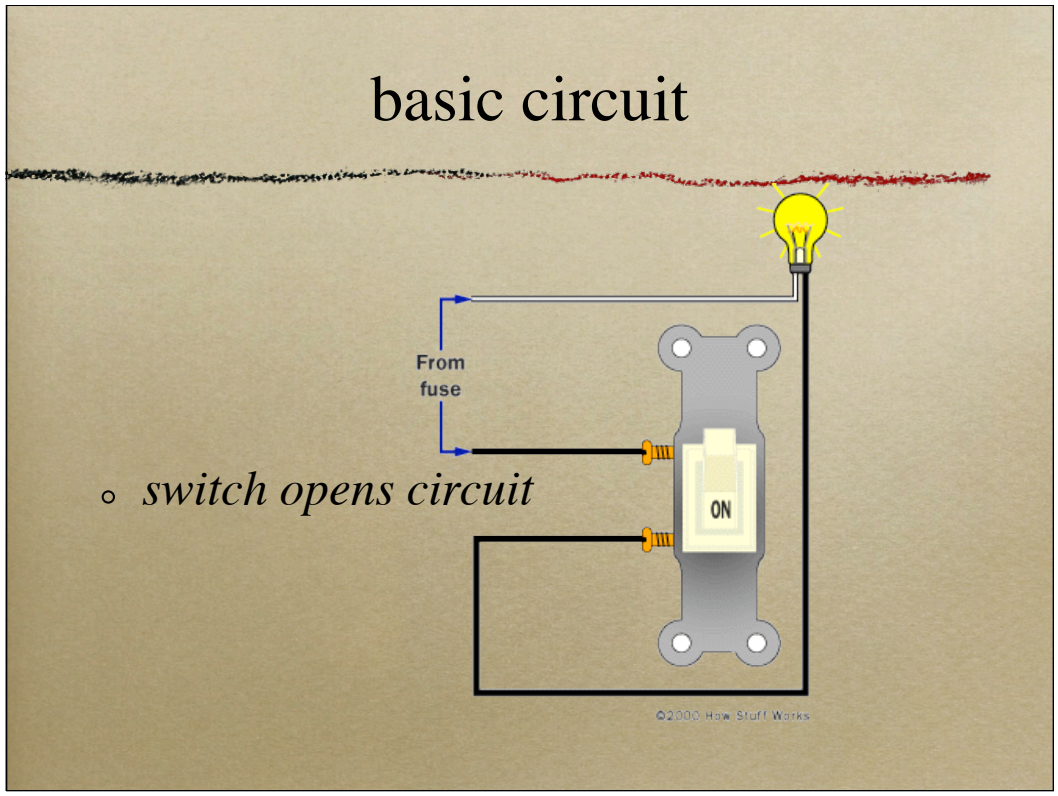
focus on “closed”

- *keep current flowing only on intended path*
- *electricity will seek the path of _____ resistance*
- *actually will seek out any and all paths and split proportionately based on Z*

Examples



basic circuit



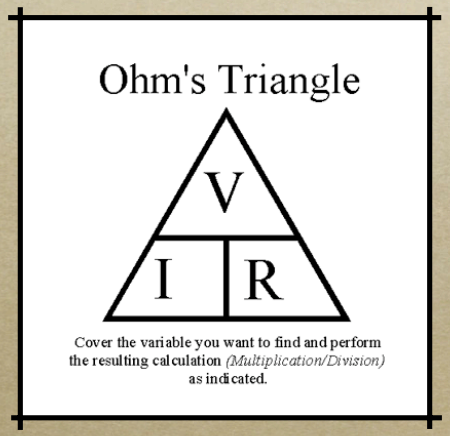
- *switch opens circuit*

Ohm's law

- *Voltage is equal to amps times resistance*
  - *V = I x R*
  - *can be manipulated to determine unknown variable*
- *Power is equal to amps times volts*
  - *P = I x E*

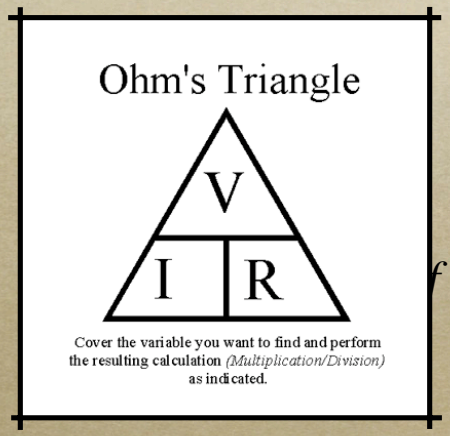
Examples

- *A 120 volt circuit with 10 ohms of impedance will draw ____ amps of current*



Examples

- *A 120 volt circuit with 10 ohms of impedance will draw 12 amps current*

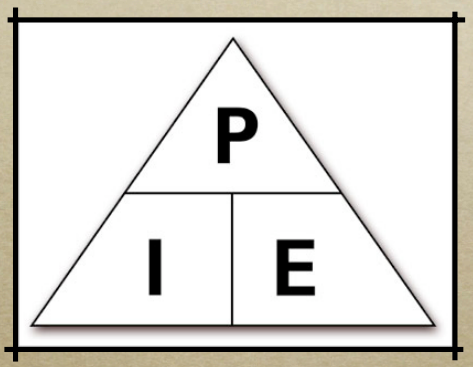


Power (W)

- *Defined as the rate at which work is done*
- *Measured in Watts (resistive loads)*
- *Example - 100 watt light bulb at your house (120V) draws nearly 1 amp of current.*

Power (W)

- *Watts / Volts = amps*
- *1500 watt heater at 120 V = 12.5 Amps*
- *at 240 V = 6.25 Amps*
- *at 480 V = 3.125 Amps*



Units of measurement

- *most common values are volts, amps, ohms and watts*
- *much larger values in the form of*
  - *mega or million*
  - *kilo or thousand*
  - *milli or thousandth*

Units of measurement

- *The NIETC is fed from a utility source of 12.5 KV or 12,500 volts to our step - down transformer rated at 500 KVA or 500,000 Volt-Amperes.*
  - *(Steps down the voltage from distribution level to 480 volt utilization level.)*


1217
500 KVA
480/277
NT

Units of measurement

- *The 480 volts of electrical pressure is routed on aluminum conductors, surrounded with insulation having many megaohms of resistance, to our 1600 amp rated electrical service*
- *This service is required to be GFI protected at 50 milliamps.*

More terminology

- *service entrance conductors*
- *grounding vs. grounded*
  - *what about bonded?*
- *grounding electrode*
- *grounding electrode conductor*
- *What does "grounding" accomplish?*

service entrance conductors

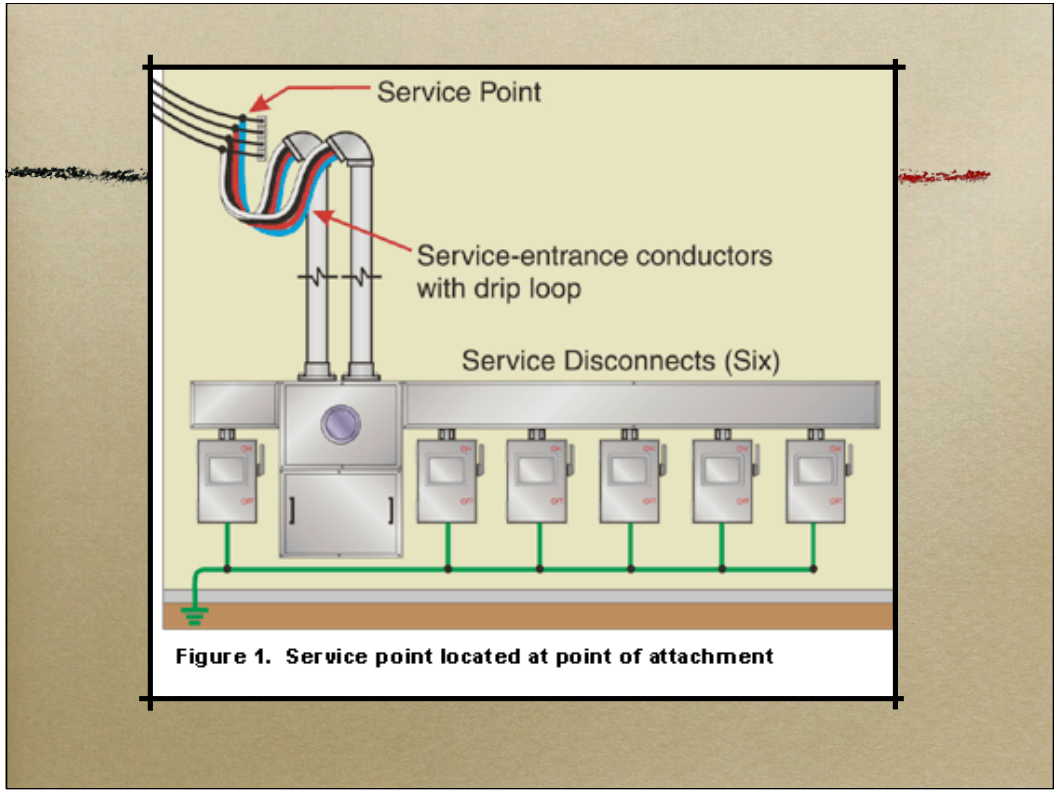
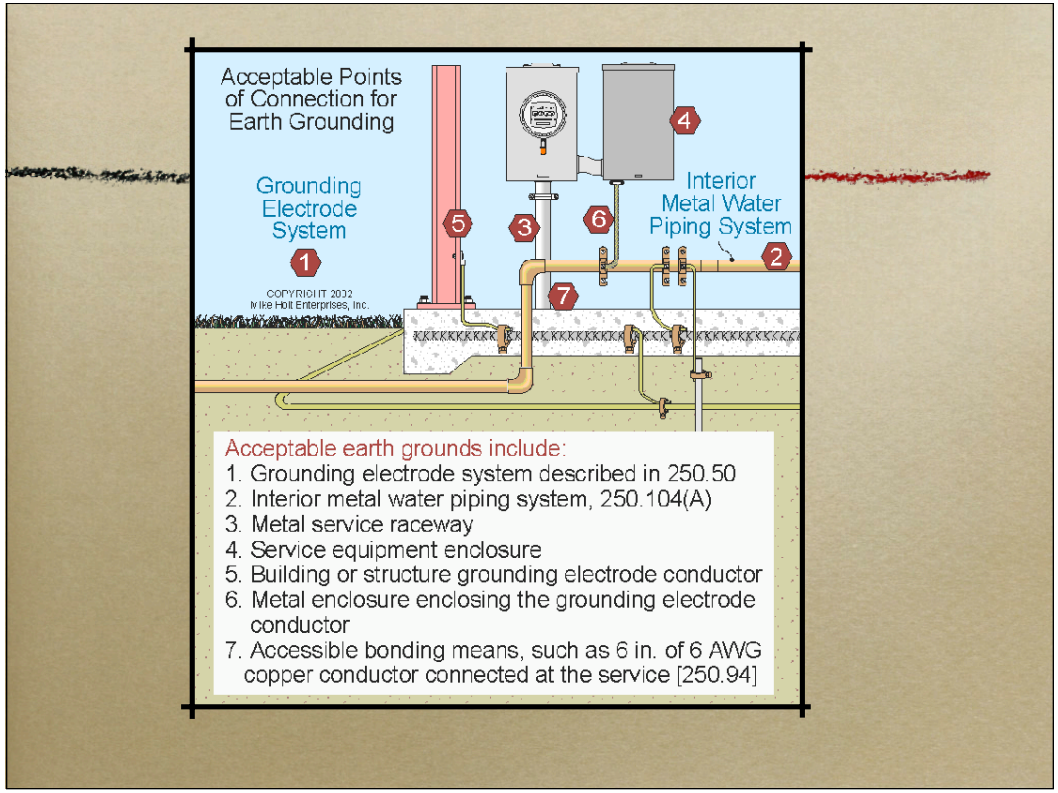


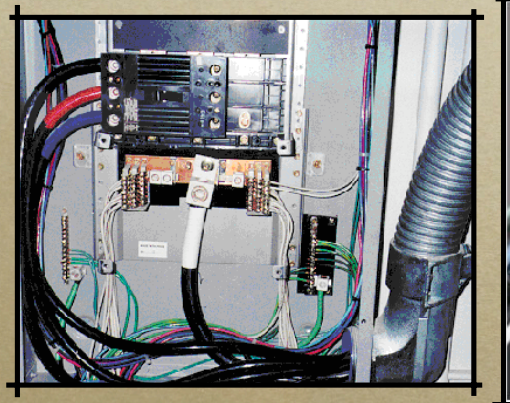
Figure 1. Service point located at point of attachment

service entrance conductors

Grounded / Grounding


Acceptable Points of Connection for Earth Grounding
Grounding Electrode System
1
Interior Metal Water Piping System
2
3
4
5
6
7
COPYRIGHT 2022
Mike Holt Enterprises, Inc.
Acceptable earth grounds include:
1. Grounding electrode system described in 250.50
2. Interior metal water piping system, 250.104(A)
3. Metal service raceway
4. Service equipment enclosure
5. Building or structure grounding electrode conductor
6. Metal enclosure enclosing the grounding electrode conductor
7. Accessible bonding means, such as 6 in. of 6 AWG copper conductor connected at the service [250.94]

grounded conductor



grounded conductor

- *Current carrying conductor intentionally connected to earth to provide a path back to the source (utility transformer)*
- *Color coded - white or grey only*
- *Cannot be used for any other purpose*
- *Original "safety" wire before 3 wire branch circuits were required by code*

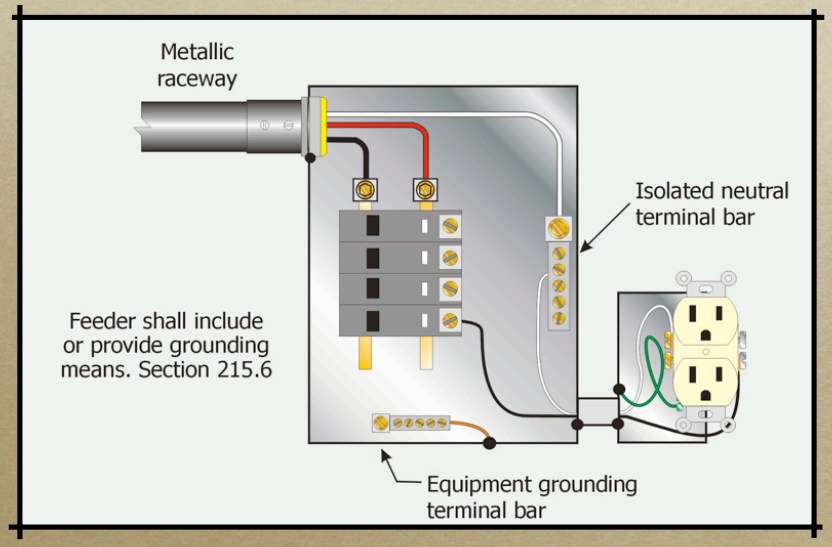
Earthing & Bonding

- *Terms help define location of "safety" wire in the electrical system*
- *Point of Earthing or connection to Earth is generally considered "Grounding"*
- *Then all metallic items which could become accidentally energized are "bonded" together and tied back to the original grounding point*

Equipment Grounding Conductor

- *Term for conductor primarily used for safety*
- *Provides low impedance, continuous connection back to earthing point*
- *Not White! Can be buss or conductor, bare or insulated - typically green or black - copper or aluminum, or even through approved metallic conduit systems*
- *Facilitates operation of Overcurrent Protection Devices - Fuse and Circuit Breakers*

Equipment Grounding Conductor



Conductor Terminology

- *1910.305 (f)*
- *Ungrounded*
- *Grounded*
- *Eq. Grounding*
- *Feeder*
- *Branch Circuit*

Conductor Terminology

- *Feeder - conductor protected by an Overcurrent device at source and terminates in another Overcurrent device*
- *sub panels, fused disconnects, any equipment with supplementary OCPD*

Conductor Terminology

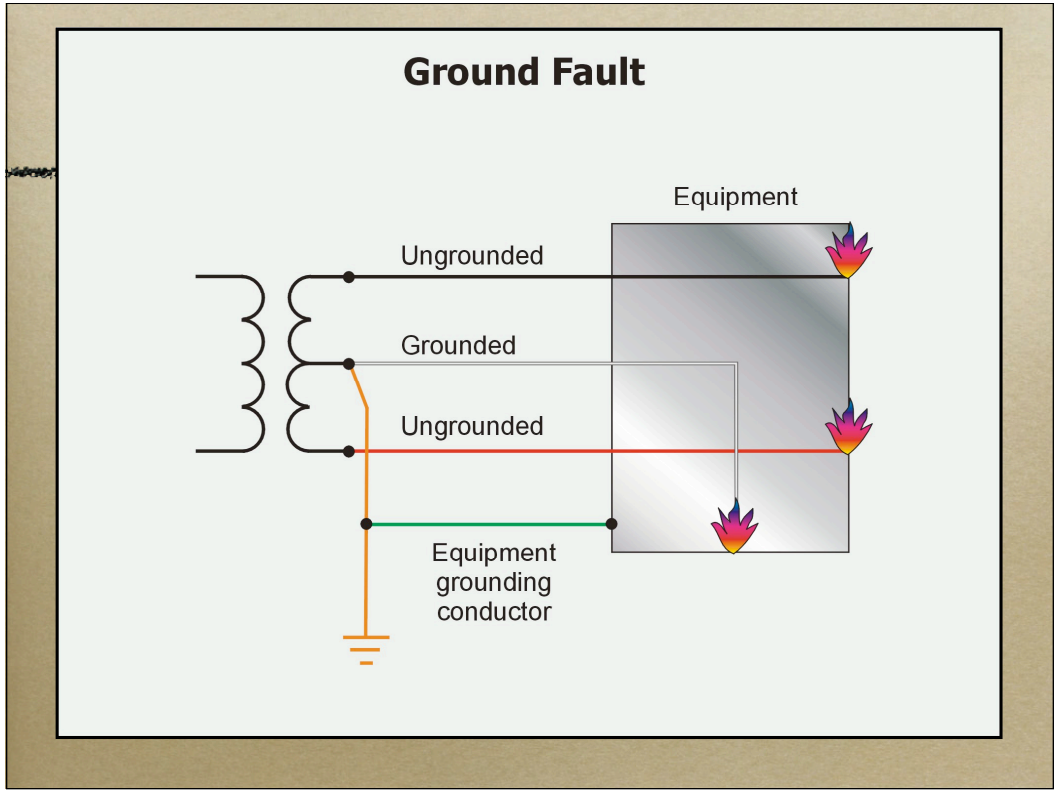
- *Branch Circuit - most common circuit found within a structure*
- *has OCPD at source but terminates in a device (receptacle) or at intended load (wall heater)*

Function of OCPD

- *Overcurrents - low level and extremely high level*
- *low level = Overload condition - too many loads on circuit*
  - *creates elevated heat levels and magnetic fields*
  - *condition causes fires*

Function of OCPD

- *high level = ground faults and short circuits*
  - *very high level current flow - thousands of amps*
  - *must be corrected in a very short time frame - 6 to 15 cycles (.1 - .25 seconds) for equipment protection*


Ground Fault
Equipment
Ungrounded
Grounded
Ungrounded
Equipment
grounding
conductor

OCPD operation

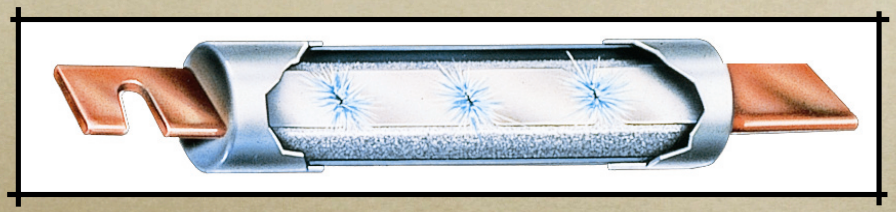
- *Current causes OCP devices to operate*
- *Thermal / Magnetic principles*
- *Equipment design - reliability, selective coordination, reduced mechanical stresses (massive mag fields)*
  - *Personnel protection??*

OCPD operation

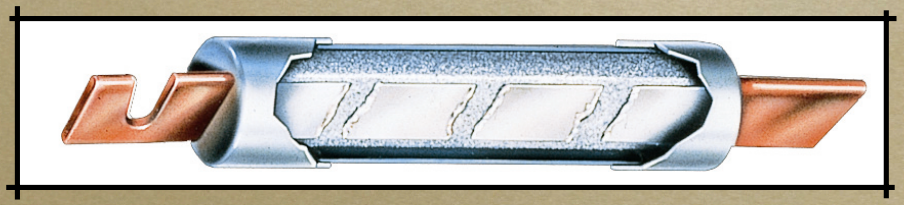
- *pros and cons of CB vs Fuses*
  - *manual resetting*
  - *mechanical device*
  - *delay settings - adjustability*

OCPD operation

OCPD operation

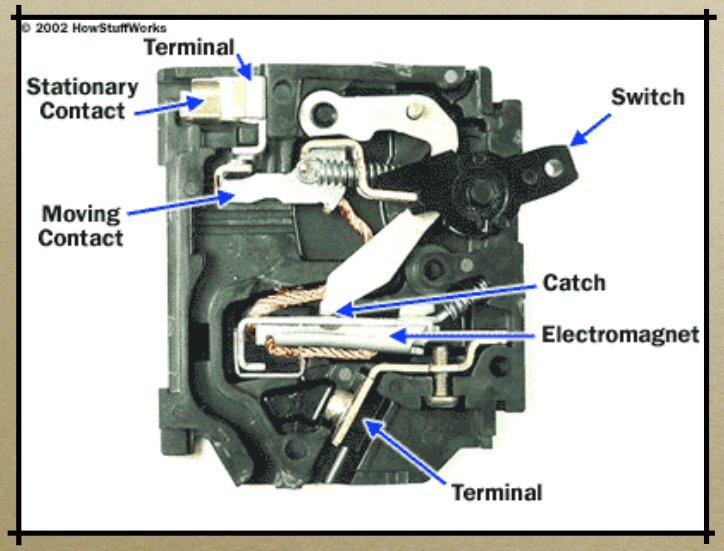


- *excessive current melts link*



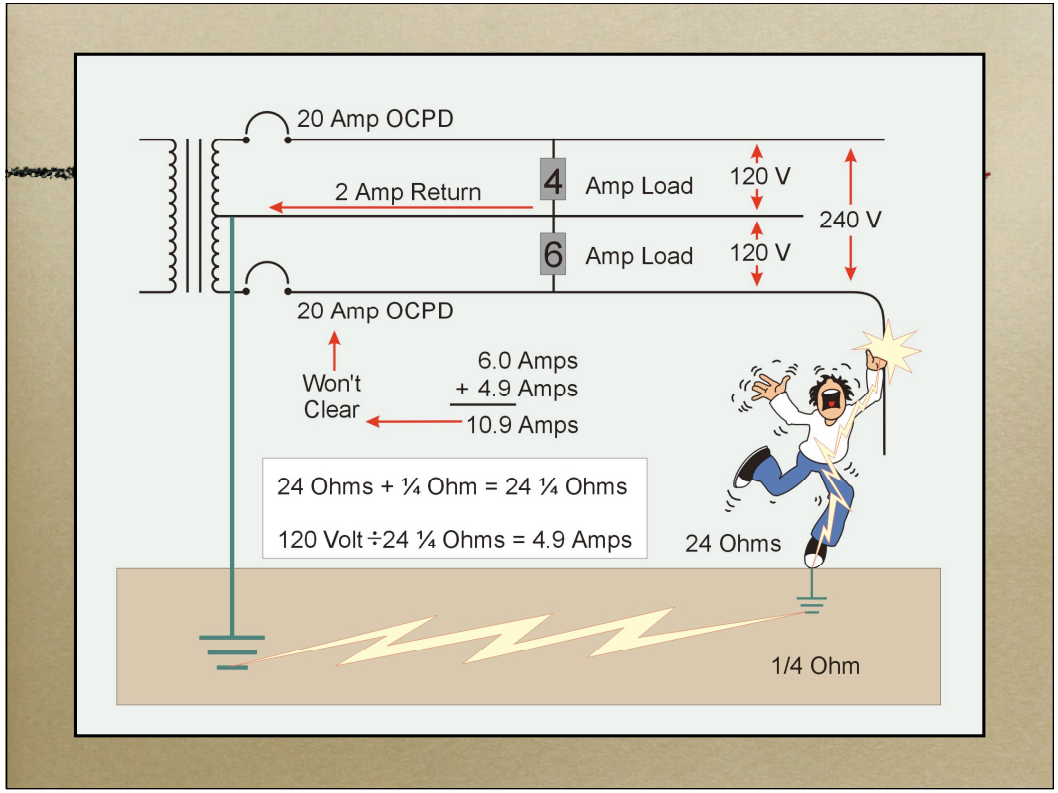

PHASE
511847P1
A
B
C
Spectra RMS
HI-BREAK
CIRCUIT BREAKER
225A
CAUTION
PLUG-IN JAWS
ASS. FACTORY SET
DO NOT ADJUST
DO NOT REMOVE
JOINT COMPOUND
FROM
PLUG-IN JAWS
CURRENT
INTERRUPTING
RATING
24
22
20
ON
50
OFF
A
B
C

OCPD operation



OCPD operation

- *fuses and circuit breakers protect the electrical equipment and structures*
- *they do not directly protect people from electrical shock or arc flash hazards*
- *Ohms law example -*
  - *20 amp breaker opens the circuit at 21 amps - (think 21,000 milliamps)*


20 Amp OCPD
2 Amp Return
4
Amp Load
120 V
240 V
6
Amp Load
120 V
20 Amp OCPD
Won't
Clear
6.0 Amps
+ 4.9 Amps
10.9 Amps
24 Ohms + ¼ Ohm = 24 ¼ Ohms
120 Volt ÷ 24 ¼ Ohms = 4.9 Amps
24 Ohms
1/4 Ohm

multi-wire branch circuit

- *“shared neutral” condition*
- *single phase - residence*
- *three phase - this building*
- *very common practice*
- *kills*

GFCI

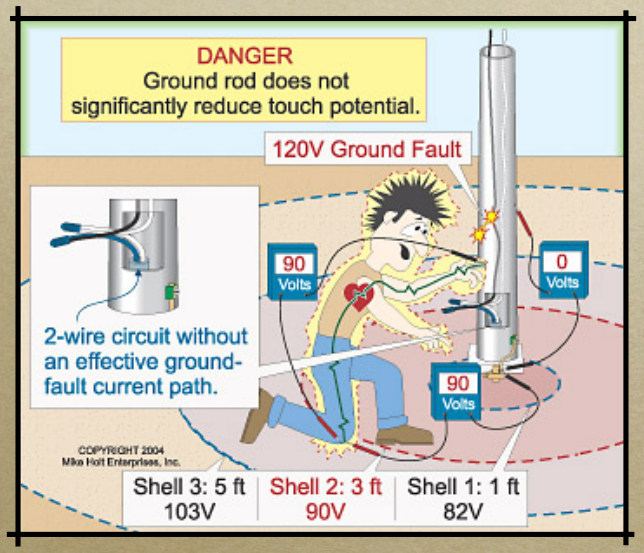
- *ground fault circuit interruptor*
- *not to be confused with GFI protection*
  - *50 - 200 mA range*
- *device can be receptacle, breaker or inline adaptor for extension cord / tool use*

GFCI

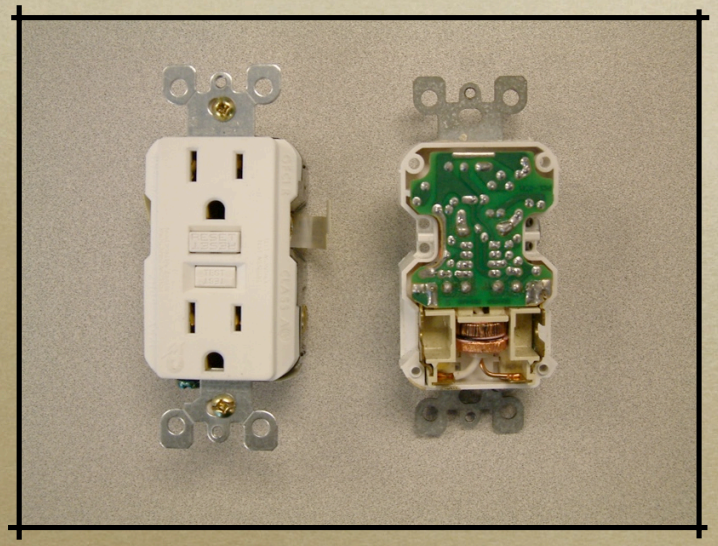
- *NEC requirements*
- *wet or damp locations*
- *resistance down = current up*
- *limits shock protection to ground faults only*

increased shock potential

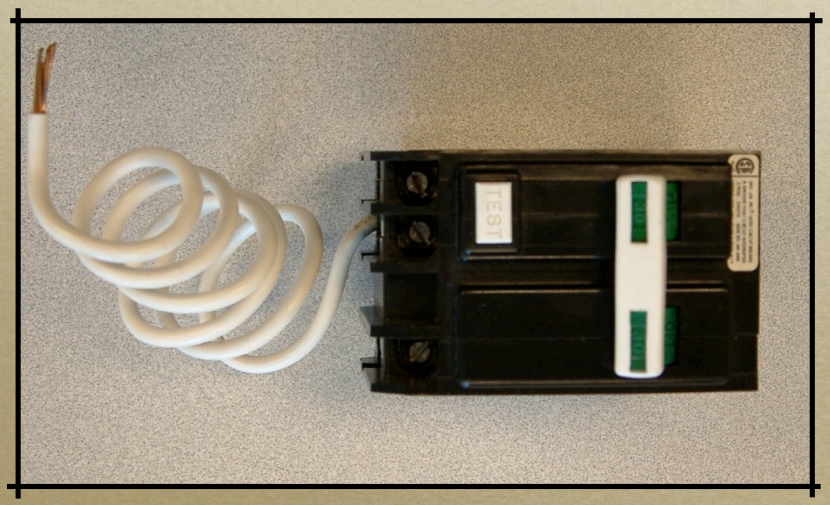
shock protection - non GFCI



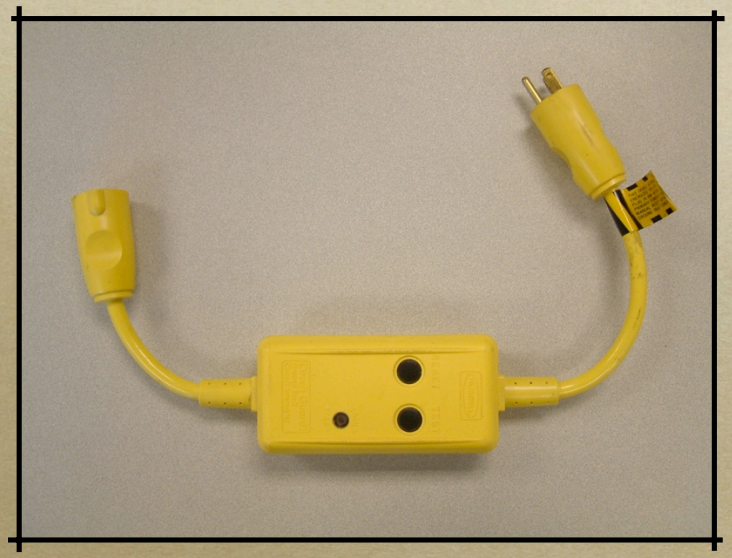
GFCI devices



GFCI devices

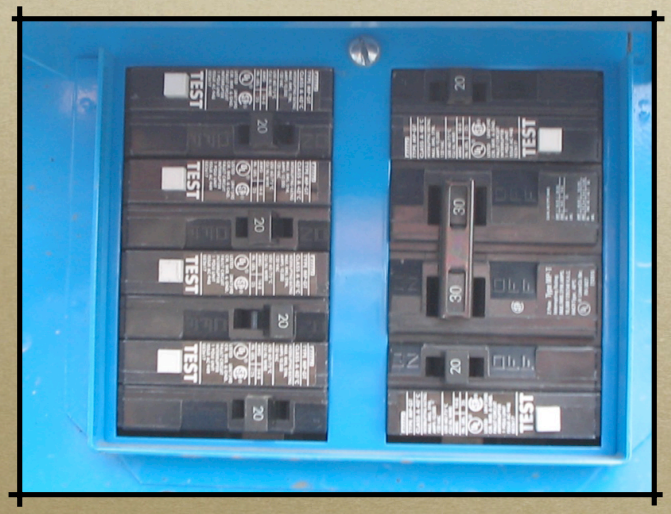


GFCI devices

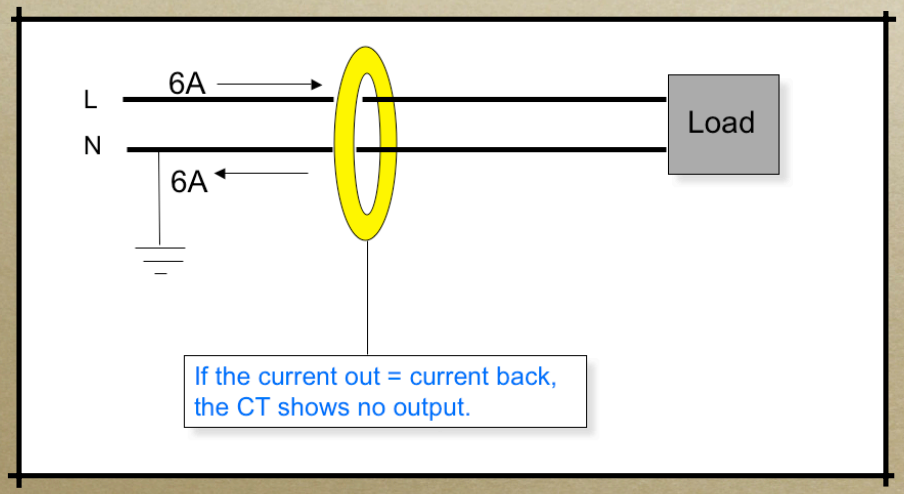


GFCI devices

GFCI devices



GFCI operation



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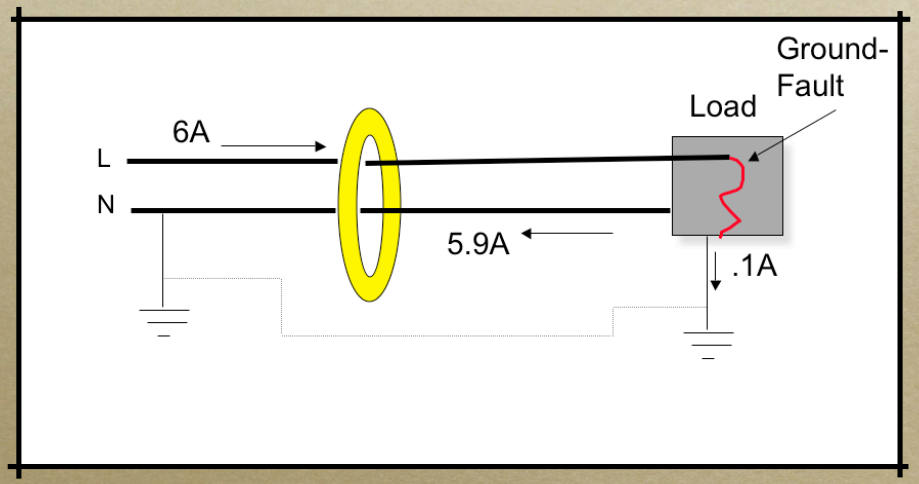
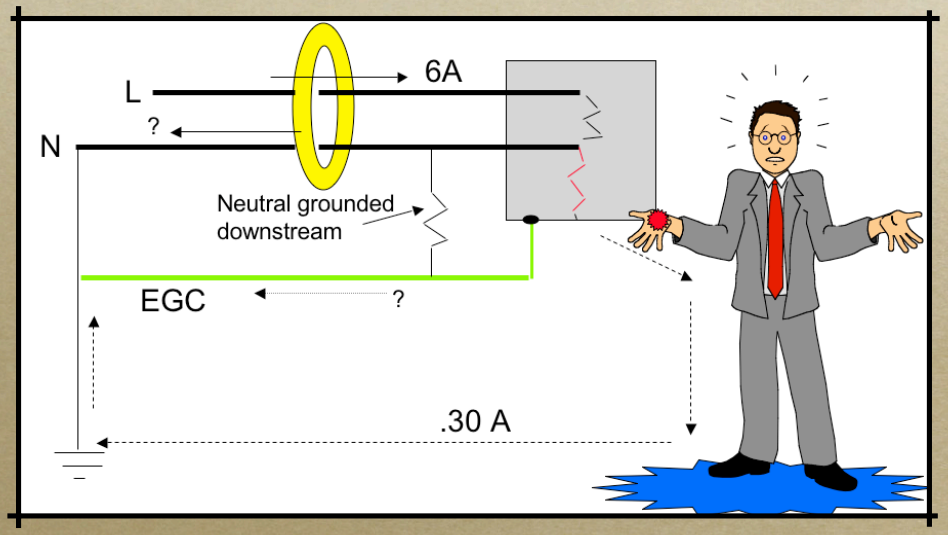
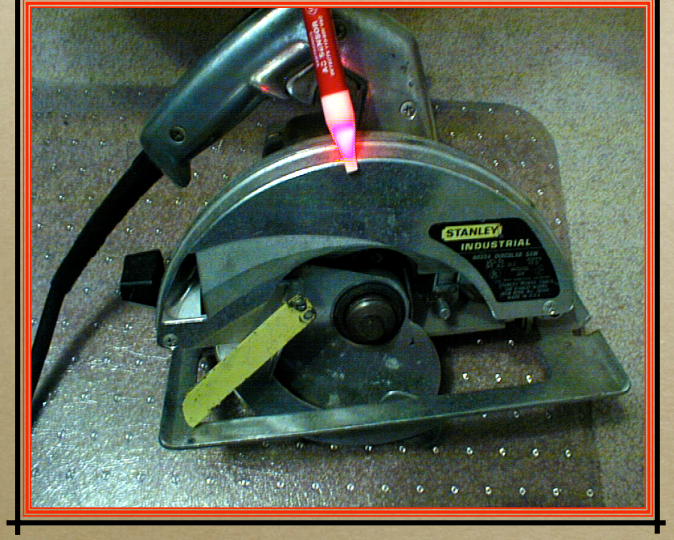


GFCI operation



EGC or GFCI



Amperes Operate Overcurrent Devices

E = Electromotive force R = Resistance I = Intensity
E = Voltage R = Ohms I = Amperes

Voltage	=	*Resistance	x	**Current
120	=	60	x	2
120	=	40	x	3
120	=	20	x	6
120	=	10	x	12
120	=	5	x	24

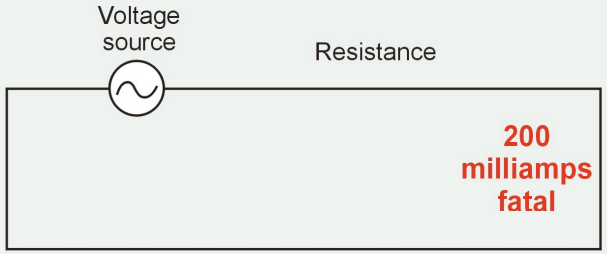
* As the resistance or opposition to current flow increases, the current that will flow in the circuit decreases

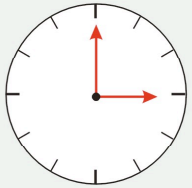
** As the resistance or opposition to current flow decreases, the current that will flow in the circuit increases

Severity of Electric Shock

The severity of electric shock is determined by three elements. If the combination of these three elements is just right, the shock can be severe or lead to electrocution.

1. **Amount of current that will flow.**
2. **Length of time that the current will flow.**
3. **Path of current through the body.**





Amount of time current is allowed to pass through the body.

Effects of Contact

- **0.5 - 3 mA** - Tingling sensations
- **3 - 10 mA** - Muscle contractions and pain
- **10 - 40 mA** - "Let-go" threshold
- **30 - 75 mA** - Respiratory paralysis
- **100 - 200 mA** - Ventricular fibrillation
- **200 - 500 mA** - Heart clamps tight
- **1500 + mA** - Tissue and Organs start to burn

Effects of Electricity on Humans

1000 milliamperes or 1 ampere

It doesn't take much current to cause damage or to cause death.

milliamperes

1000	Will light a 100 watt bulb
900	
300	Severe burns Breathing stops
200	
100	Heart stops beating
90	
60	
30	Suffocation possible
20	Muscle contraction
10	Cannot let go
5	GFCI will trip
2	Mild shock
1	Threshold of sensation

NFPA Shock Statistics

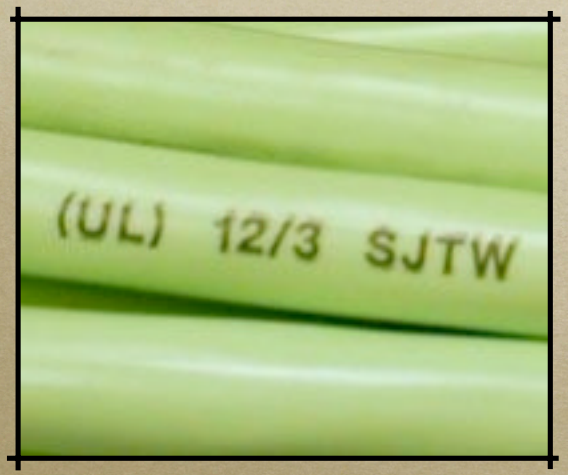
- *Over 30,000 non-fatal shock accidents occur each year*
- *Over 600 people die from electrocution each year (2+ each workday)*
- *Electrocution remains the 4th highest cause of industrial fatalities*
- *Most injuries and deaths could be avoided*

Insulation Damage

Insulation Damage

- *contact with sharp surfaces*
- *general abuse - wear and tear*
- *improper ratings for environmental conditions*
  - *SJ, SO, SEO, etc*
- *improper ratings for applied voltage*
- *strain relief*

Insulation Ratings



Repair - Black Tape?

Strain Relief

Insulation Damage

- *Temporary Wiring Conditions*
  - *Romex exposed?*
  - *90 day duration - other than construction*
  - *weather conditions*

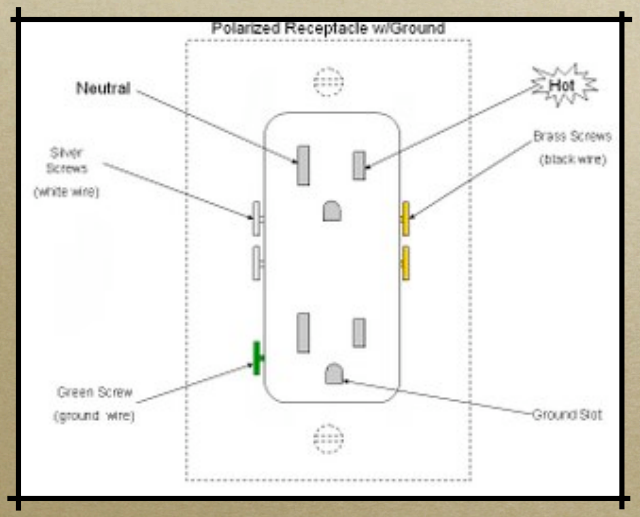
Insulation Damage

- *Fixed Wiring Methods*
  - *neat and workmanlike ??*
  - *strapped and secured*
  - *damaged during installation*
    - *Megger tests*

Tool Use

- *Internal damage*
- *Reverse polarity at plug or cordcap*
- *wet location*
- *missing ground pin on cordcap*
- *open ground on extension cord or wall plug*

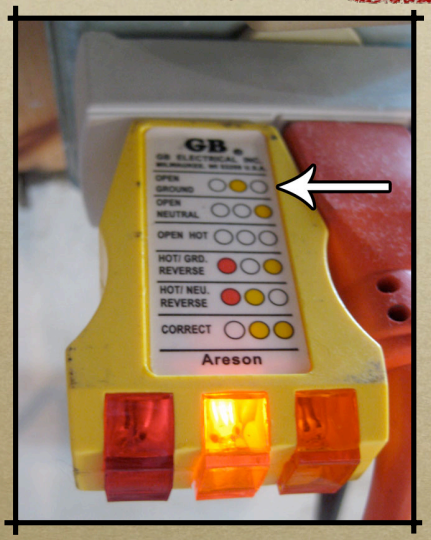
Reverse Polarity



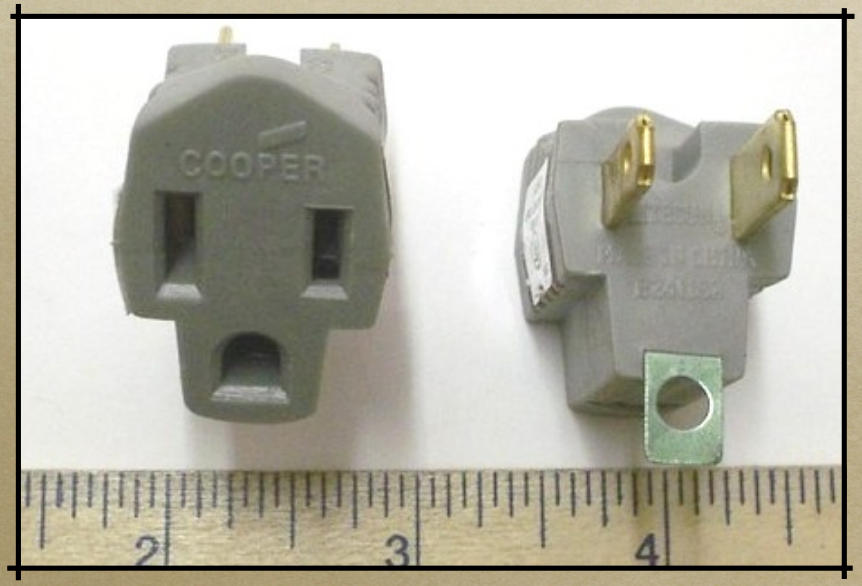
Reverse Polarity

- *more likely to become energized*
- *voltage present through tool rather than just at switch*
- *tool could auto start when plugged in*
- *proper polarity increases safety*
- *lamp holder shell and pin example*

open ground

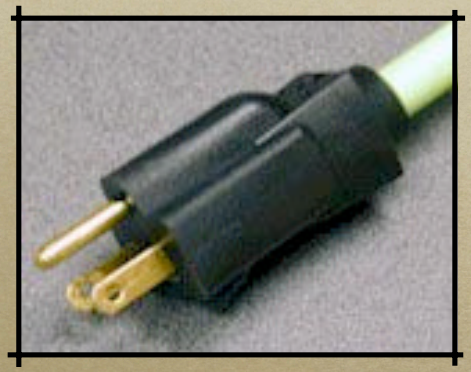

GB
OPEN GROUND
OPEN NEUTRAL
OPEN HOT
HOT/ GRD. REVERSE
HOT/ NEU. REVERSE
CORRECT
Areson

Does not magically create a ground path



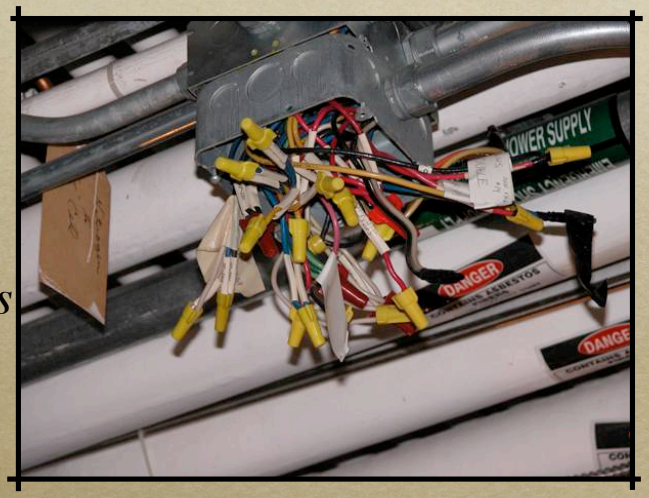
NIOSH Report

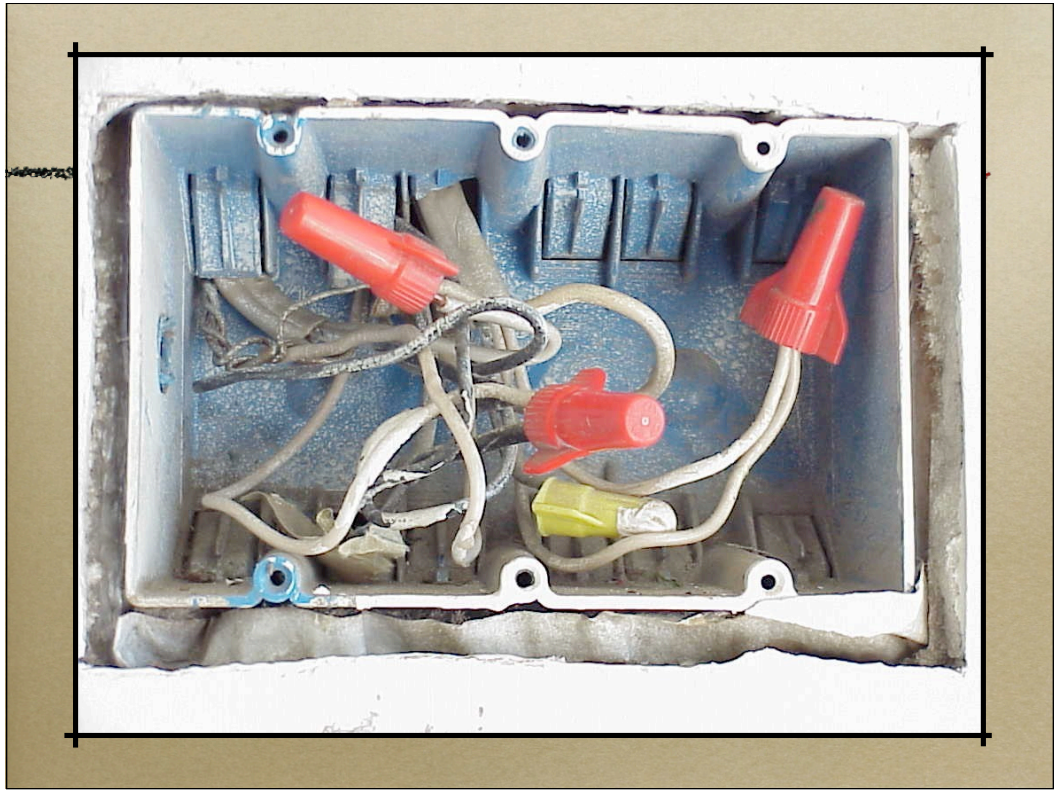
- *http://cdc.gov/niosh/87-100.html*
- *broken male or female connectors*
- *missing ground pins*
- *not continuous from tool to panel*



Shock Potential

- *Open J box covers*





Shock Potential

- *missing KO seals or blanks on panels*


Cutler-Hammer
PRL1a
Panelboard
LISTED
No. QX 244496
CLASS CTL
PANELBOARD
DANGER
Hazardous voltage will cause severe injury or death.
Turn off power supplying this equipment before working inside.
1 2
3 4
5 6
7 8
9 10
11 12
13 14
15 16
15
15
20

Shock Potential

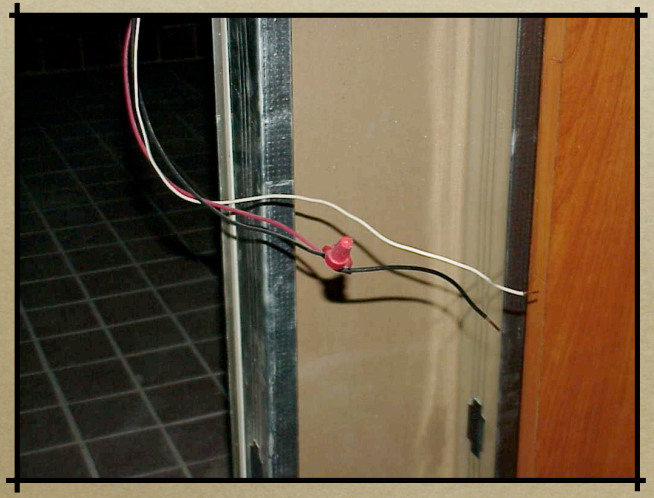
- *broken faceplates on switches or plugs*

Shock Potential

- *Exposed live wires*

Shock Potential

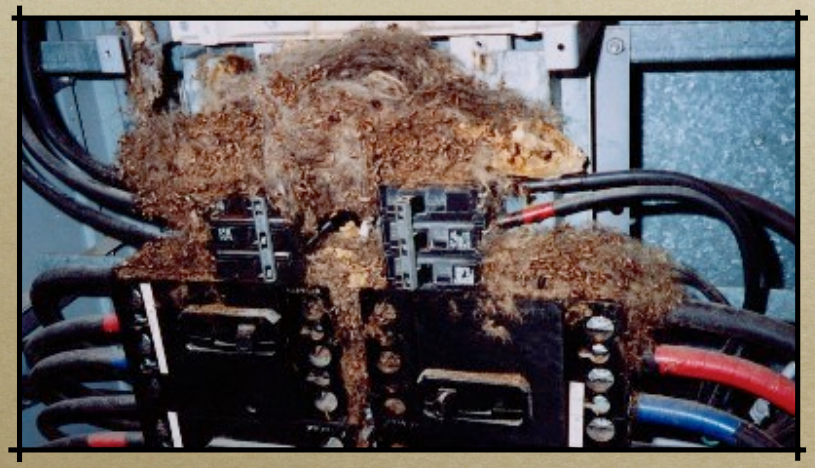
- *open splices*



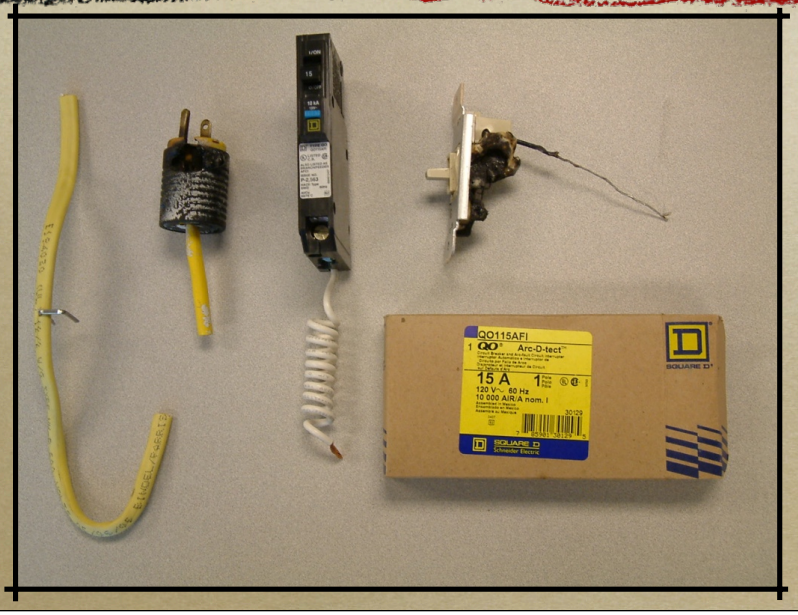
Other Electrical Hazards - Fires

- *Arcing / overheating of equipment and conductors*
- *Improperly sized overcurrent protection or conductors*
- *Loose connections - improper terminations*
- *Corrosive conditions*

Examples

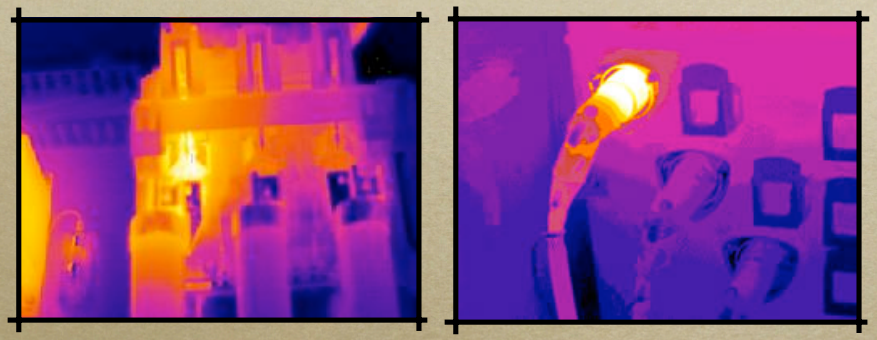


Examples



Examples

Examples



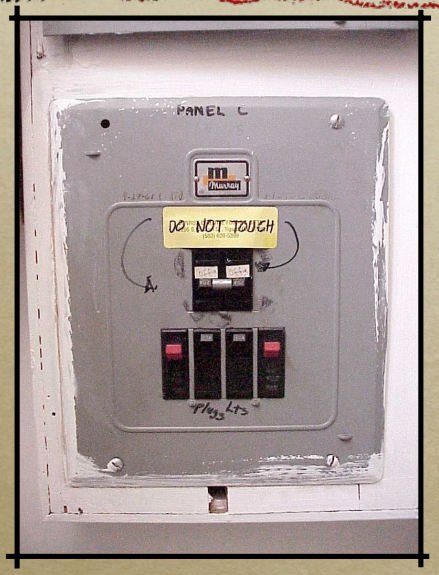
- *I R Scans depict hot spots*

Other Electrical Hazards - ID

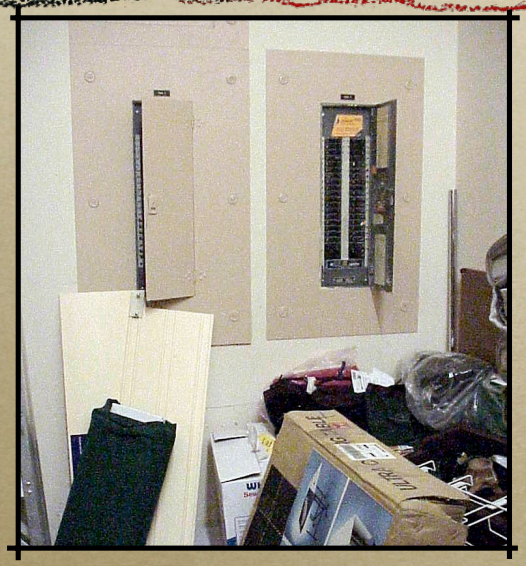
- *Lack of proper labeling of circuits at panel or disconnect location*

Other Electrical Hazards - ID

Other Electrical Hazards - ID



Other Electrical Hazards - Working space



Other Electrical Hazards - Working space

- *30 inch width minimum*
- *36 inch depth minimum*
- *height 6.25 - 6.5 feet*