Electrical Aspects of Fire Investigation

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This presentation –
https://Electrical-Forensics.com/LA-IAAI.pdf

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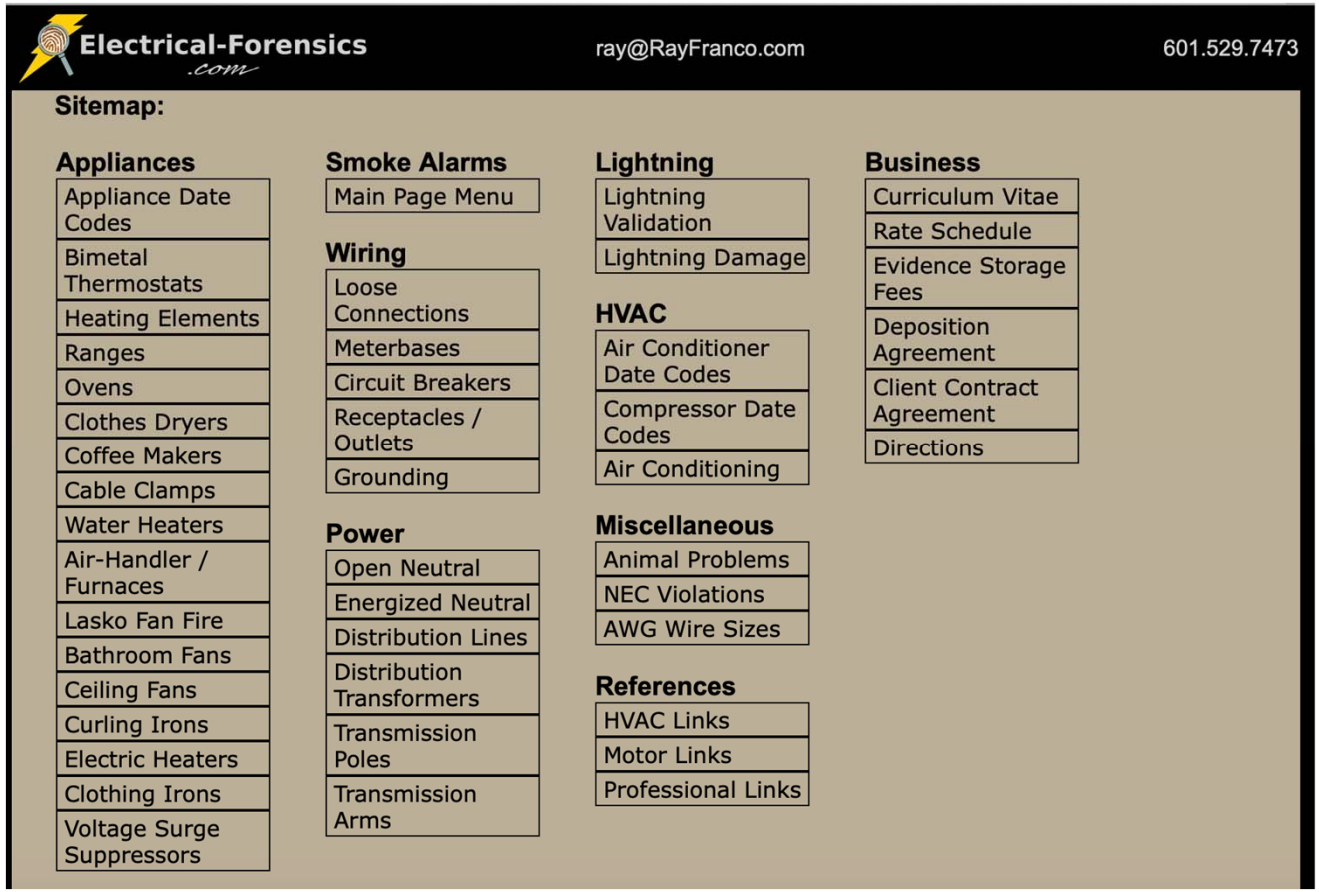


Below this, is this presentation: https://Electrical-Forensics.com/LA-IAAI.pdf

BASIC TERMS

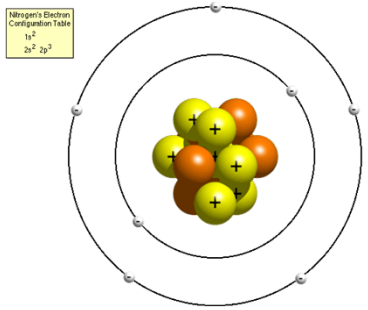
Just like in every other aspect of fire investigations, there are terms and principals that need to be understood.

For some these will be new, and others this will be a refresher.

Electricity

- Electricity is the flow of electric power or charge.
- Electrons are charged particles, so electricity is the flow of electrons.
- A conductor is a material in which electrons can easily flow. Most metals are conductors.
- An insulator is a material in which electrons can not easily flow e.g. air, plastics, and dry wood.

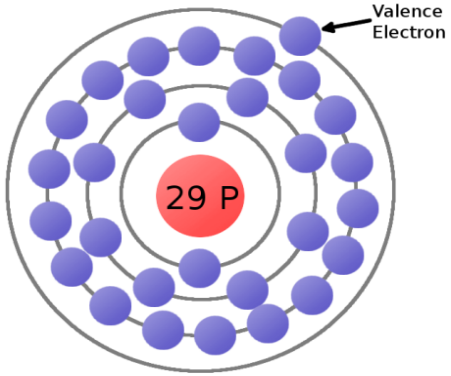
ATOMIC THEORY



- All matter is made of atoms.
- Protons + neutrons = nucleus.
- Electrons forms valance rings.
- # of electrons = # of protons.
- Outer valence ring has 1 to 8 electrons.
- 1-2 electrons in outer ring = unstable ring (conductor).

  Examples: Silver, Copper, Gold, Aluminum.
- 6-8 electronics in outer ring = insulator

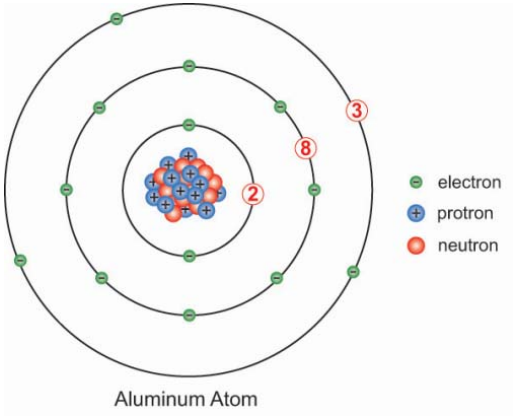
ATOMIC THEORY



Copper Atom

- More valence electrons in the outer ring = more stability
- More stability = Less conductive

- Copper atom has 1 valence electron

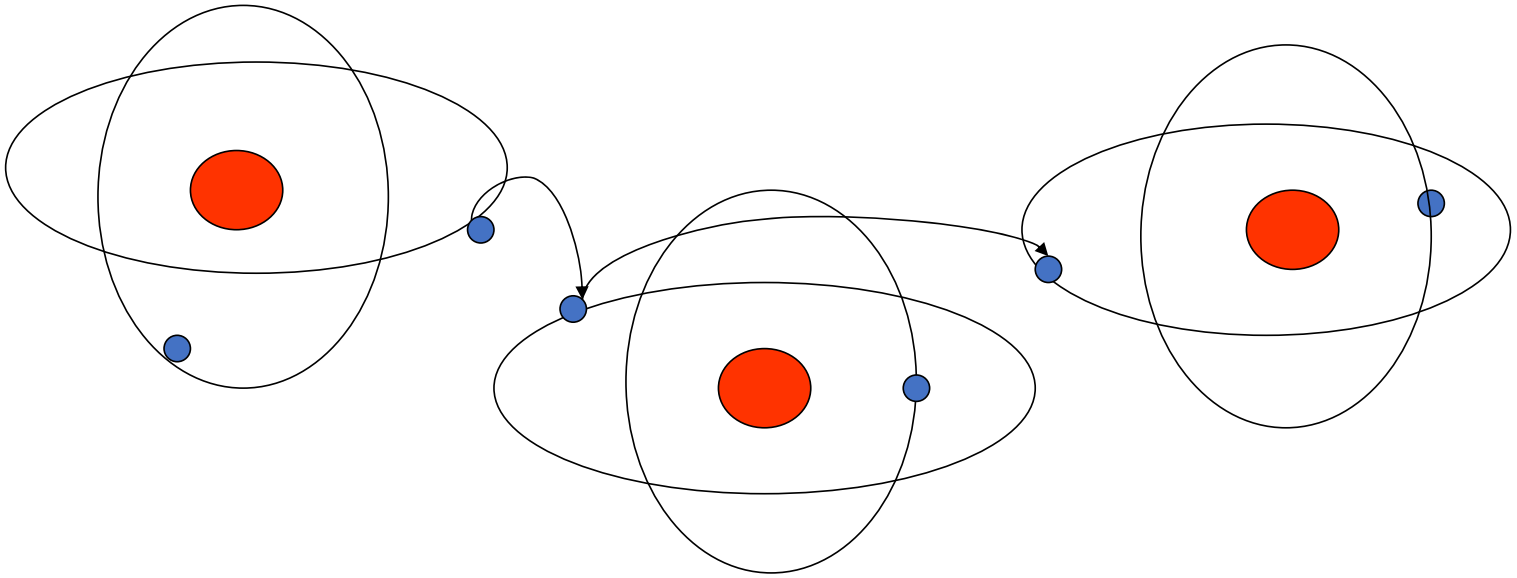


Aluminum Atom

- Aluminum atom has 3 valence electrons
- Aluminum takes 3 times as much energy to move those free electrons as copper – this is why aluminum conductors, when used, need to be larger than copper to carry the same amount of current.

ATOMIC THEORY

- When a ring is unstable electrons will bump other electrons from other similar atoms causing a electron flow... Electricity!



We can disturb (excite) the electrons in the outer shells with magnets.

CURRENT (AMPERE)

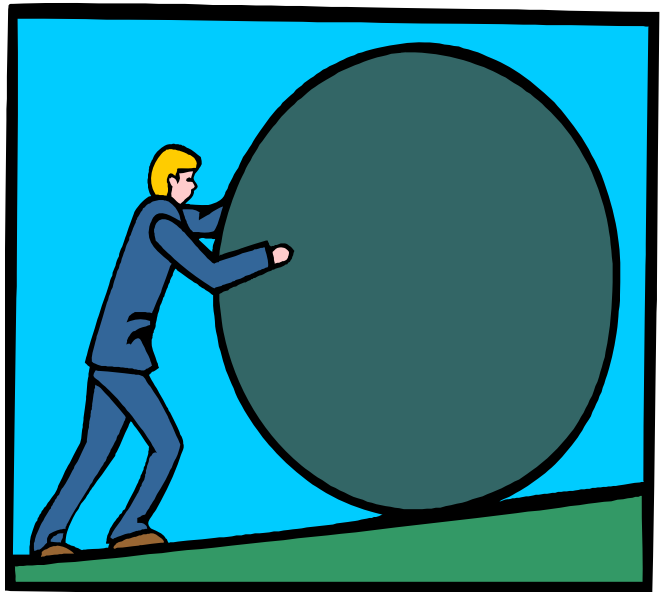
Is the rate at which electrons flow through a conductor. It is determined by measuring the amount of electrons flowing past a single point in one second.

I = Ampere or Amp

1 Amp = 6,240,000,000,000,000,000 electrons/second

$= 6.24 \times 10^{18}$

VOLTAGE (VOLTS)

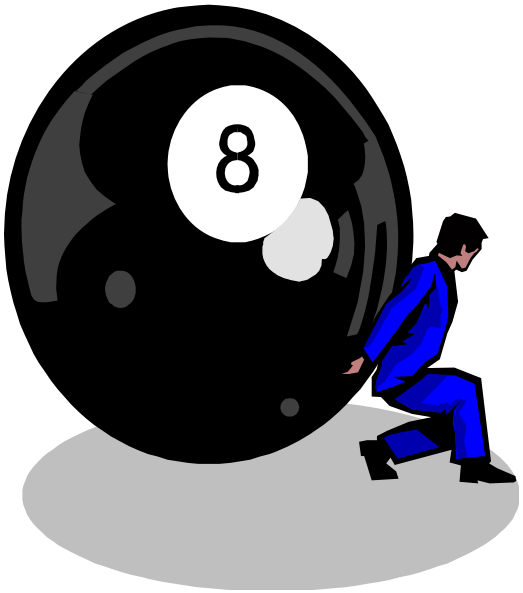


- Electrical pressure that moves the electrons through the conductor
- Also known as Electromotive Force (EMF)

E = Volts

Volts is the potential difference between two points.

RESISTANCE (OHMS)



Resistor Symbol

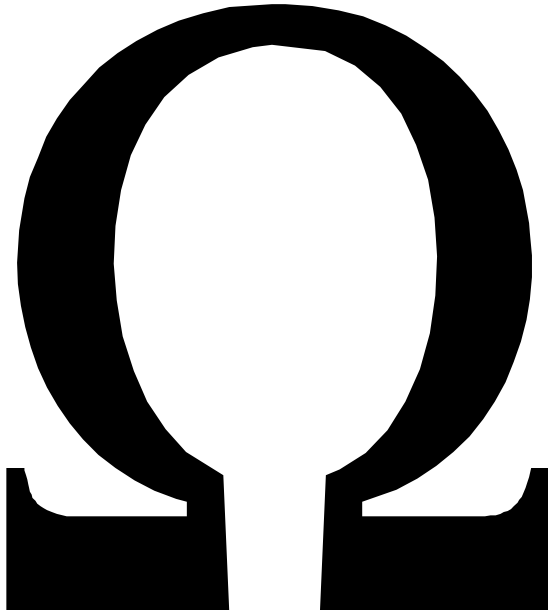
This is the opposition to current flow.

Measured in Ohms

Greek Symbol Omega

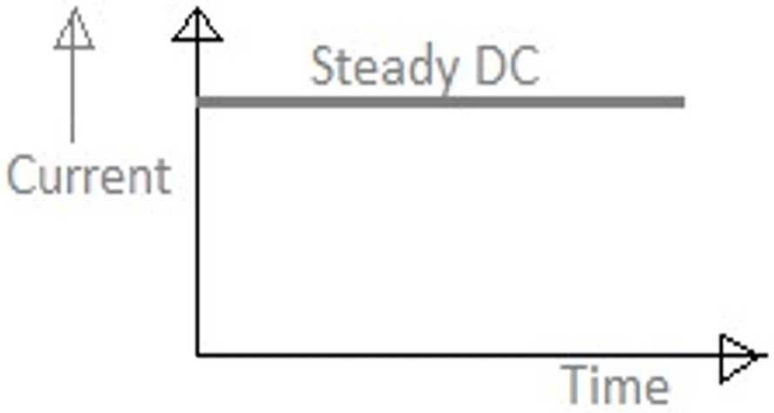
Ω=R

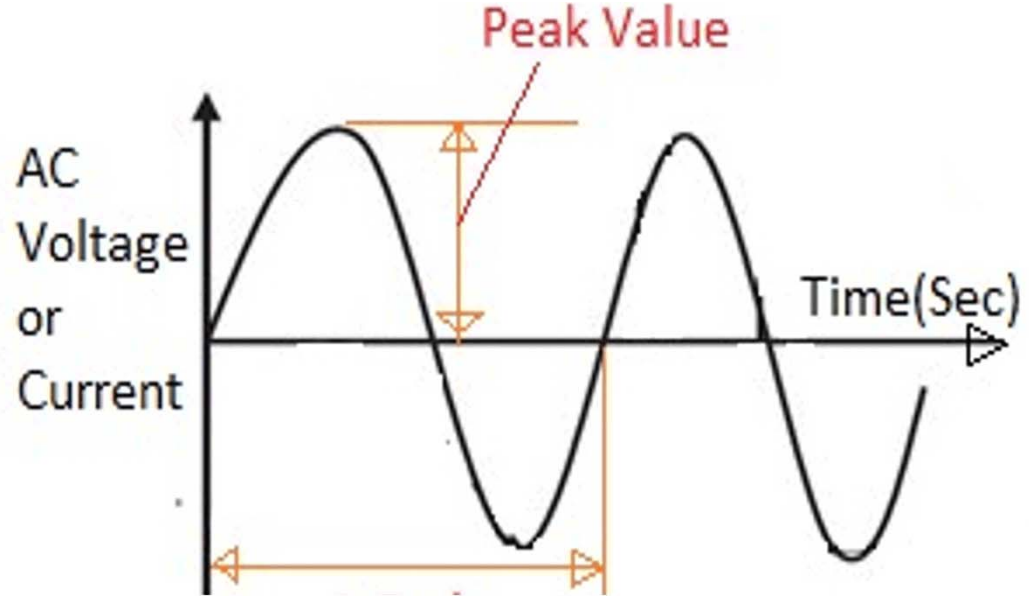
RESISTANCE (OHMS)



- When current flows through any resistance, heat is always generated. Every conductor offers some resistance.
- Every splice/connection in a circuit creates some resistance.
- Excessive resistance can create high temperatures.

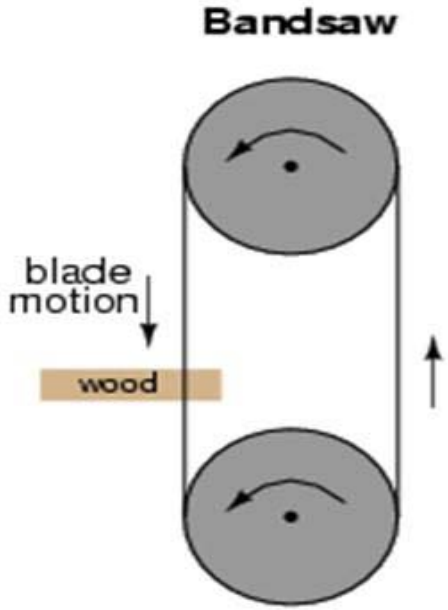
Direct Current (DC) vs Alternating Current (AC)



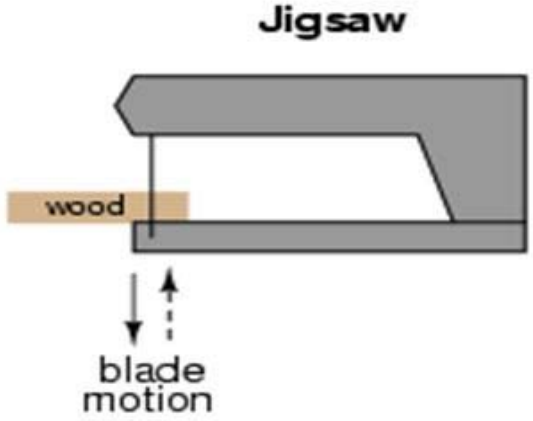


ELECTRICAL THEORY

DC vs. AC Current



(analogous to DC)



(analogous to AC)

DC CURRENT

- Most recognized as a battery, found in power supplies, DC generators.
- In some industrial applications DC is used for numerous operations.

Batteries

An electrochemical battery produces electricity with two different metals in a chemical substance called an *electrolyte*. One end of the battery is attached to one of the metals, and the other end is attached to the other metal. A chemical reaction between the metals and the electrolyte frees more electrons in one metal than it does in the other.

- What in a home uses AC Power?
- Answer - Anything that generates heat or has a motor: Cooktops, Ranges, Dryer, Refrigerator, Air Conditioners.

- What in a home uses DC Power?
- Answer - Anything that is electronic.

- What is a DC Power Supply?
- Answer – A device that converts AC Power to DC Power. This requires very few parts and is easy to design.

OHM'S LAW

Ohm's Law was named after Georg Simon Ohm (1787-1854).

Ohm's Law is stated as:

"The amount of current flowing in a circuit made up of pure resistance is directly proportional to the electromotive forces impressed on the circuit and inversely proportional to the total resistance of the circuit.“

Valid for both DC and AC circuits.

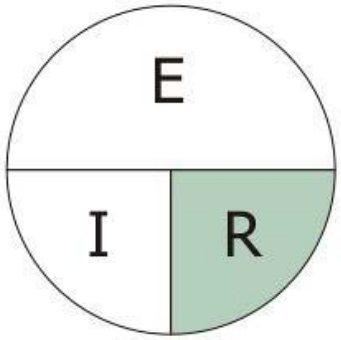
The Three forms of Ohm's Law

$$I(current) = \frac{E\ (voltage)}{R\ (resistances)}$$

$E(voltage)$ = I (current) x R (resistance)

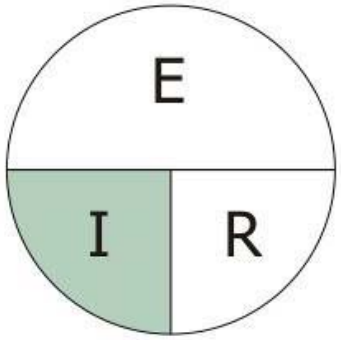
$$R(Resistance) = \frac{E\ (voltage)}{I\ (Current)}$$

BASIC OHM'S LAW



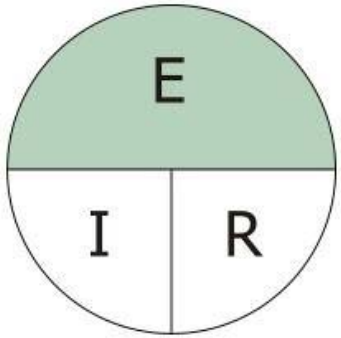
$R = \frac{E}{I}$

Resistance = Voltage ÷ Current



$I = \frac{E}{R}$

Current = Voltage ÷ Resistance



$E = I \times R$

Voltage = Current x Resistance

JOULE'S LAW

James Prescott Joule (1818-1889) formulated a relationship between the heat generated in an electric wire and the voltage across and current through that wire.

The Three forms of Joules' Law

P ($power$) = E (voltage) x I (current)

$$E(voltage) = \frac{P\ (power)}{I\ (Current)}$$

$$I(current) = \frac{P\ (power)}{E\ (voltage)}$$

Power (watts) = E (volts) x I (current)

What is a power ? It is the rate that you are using energy.

$$power = \frac{energy}{time}$$

What is a watt?

$$watt = \frac{joule}{second}$$

and a joule is a measure of energy in the metric system.

So, a 600-watt coffee maker uses 600 joules of energy every second.

But your electric bill does not say how many joules of energy you use. It says how many kilowatt-hours of energy you used.

$$power = \frac{energy}{time}$$

energy = power x time

For example, a 600-watt coffee maker that is on for 1 hr uses 0.6 kWh of energy.

kilo = 1,000 and milli = 1/1,000.

1 kW = 1,000 watts and 1 kV = 1,000 volts and 1 mA = $\frac{1}{1{,}000}$ A

The name power meter is misleading. It is an energy meter.

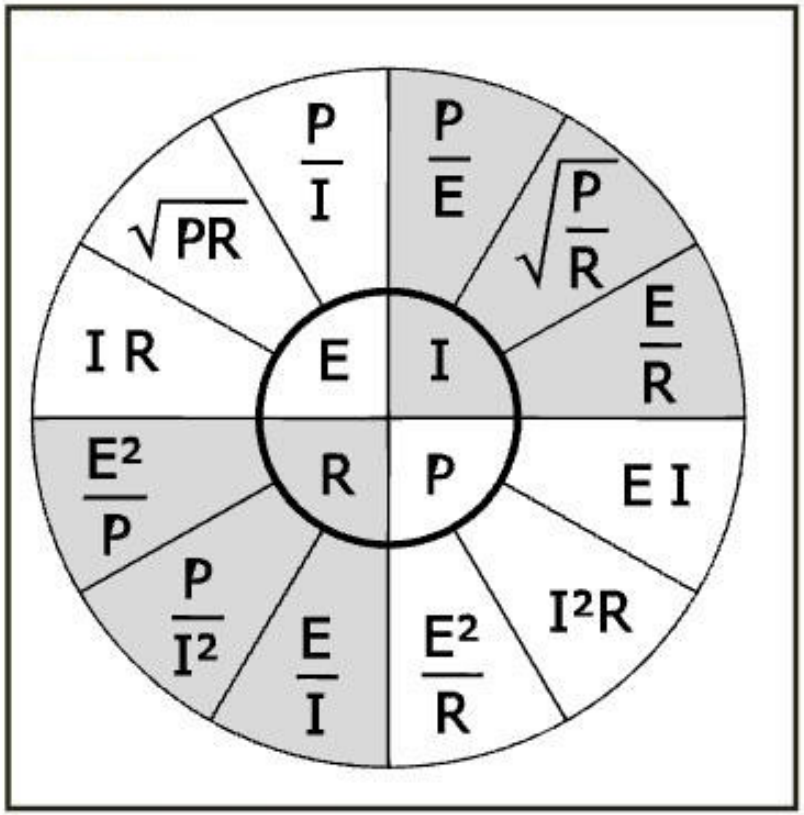
State	Nov 2023
Louisiana	9.37¢ / kWh
Mississippi	11.55¢ / kWh
Alabama	12.41¢ / kWh

In 1950, the average cost was 32¢ / kWh.

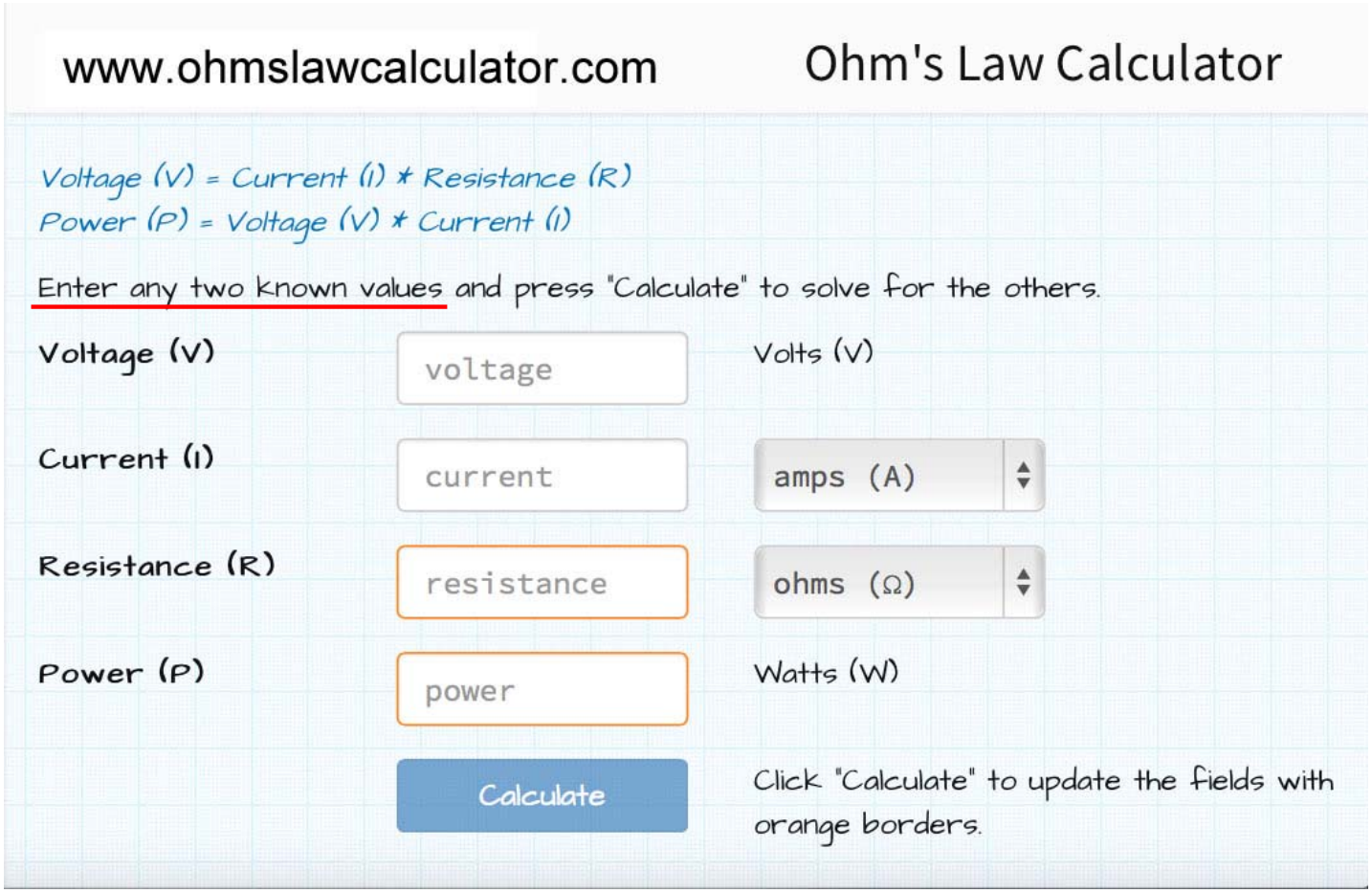
Ohm's Law Wheel - 2021 NFPA 921, Section 9.2.7

Voltage (E) = Current (I) * Resistance (R)

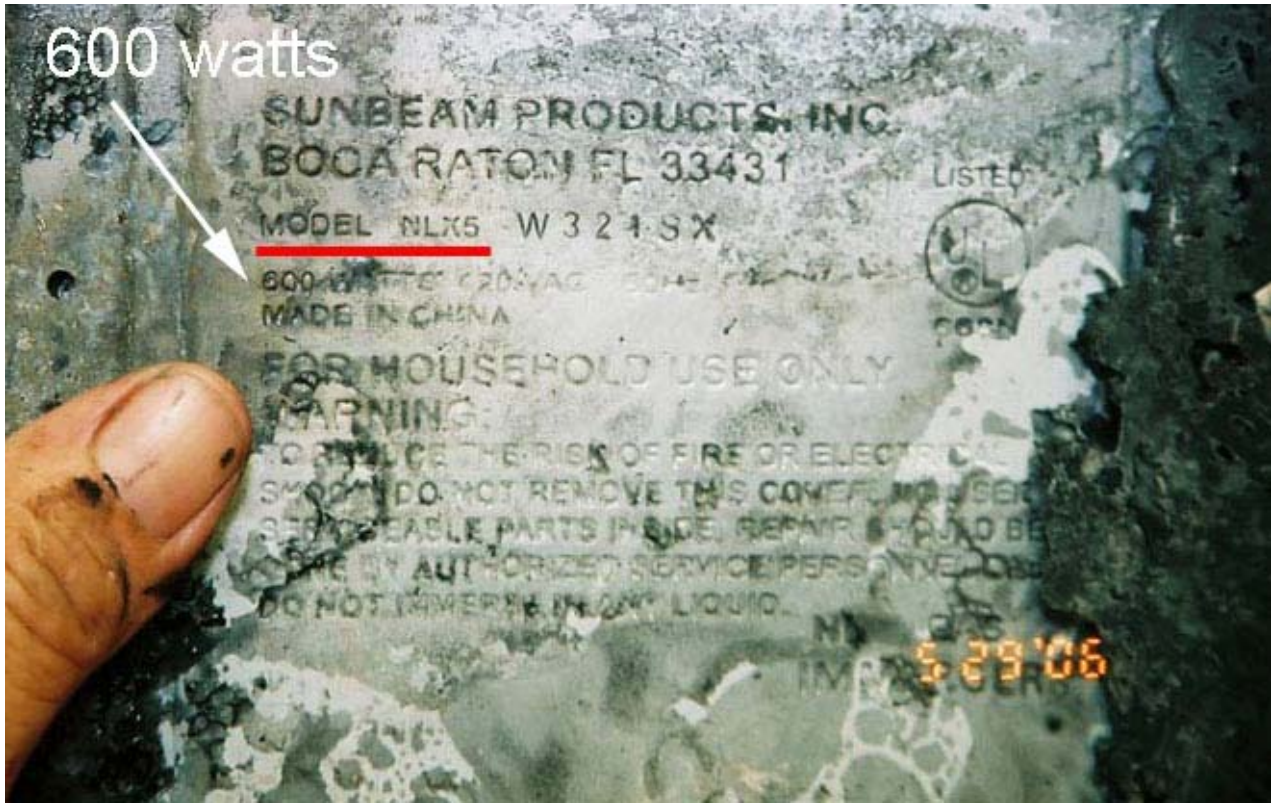
Power (P) = Voltage (E) * Current (I)



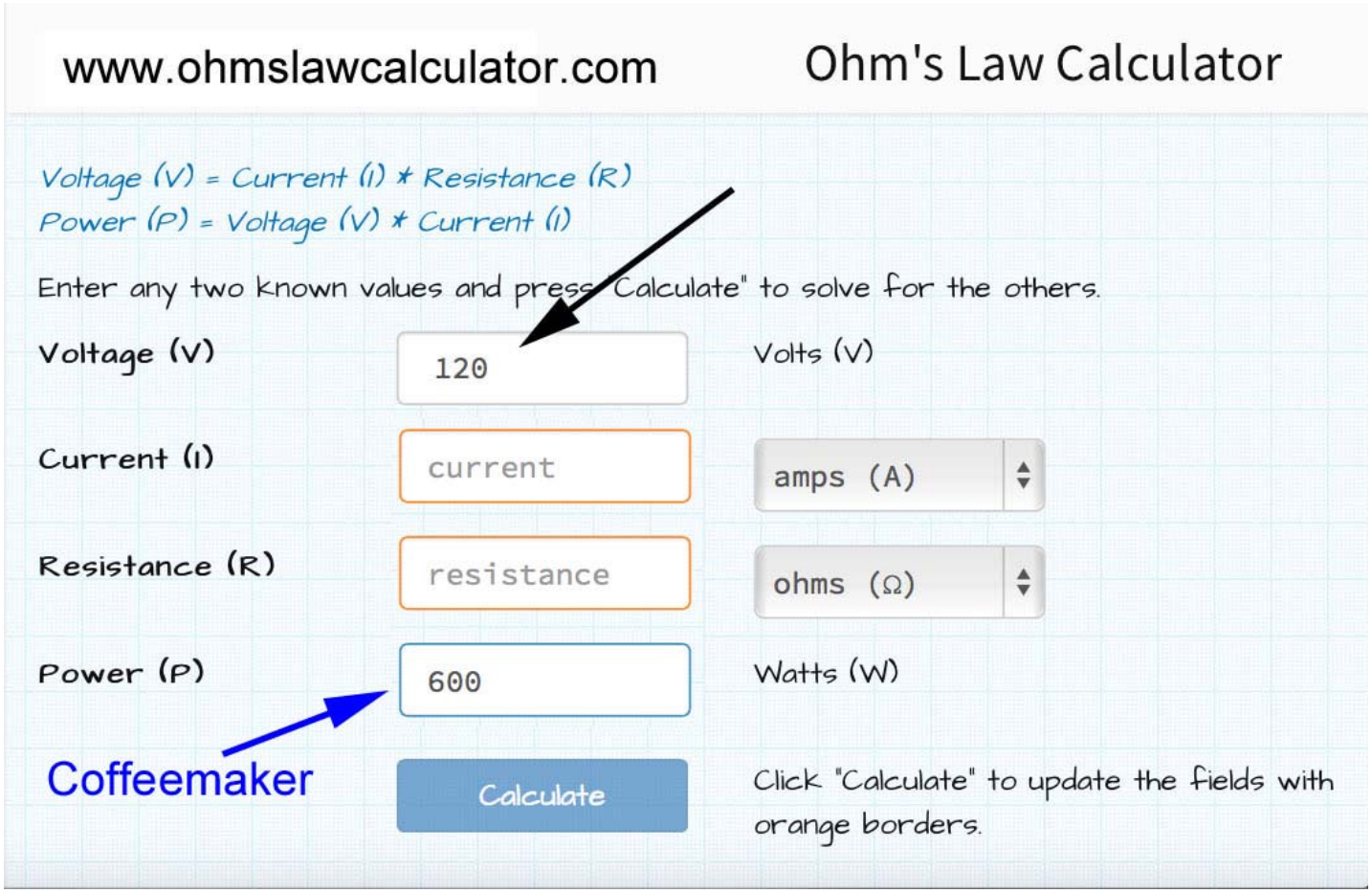
E = voltage I = current
R = resistance P = power

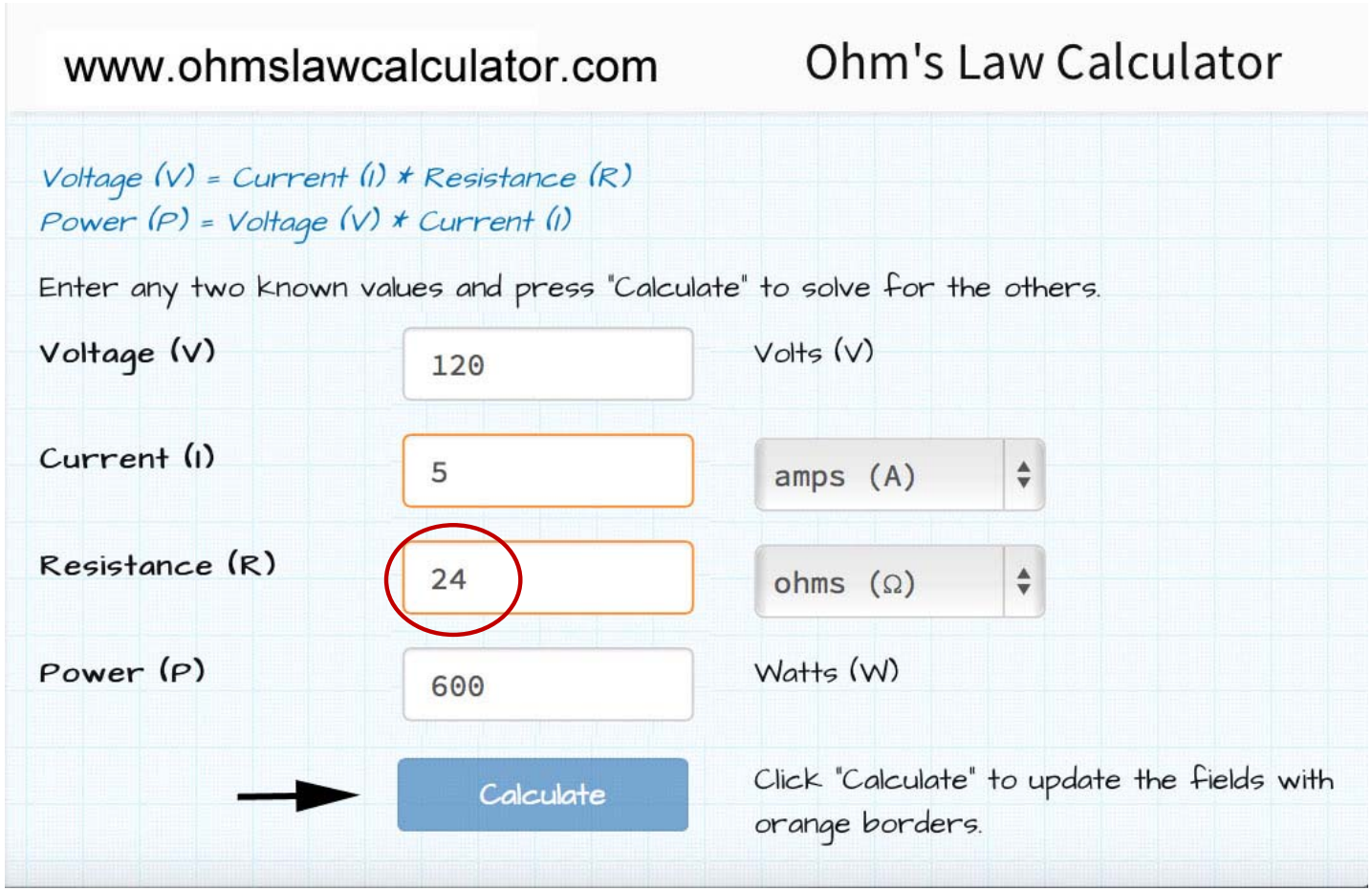

www.ohmslawcalculator.com
Ohm's Law Calculator
Voltage (V) = Current (I) * Resistance (R)
Power (P) = Voltage (V) * Current (I)
Enter any two known values and press "Calculate" to solve for the others.
Voltage (V)
voltage
Volts (V)
Current (I)
current
amps (A)
Resistance (R)
resistance
ohms (Ω)
Power (P)
power
Watts (W)
Calculate
Click "Calculate" to update the fields with orange borders.

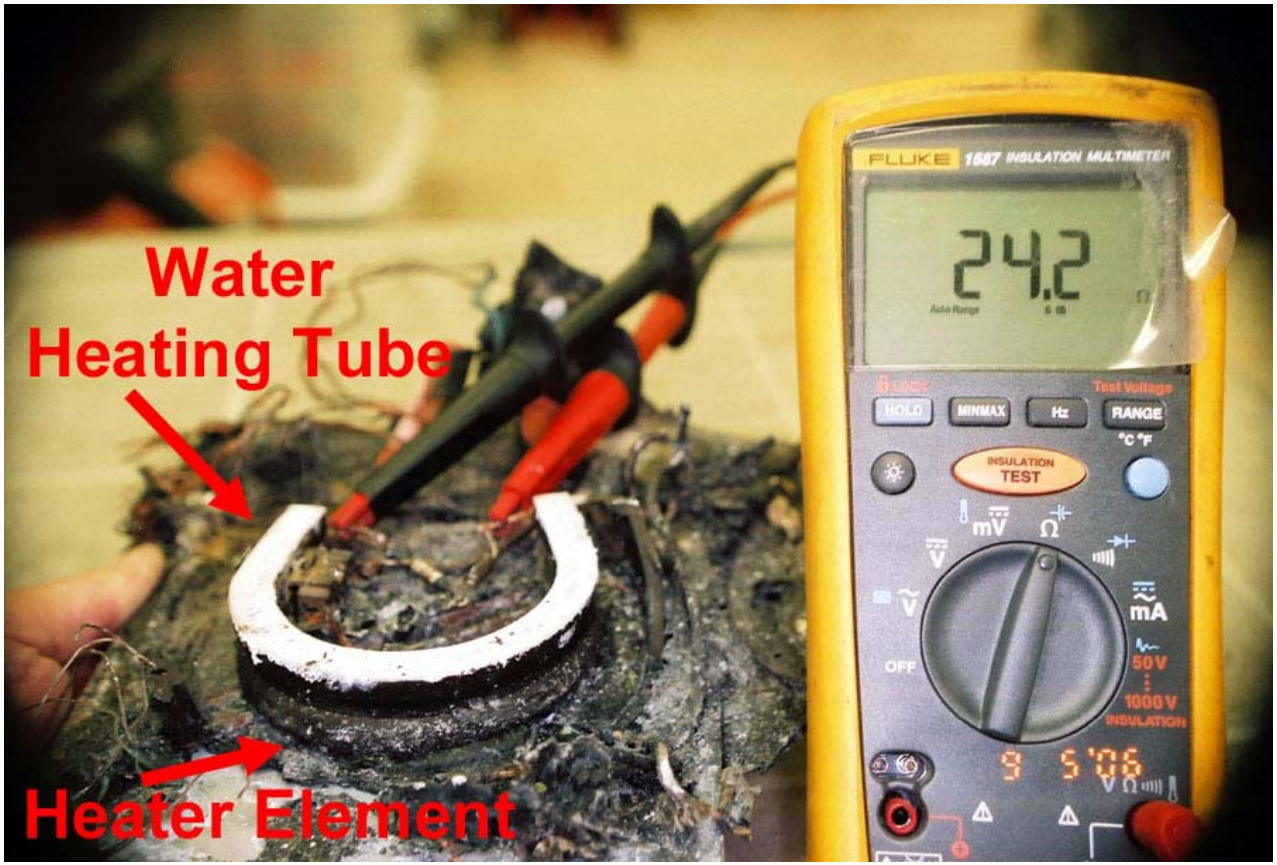
HOME APPLIANCE	WATTAGE*	HOME APPLIANCE	WATTAGE*
Broiler	1,400	Central Air Conditioning	2,000-4,000
Refrigerator / Freezer	600-800	Coffeemaker	400-800
Electric Furnace	5,000-25,000	Electric Range (oven only)	5,000
Electric Range (one element)	2,500	Hair Dryer	1,200-1,500
Table Lamp (tri-lite)	150	Sump Pump	1,500
Television	100-350	Vacuum	700-1,400
Heater (radiant)	1,300	Space Heater	1,250
Toaster	1,100-1,700	Water Heater	3,000-4,500
Microwave	1,200	Water Pump	1,000-2,000
Hot Plate	1,250	Window Air Conditioner	600-1,500
Outdoor Lighting	500-1,000	Personal Computer	500-2,000


600 watts
SUNBEAM PRODUCTS, INC.
BOCA RATON FL 33431
LISTED
MODEL NLX5 W 3 2 1 S X
MADE IN CHINA
FOR HOUSEHOLD USE ONLY
WARNING
DO NOT REMOVE THIS COVER
DO NOT IMMERSE IN ANY LIQUID
5'29'06

Burned Coffeemaker

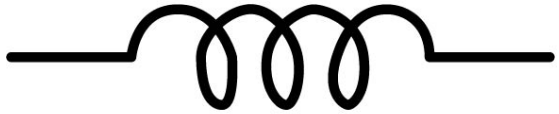

www.ohmslawcalculator.com
Ohm's Law Calculator
Voltage (V) = Current (I) * Resistance (R)
Power (P) = Voltage (V) * Current (I)
Enter any two known values and press "Calculate" to solve for the others.
Voltage (V)
120
Volts (V)
Current (I)
current
amps (A)
Resistance (R)
resistance
ohms (Ω)
Power (P)
600
Watts (W)
Coffeemaker
Calculate
Click "Calculate" to update the fields with orange borders.


www.ohmslawcalculator.com
Ohm's Law Calculator
Voltage (V) = Current (I) * Resistance (R)
Power (P) = Voltage (V) * Current (I)
Enter any two known values and press "Calculate" to solve for the others.
Voltage (V)
120
Volts (V)
Current (I)
5
amps (A)
Resistance (R)
24
ohms (Ω)
Power (P)
600
Watts (W)
Calculate
Click "Calculate" to update the fields with orange borders.

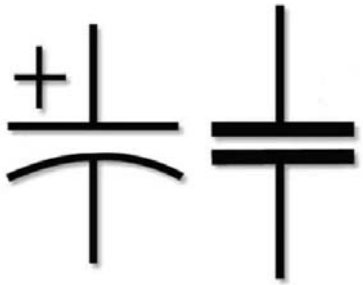

Water
Heating Tube
Heater Element
FLUKE 1507 INSULATION MULTIMETER
24.2
HOLD
MINMAX
Hz
RANGE
INSULATION
TEST
OFF
50 V
1000 V
INSULATION

Inductors and Capacitors

- An inductor is a coil of wire, usually wrapped around soft iron. The windings in a motor are inductors.



- A capacitor consists of two conducting surfaces on which a charge may be stored, separated by a thin insulating layer, which has a very high resistance.



- In a direct current circuit:
- An inductor looks like a short circuit
- A capacitor looks like an open circuit

- However, in an alternating current circuit, inductors and capacitors imped the flow of electrons. We use the letter Z for impedance.

The impedance of an inductor is: $Z_L = j2\pi fL$ = j377 L Ω

The impedance of a capacitor is: $Z_C = 1/(j2\pi fC)$ = 1 /(j377 * C) Ω

Where $j = \sqrt{-1}$; so now we are dealing with complex number that have both real and imaginary part.

- The unit for impedance is the same as that for resistance – ohms.

HOME APPLIANCE	WATTAGE*	HOME APPLIANCE	WATTAGE*
Broiler	1,400	Central Air Conditioning	2,000-4,000
Refrigerator / Freezer	600-800	Coffeemaker	400-800
Electric Furnace	5,000-25,000	Electric Range (oven only)	5,000
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Microwave	1,200	Water Pump	1,000-2,000
Hot Plate	1,250	Window Air Conditioner	600-1,500
Outdoor Lighting	500-1,000	Personal Computer	500-2,000

Ohm's Law Calculator for Central Air Conditioner

*Voltage (V) = Current (I) * Resistance (R)*
*Power (P) = Voltage (V) * Current (I)*

Enter any two known values and press "Calculate" to solve for the others.

Voltage (V)	240	Volts (V)
Current (I)	current	amps (A)
Resistance (R)	resistance	ohms (Ω)
Power (P)	3000	Watts (W)

Calculate

Click "Calculate" to update the fields with orange borders.

Ohm's Law Calculator for Central Air Conditioner

*Voltage (V) = Current (I) * Resistance (R)*
*Power (P) = Voltage (V) * Current (I)*

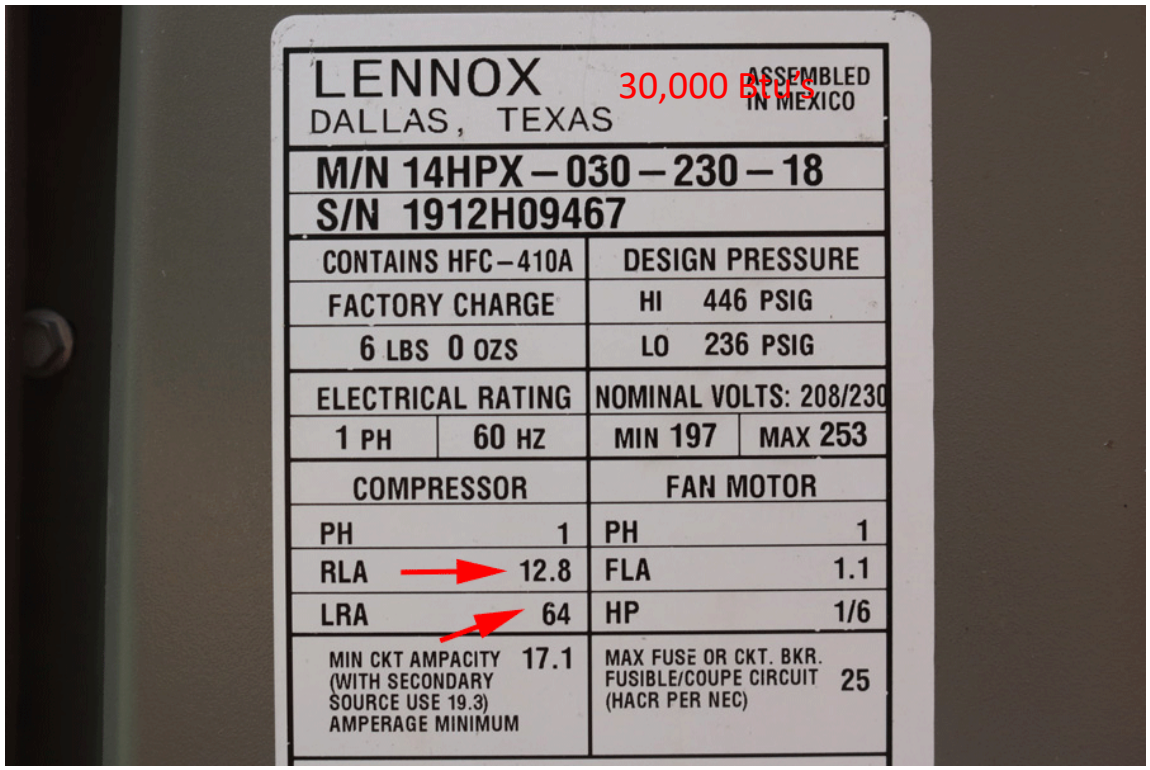
Enter any two known values and press "Calculate" to solve for the others.

Voltage (V)	240	Volts (V)
Current (I)	12.5	amps (A)
~~Resistance (R)~~ Impedance	19.2	ohms (Ω)
Power (P)	3000	Watts (W)

Calculate

Click "Calculate" to update the fields with orange borders.

We do not have a hand-held meter to measure impedance.

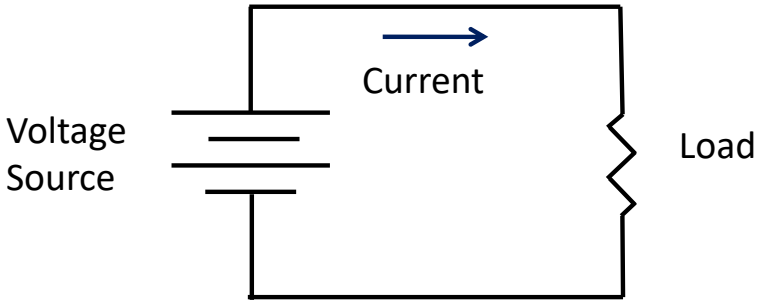


RLA = Rated Load Amps

LRA = Locked Rotor Amps.

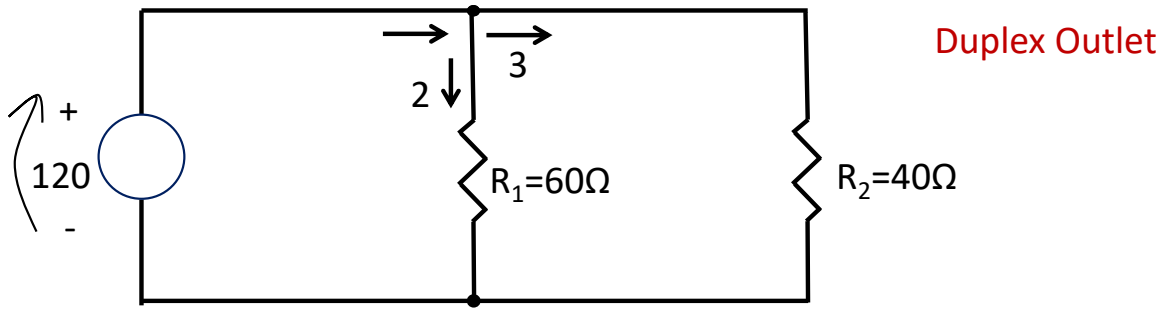
It is takes ≈ 5 times more current to start a motor turning.

- For electricity to flow, there must be a complete path back to the source.



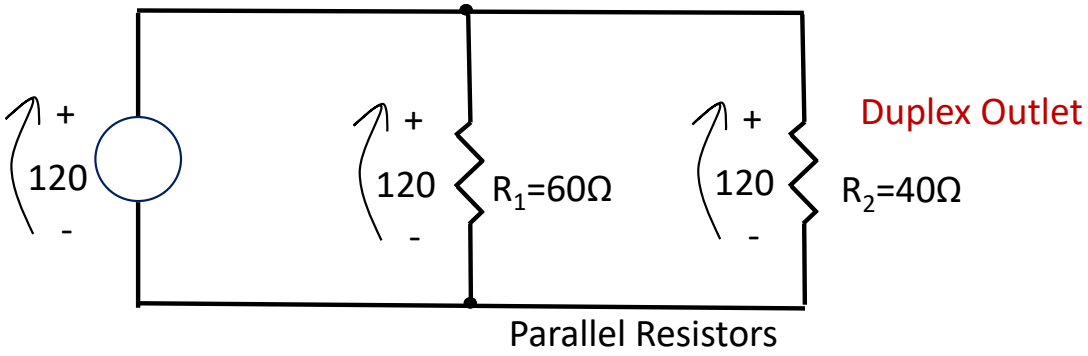
Electricity does not want to flow into the earth. It wants to go back to the source. However, if there is a path through the earth back to the source, some current will take this path. Electricity takes all paths. Compared to a wire, the resistance of the earth is large.

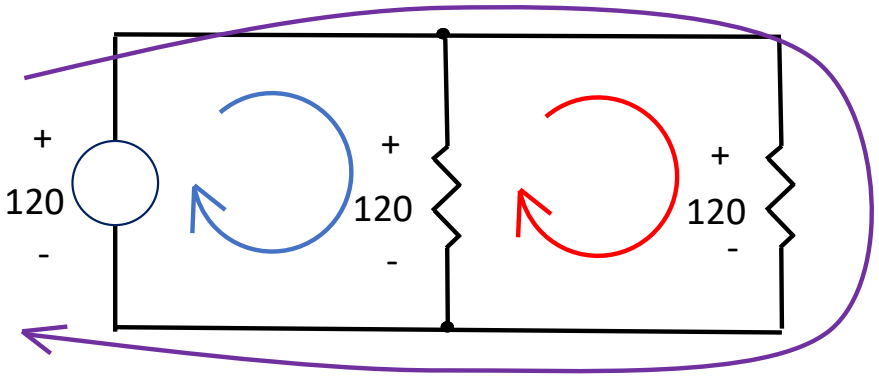
Kirchhoff's Current Law: The sum of the currents flowing into a node is zero, or the sum of the currents entering a node equal the sum of the currents leaving the node.



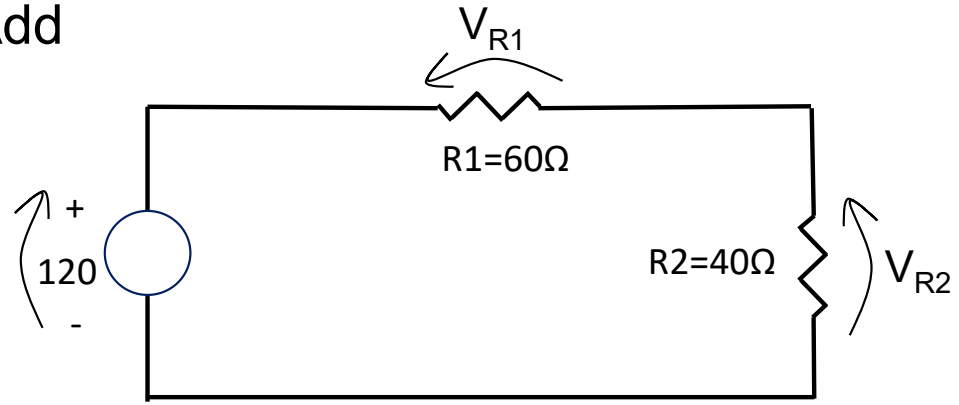
If 4 receptacles are connected to the same circuit breaker, the current flowing through the circuit breaker is the sum of the currents flowing through each receptacle.

Kirchhoff's Voltage Law: "The sum of the voltages around any closed loop is zero".





Series Resistors Add



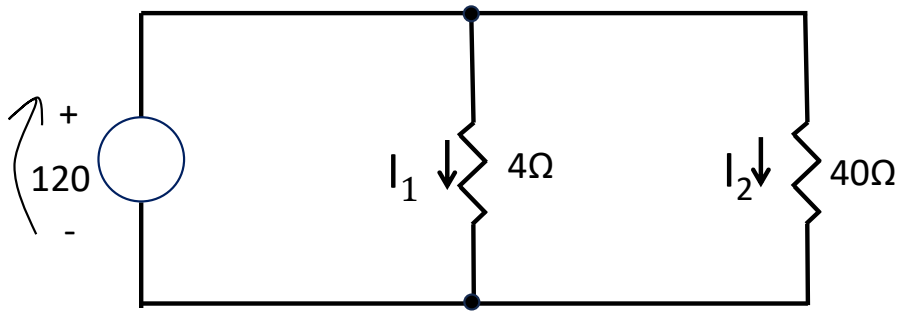
$$I = \frac{V}{R_{Total}} = \frac{120}{R1+R2} = \frac{120}{60+40} = 1.2 \text{ amps}$$ Ohms Law

$$V_{R1} = I * R1 = 1.2\ x\ 60 = 72\ volts$$ Ohms Law

$$V_{R2} = I * R2 = 1.2\ x\ 40 = 48\ volts$$ Ohms Law

$$120 = VR_1 + VR_2 = 72 + 48$$ Kirchhoff's Voltage Law

The statement that electrical current takes the path of least resistance is misleading. It takes all paths. The majority of the current takes the path of least resistance.



$$I_1 = \frac{120}{4} = 30 \text{ amps}$$

$$I_2 = \frac{120}{40} = 3 \text{ amps}$$

Test Question

Kirchhoff's voltage law states that the sum of the voltages around any closed loop is zero.

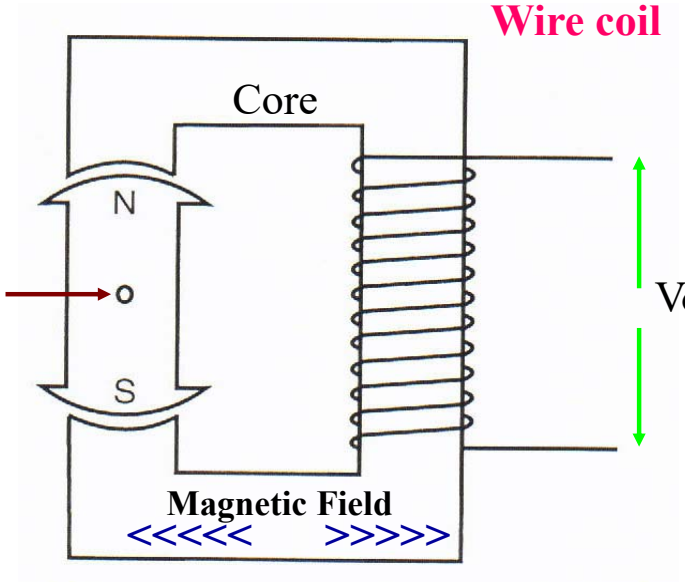
A) True
B) False
C) Except when transformers are used.

Electricity and Magnetism

The properties of magnets are used to make electricity. Moving magnetic fields pull and push electrons. Metals such as copper and aluminum have electrons that are loosely held. Moving a magnet around a coil of wire, or moving a coil of wire around a magnet, pushes the electrons in the wire and creates an electrical current. Electricity generators essentially convert kinetic energy (the energy of motion) into electrical energy.

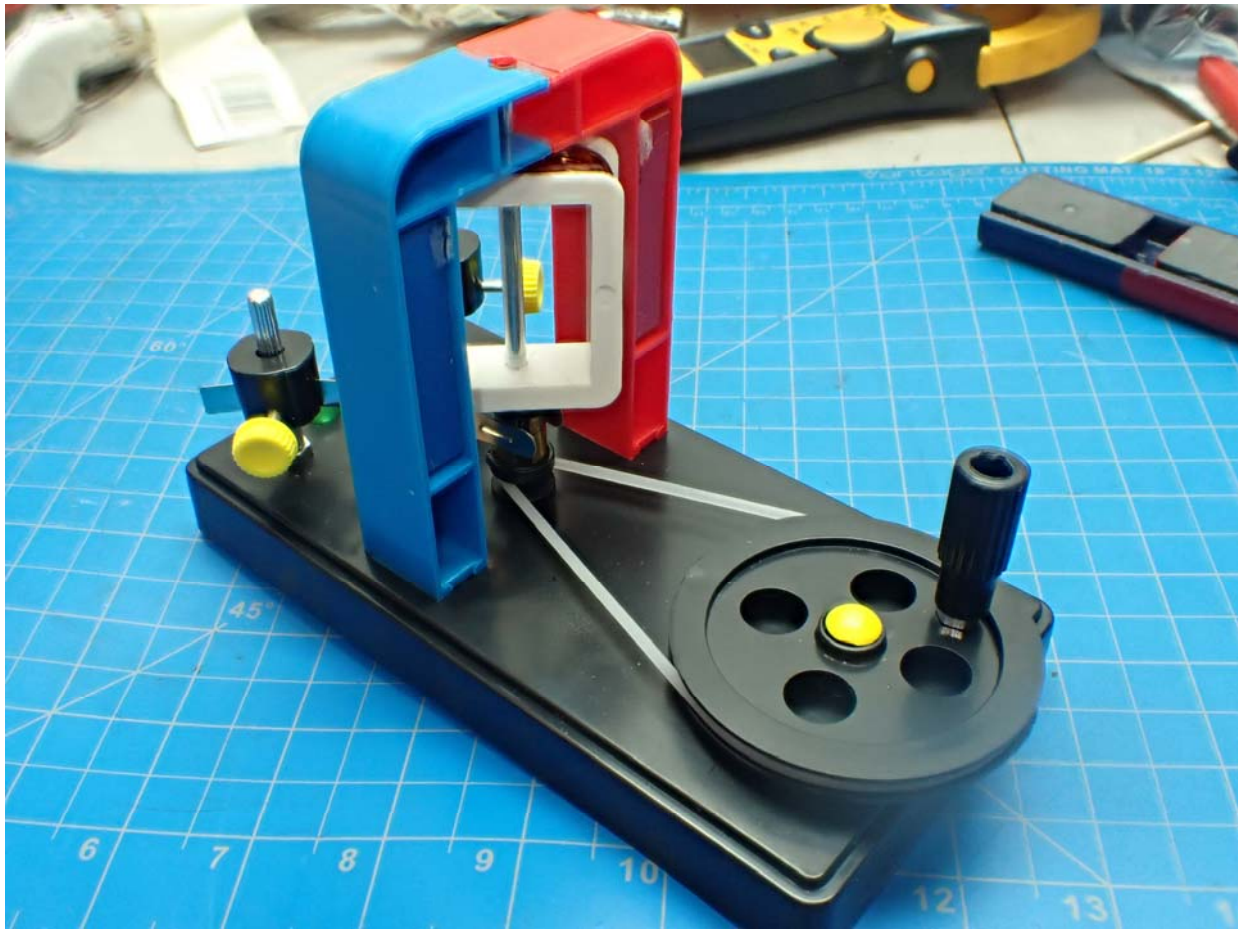
WHAT CAUSES THE ELECTRONS TO MOVE: MAGNETISM

A magnet is rotated in a core



As the magnet is rotated, it creates a magnetic field in the core.
This field is strongest when the magnet is aligned vertically as shown.
When the magnet is rotated to horizontal the field is decreasing to zero.
The field reverses and increases as the magnet continues to rotate.
This increasing, decreasing and reversing field creates a voltage potential in the coil. The voltage waveform is a sine wave, this is how A/C or alternating current is generated.

Demo of a Generator

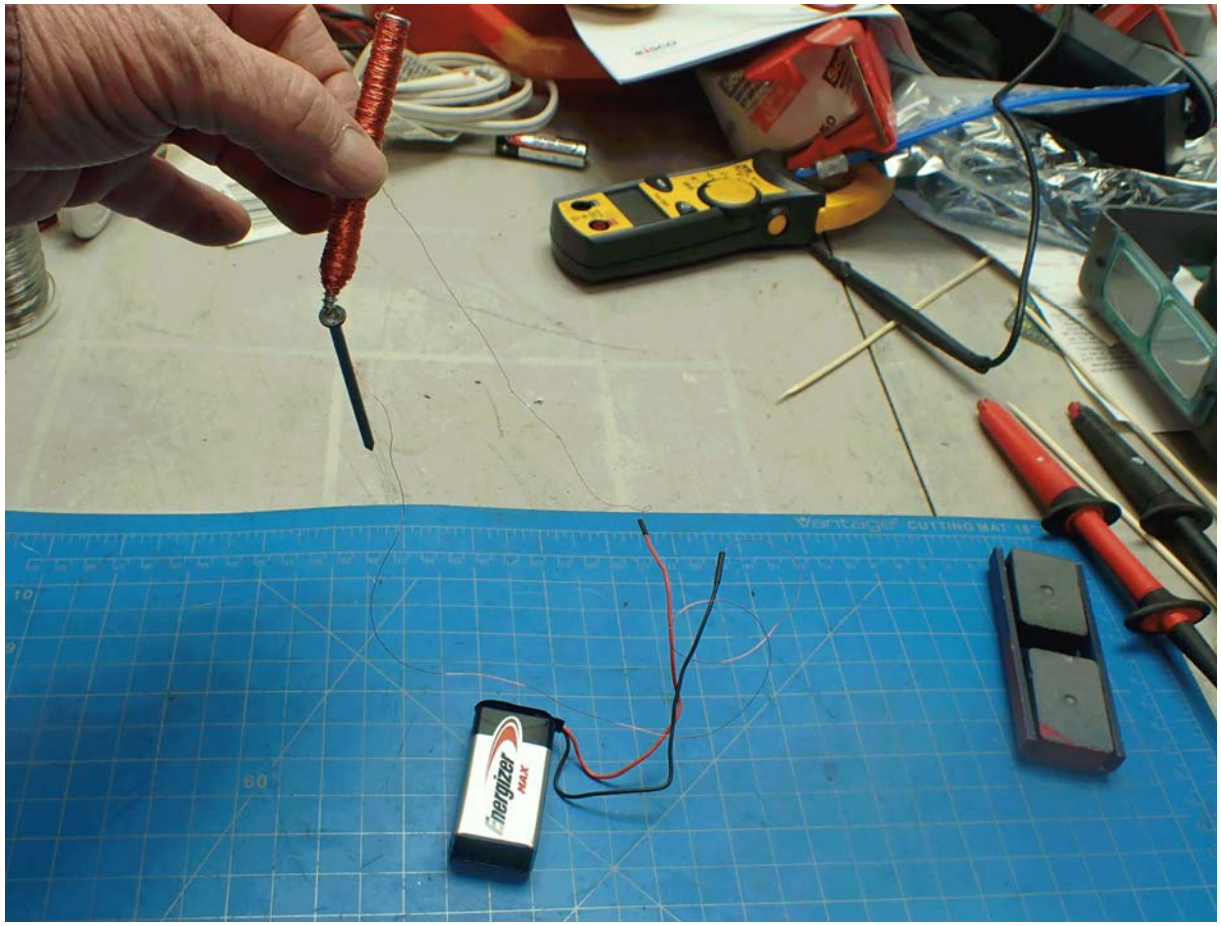


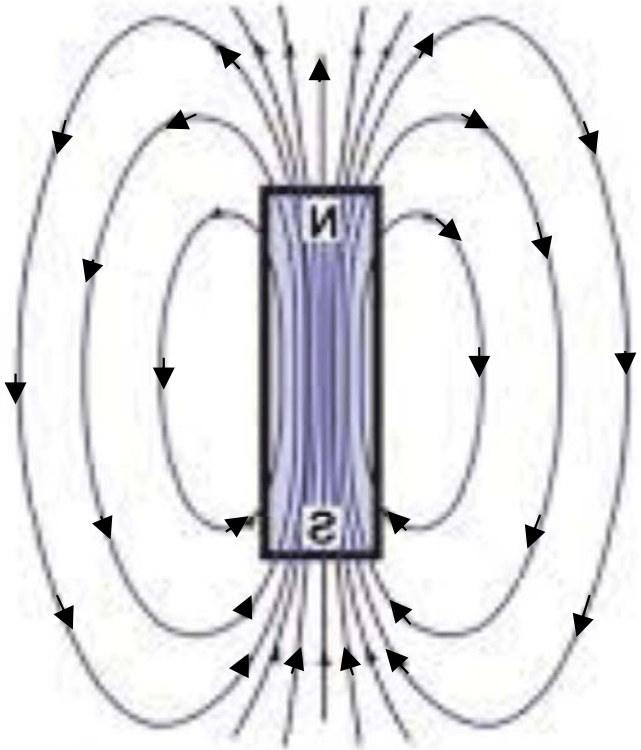
Electromagnets

The inverse is also true. Current flowing into a coil of wire will produce a magnetic field.

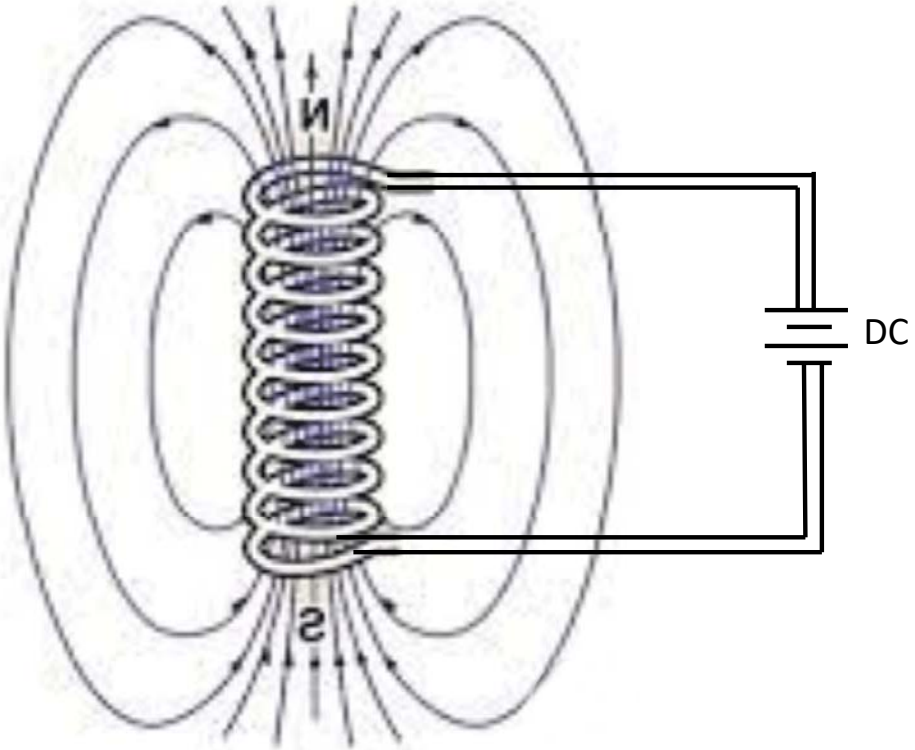
A simple electromagnet consisting of a coil of wire wrapped around an iron core. A core of ferromagnetic material like iron serves to increase the magnetic field created. The strength of magnetic field generated is proportional to the amount of current through the winding.

Demo of an Electromagnet

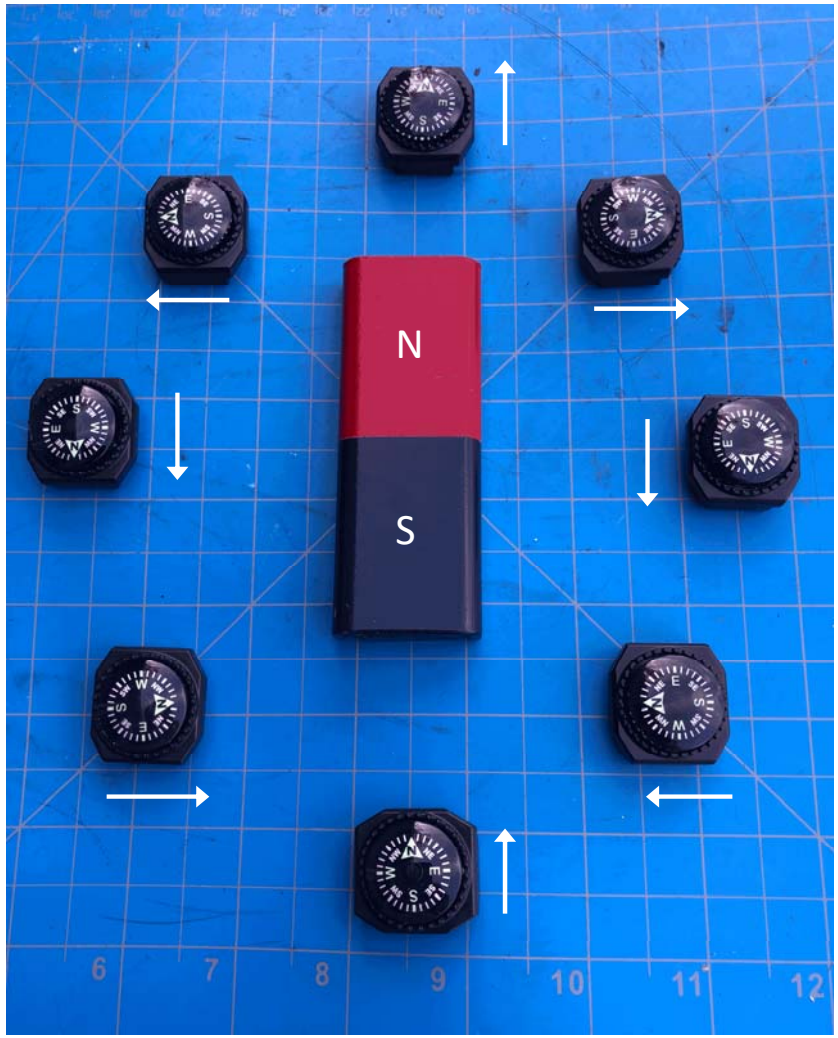


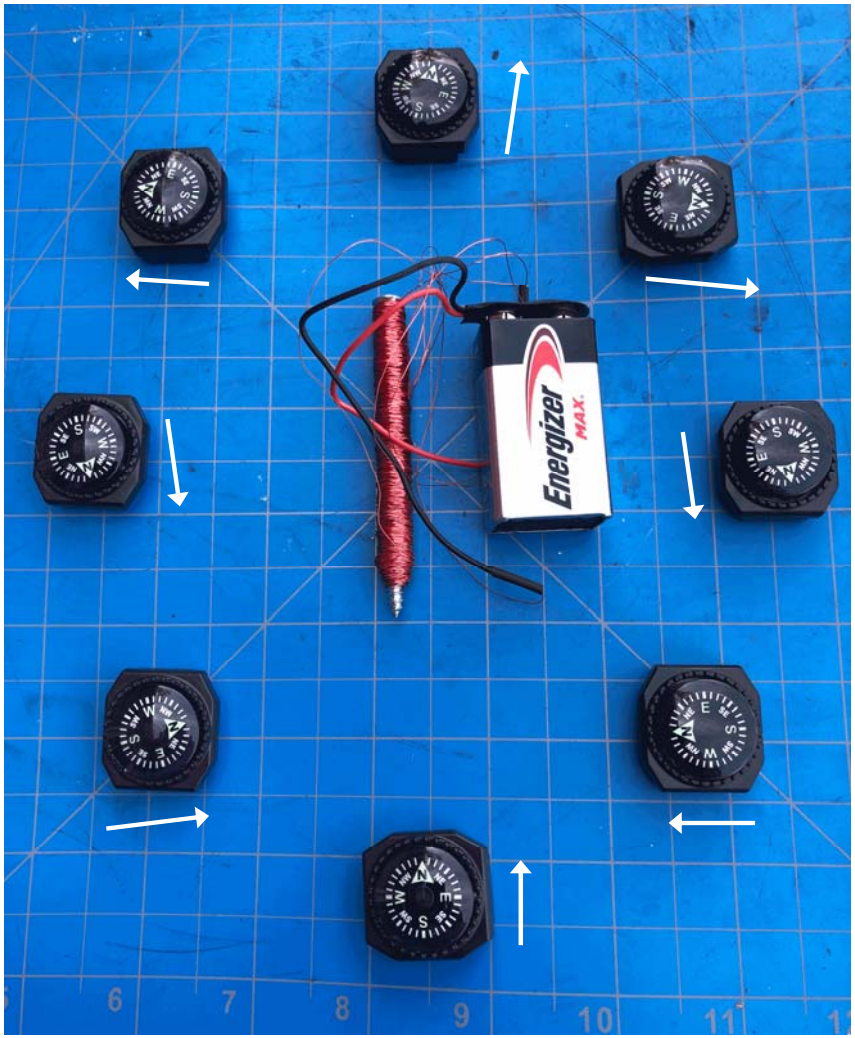


Bar Magnet



Electromagnet


N
S


Energizer
MAX

Since the magnetic forces are the same for a bar magnet and an electromagnet, can we replace the bar magnets in our generator with electromagnets?

YES !

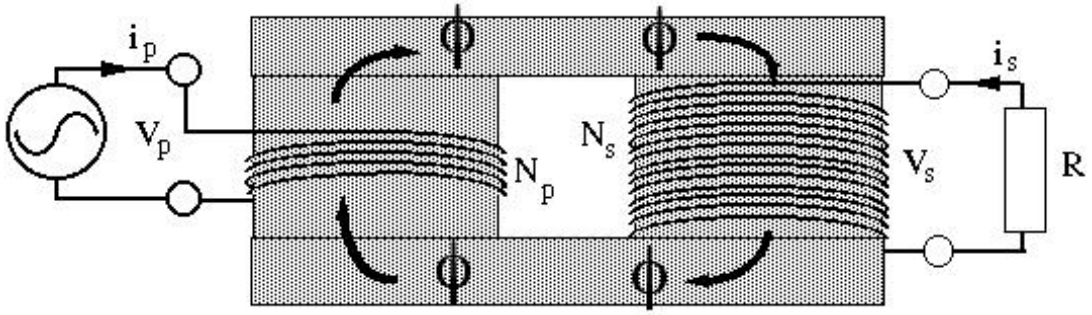
Edison vs Tesla and Westinghouse

- In the late 19th century, three brilliant inventors, Thomas Edison, Nikola Tesla and George Westinghouse, battled over which electricity system—direct current (DC) or alternating current (AC)–would become standard. During their bitter dispute, dubbed the War of the Currents, Edison championed the direct-current system, in which electrical current flows steadily in one direction, while Tesla and Westinghouse promoted the alternating-current system, in which the current's flow constantly alternates.

- Tesla and Westinghouse won because of the transformer.

TRANSFORMERS

- Used to increase or decrease voltage.
- Consists of two isolated coils of wire around an iron core.
- **Primary coil** is the input voltage coil.
- **Secondary coil** is the output voltage coil.



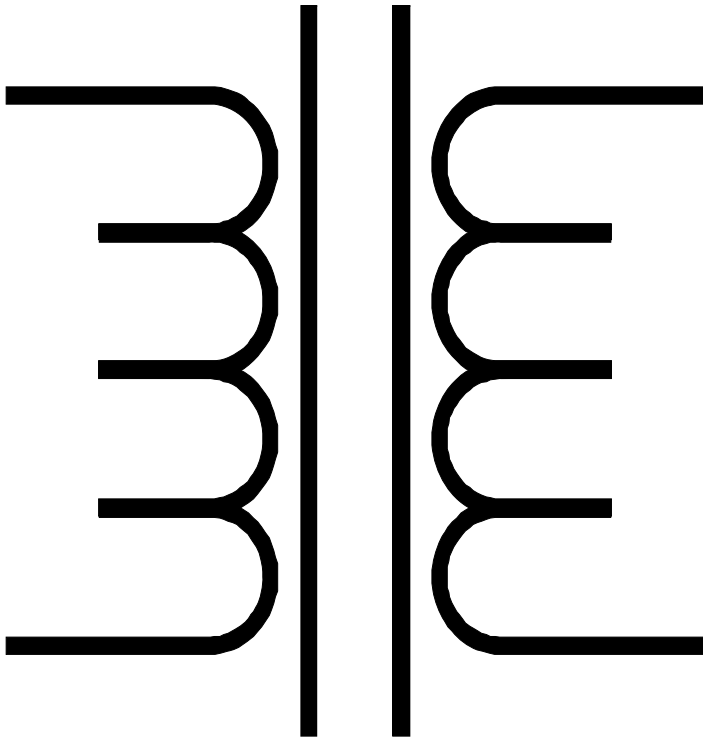
Electromagnet with Alternating Poles

Generator

Under load, Transformers make a humming sound.

The core is made out of steal laminations. The magnetic forces induced into the core, pull and push on the steal laminations, 60 times per second. The hum is referred to as 60 cycle hum.

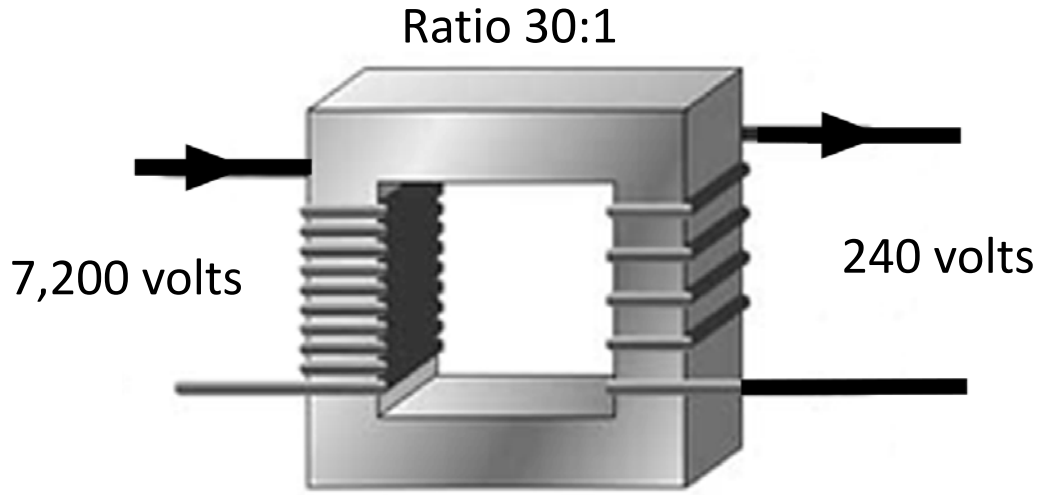
TRANSFORMERS



- Used to step AC voltage up or down.
- DC can not be transformed.

TRANSFORMERS

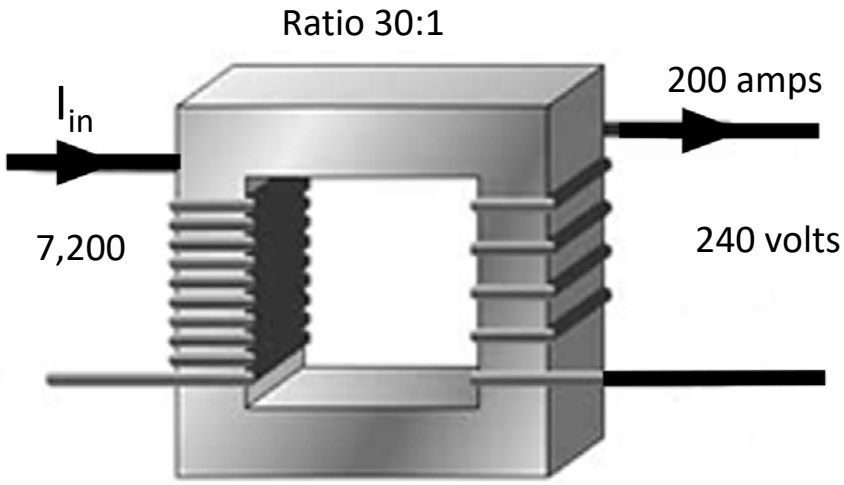
- Ratio of coil turns determines voltage change



Voltage levels and turns ratio are typical of a distribution transformer.

Power In = Power Out – Losses

Transformers are usually efficient enough that we can neglect the losses.



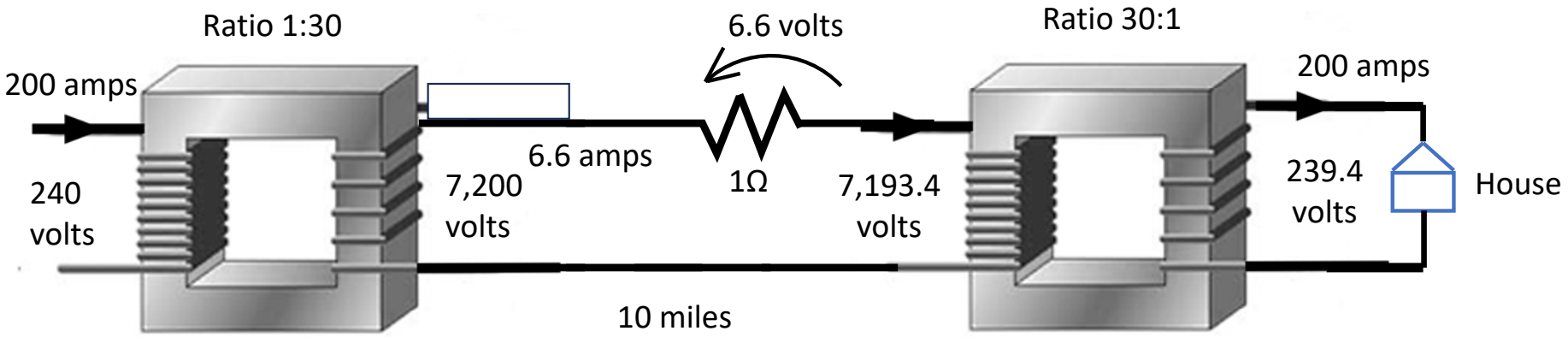
Power In = Power Out

$I_{in} * 7{,}200 = 200 * 240 = 48{,}000$ watts

$I_{in} = 200 * (240/7200) = 200/30 = 6.6$ amps

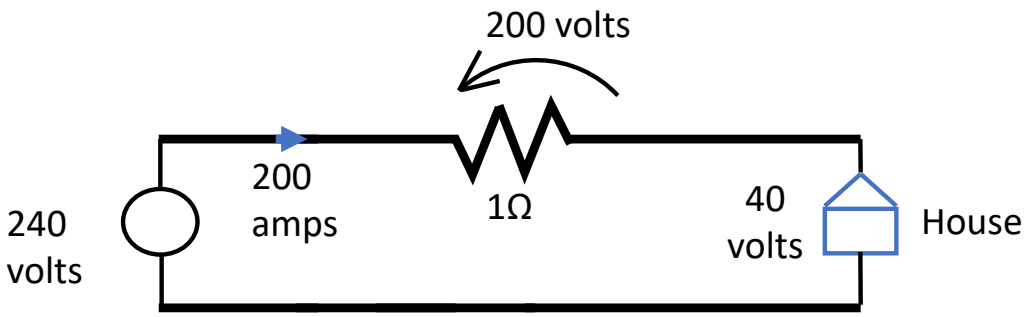
Thus, if we increase the voltage by a factor of 30, we decrease the current by a factor of 30.

We use step up transformers to deliver power over long distances. We use a step-down transformer when we reach the desired location. Example: deliver 240 volts, 200 amps to a home over a distance of 10 miles with a line resistance of 1 ohm.

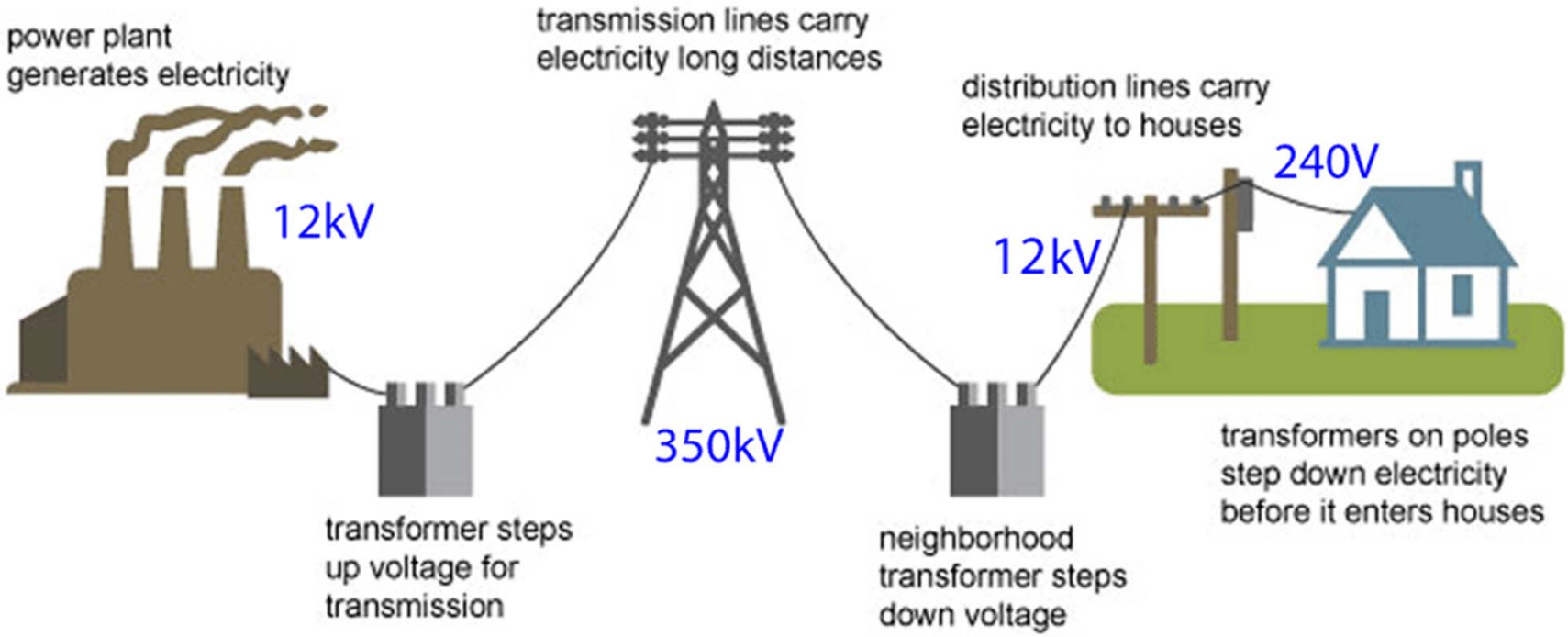


The voltage drop across the 10 mile long line is only 6.6 volts and the voltage delivered to the house is: (7,200 – 6.6) / 30 = 239.7 volts

Try to deliver 240 volts, 200 amps, without the transformers.



Electricity generation, transmission, and distribution



Source: Adapted from National Energy Education Development Project (public domain)

Key Points:

- We generate ac by rotating a magnet around a coil of wire or rotating a coil of wire around a magnet. The magnet can be a permanent magnet or an electromagnet.

- The reason that we have ac going to our homes instead of dc is that we can transfer it over long distances with step up transformers.

THREE PHASE POWER

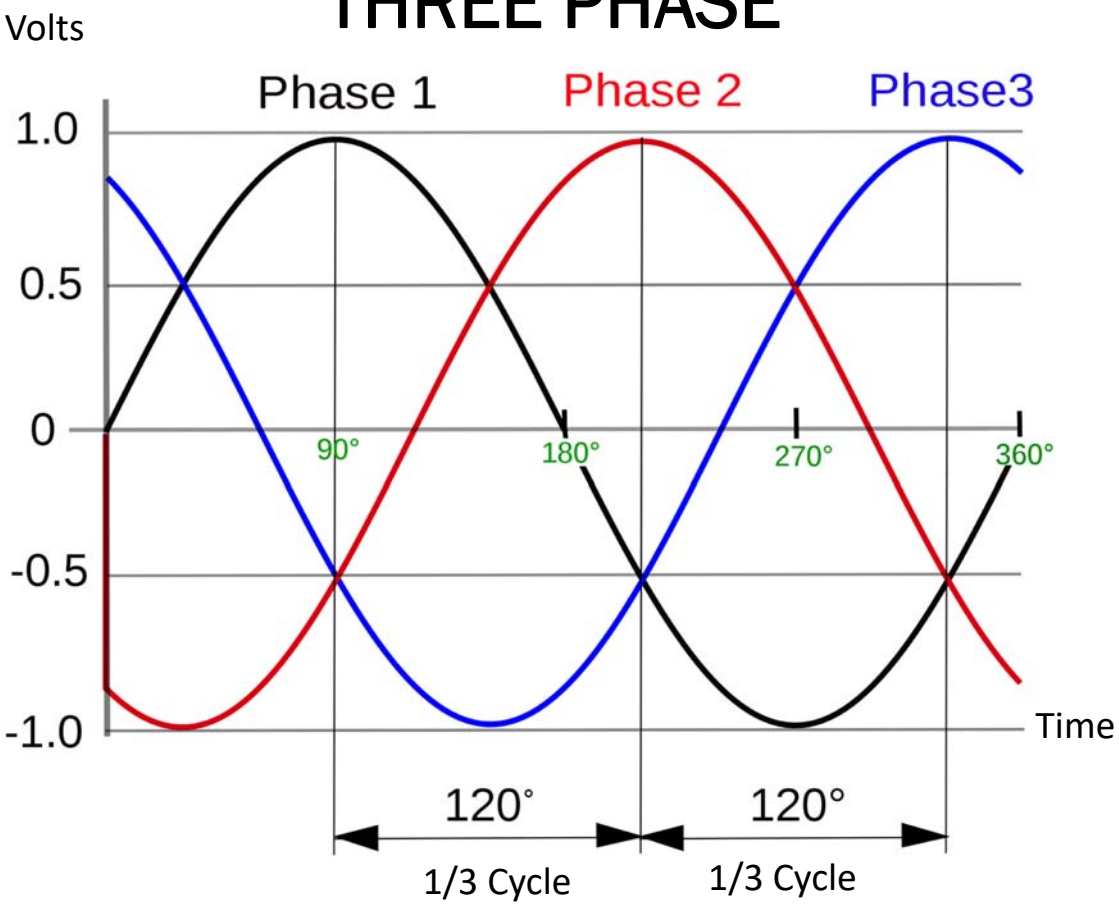
- Used in larger occupancies where motor and lighting and loads are greater than a residential occupancy.

- Motors are less costly and run more efficiently.
- Higher Voltage = Less amperage to deliver the same amount of energy (Joule's Law) and therefore allows the use of smaller size conductors.

- Common Three Phase system voltages are:

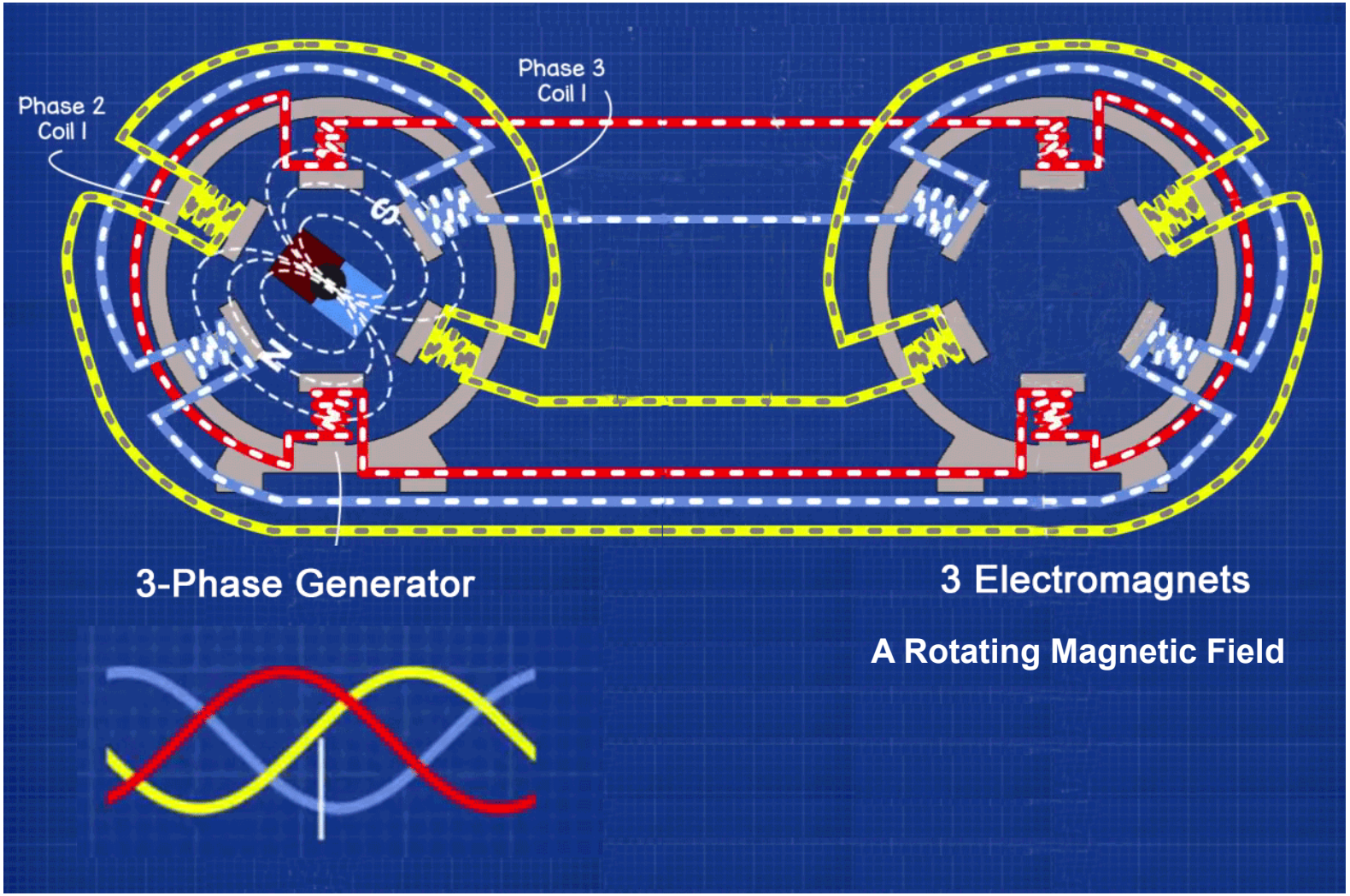
120/240 with a 208 "High Leg"- Orange in Color / B Phase
208/120
480/277

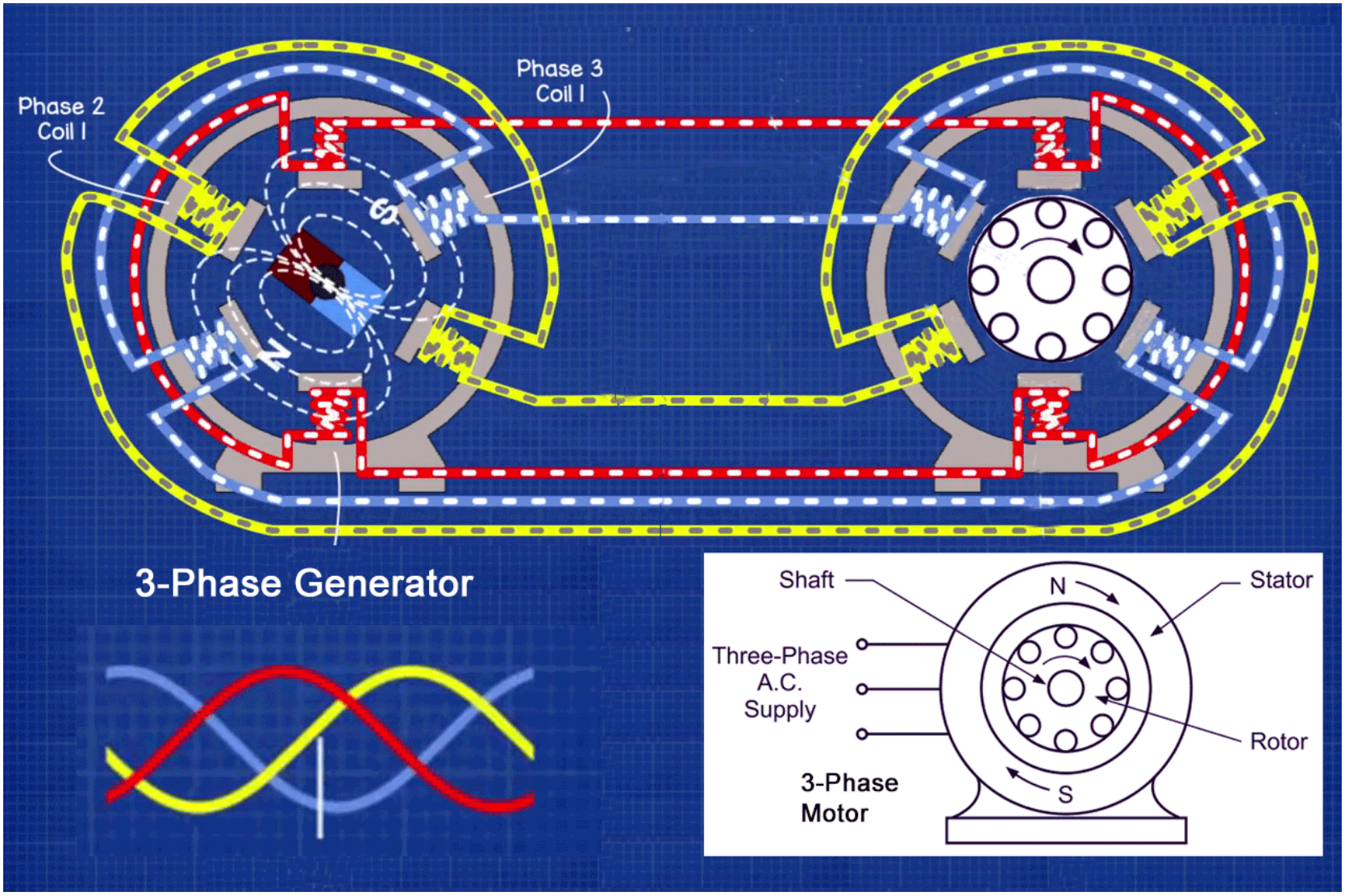
THREE PHASE

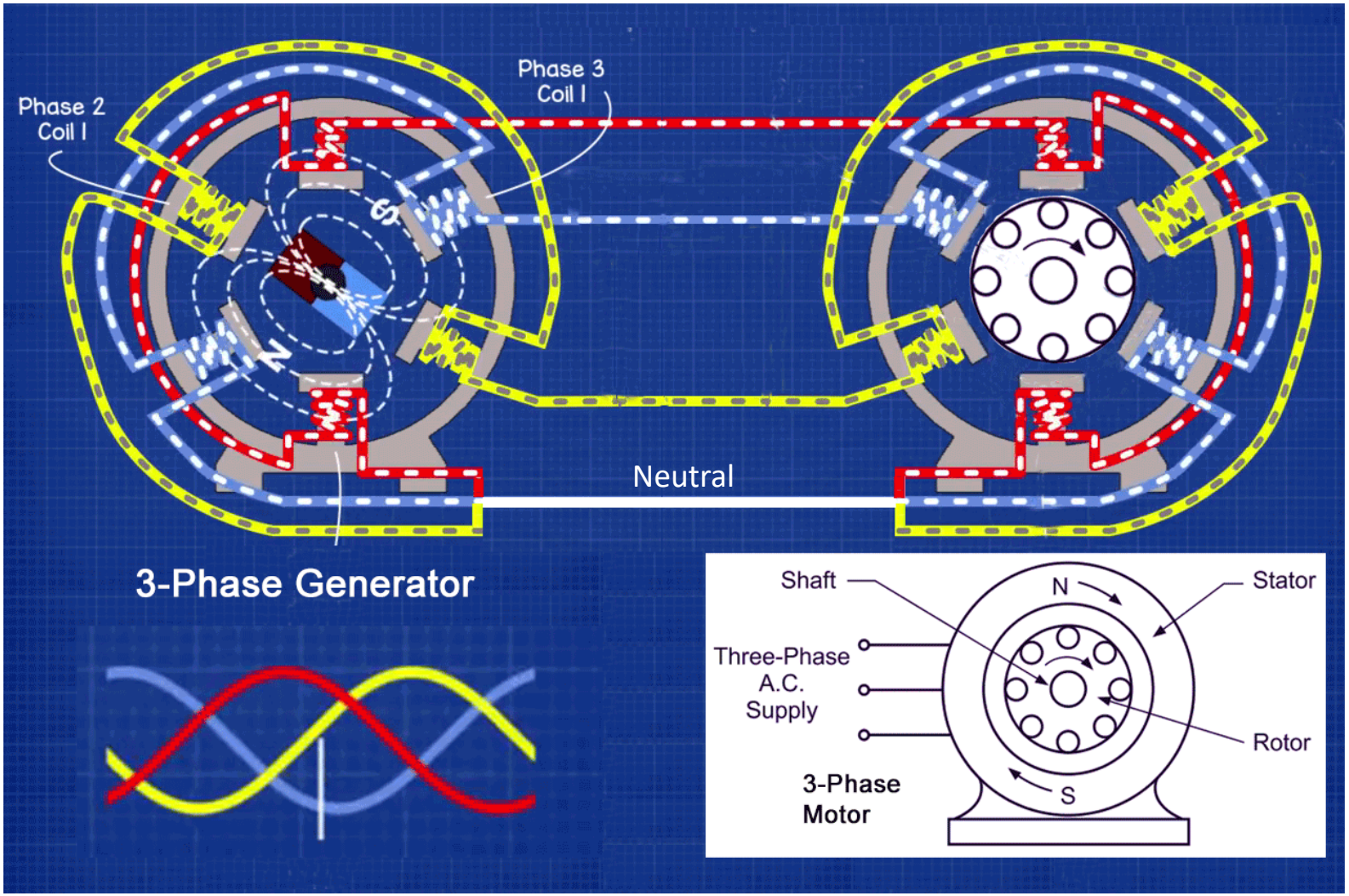

Volts
Phase 1
Phase 2
Phase3
1.0
0.5
0
-0.5
-1.0
90°
180°
270°
360°
Time
120°
120°
1/3 Cycle
1/3 Cycle

Three-Phase Power

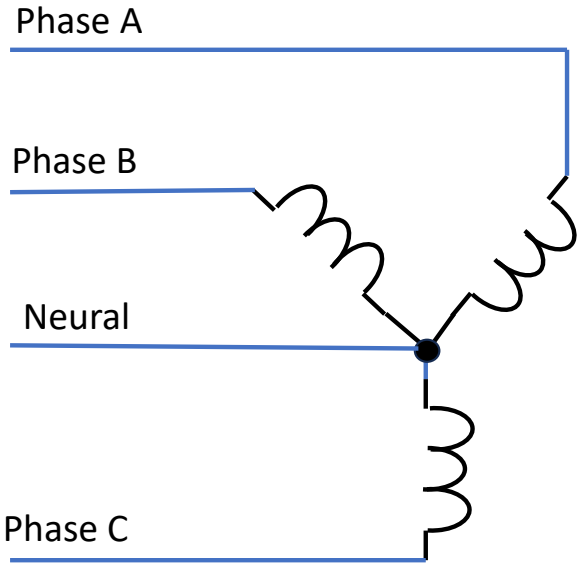
https://www.youtube.com/watch?v=4oRT7PoXSS0


Phase 2
Coil I
Phase 3
Coil I
S
N
3-Phase Generator
3 Electromagnets
A Rotating Magnetic Field


Phase 2
Coil I
Phase 3
Coil I
S
N
3-Phase Generator
Shaft
N
Stator
Three-Phase
A.C.
Supply
Rotor
3-Phase
Motor
S

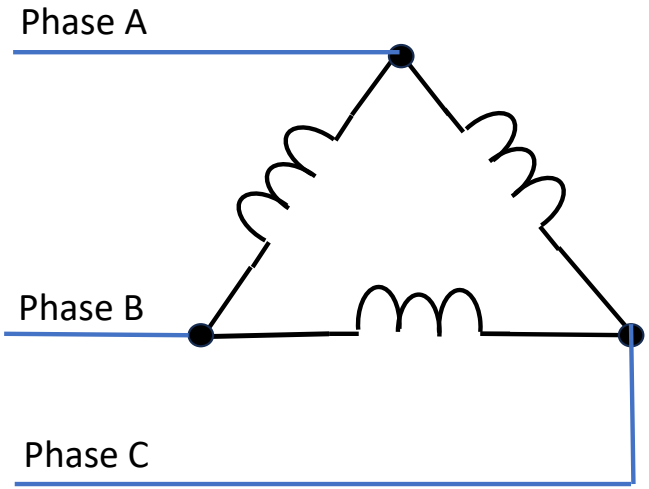

Phase 2
Coil I
Phase 3
Coil I
Neutral
3-Phase Generator
Shaft
Stator
N
Three-Phase
A.C.
Supply
Rotor
3-Phase
Motor
S

Y Configured 3-Phase Motor

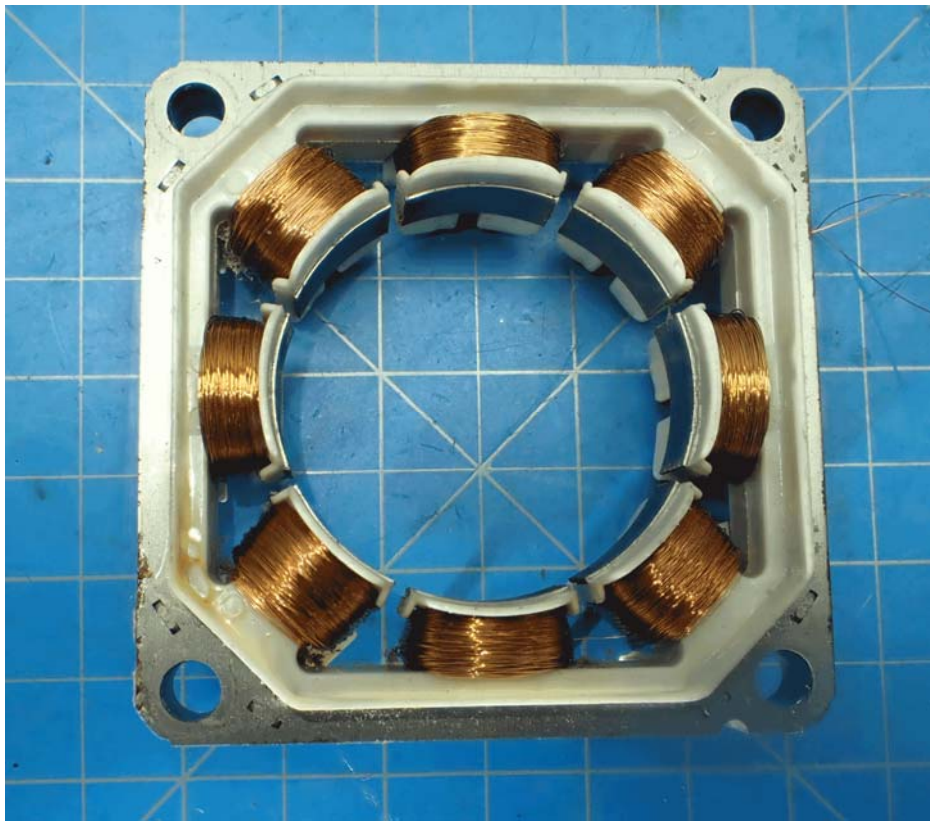


$$I_A + I_B + I_C = 0$$

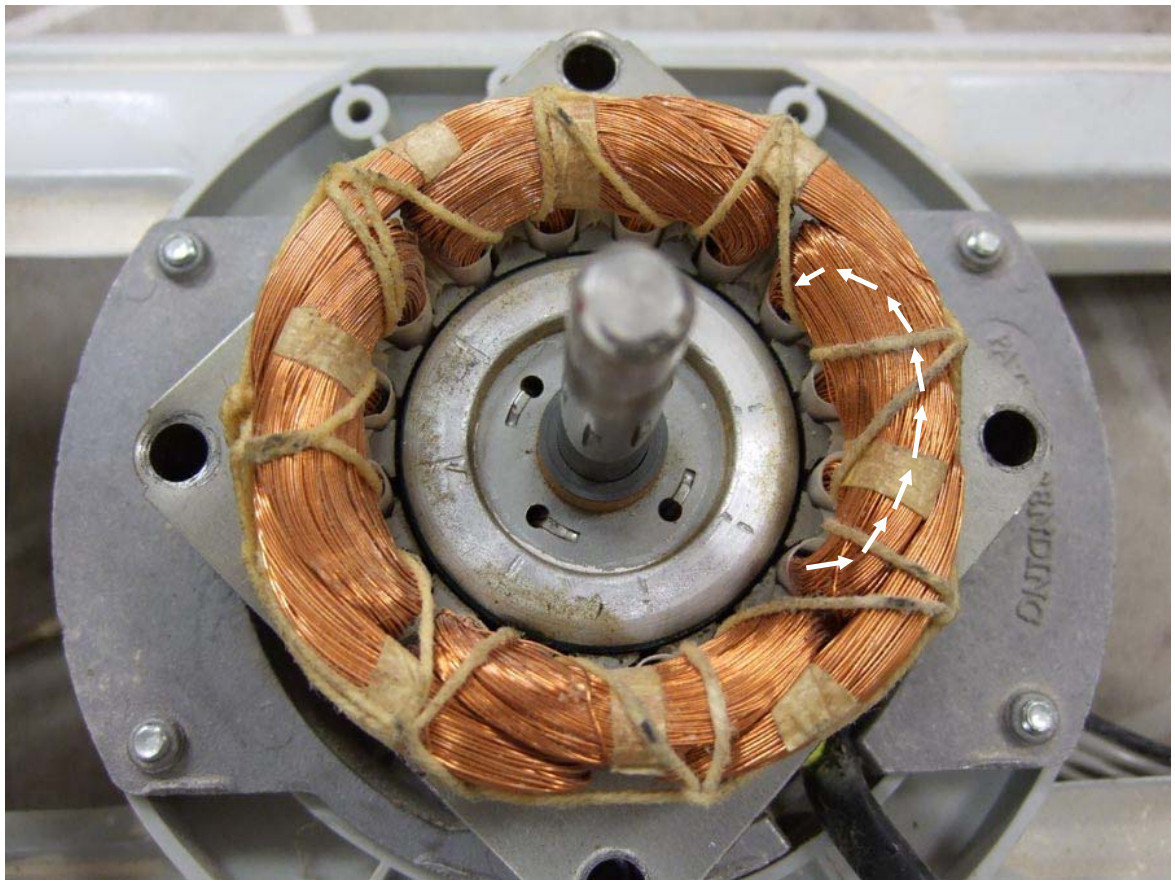
Delta Configured 3-Phase Motor



If 3-phase, the service entrance cable will have 3-hots wires and a neutral.



Single-phase motor with non-overlapping magnetic poles.



Single-phase motor with overlapping magnetic poles.

Three Phase Power Facts:

- If you exchange any two voltage wires to a three-phase motor, the motor will turn in the opposite direction.

- The voltage between any phase (line) V_{LN} and the neutral is the same. However, the voltage between any two phase lines is higher:

$$V_{LL} = \sqrt{3}\, V_{LN} = 1.732\, V_{LN}$$

Some common three phase voltages are:

Distribution	Commercial
13,800/7,960	480/277
12,470/7,200	208/120
34,500/19,920	

Sometimes they only give you the highest voltage.

Key Points:

- We generate ac by rotating a magnet around a coil of wire or rotating a coil of wire around a magnet. The magnet can be a permanent magnet or an electromagnet.

- The reason that we have ac going to our homes instead of dc is that we can transfer it over long distances with step up transformers.

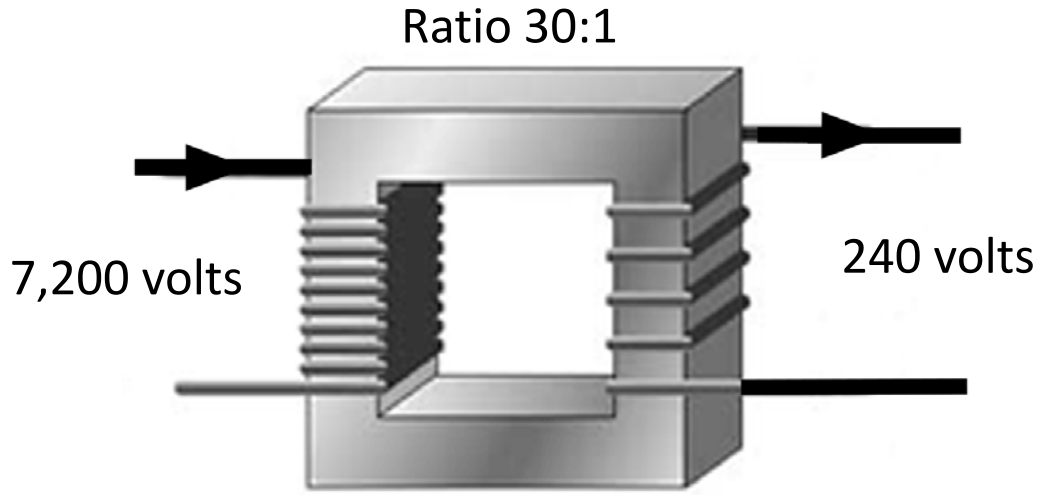
Key Points:

- Electric companies generate and distribute 3-phase power because it creates a torque that will make a motor turn.

- To get a single phase motors to turn, we have to add start windings and capacitors to shift the voltage in time. Single phase motors are not as energy efficient as 3-phase motors.

TRANSFORMERS

- Ratio of coil turns determines voltage change



Voltage levels and turns ratio are typical of a distribution transformer.

Test Question

Kirchhoff's voltage law states that the sum of the voltages around any closed loop is zero.

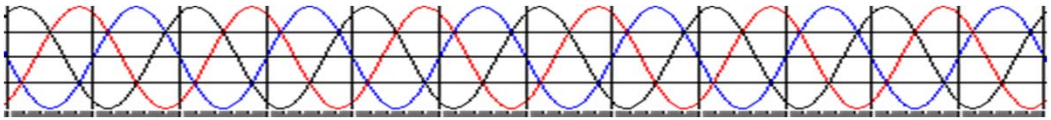
A) True
B) False
C) Except when transformers are used.

TRANSMISSION LINES

Typical transmission voltages between power generators and sub stations are 69,000, 138,000, 345,000, 500,000, and 1,100,000.

138,00 volts exist between wires

DANGER: THESE WIRES ARE NOT INSULATED



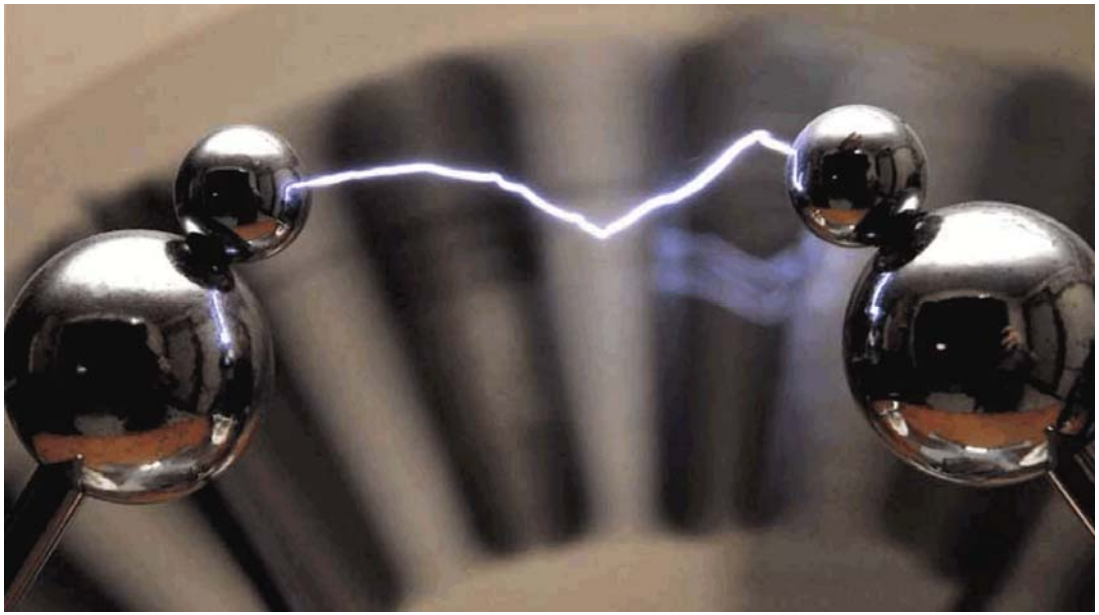
Notice the tower on the right has three wires. This is a three phase, A/C system. Each wire carries a sinusoidal voltage wave 120°out of phase from the others. The color graph above shows three sinusoidal waveforms over time.

SUBSTATIONS

Entergy Arc and Spark Show
at the Mississippi Fire Investigators Association
(IAAI Chapter)

Air is an Insulator

However, it you put enough voltage across it, you can break it down (ionize it) and create an arc.

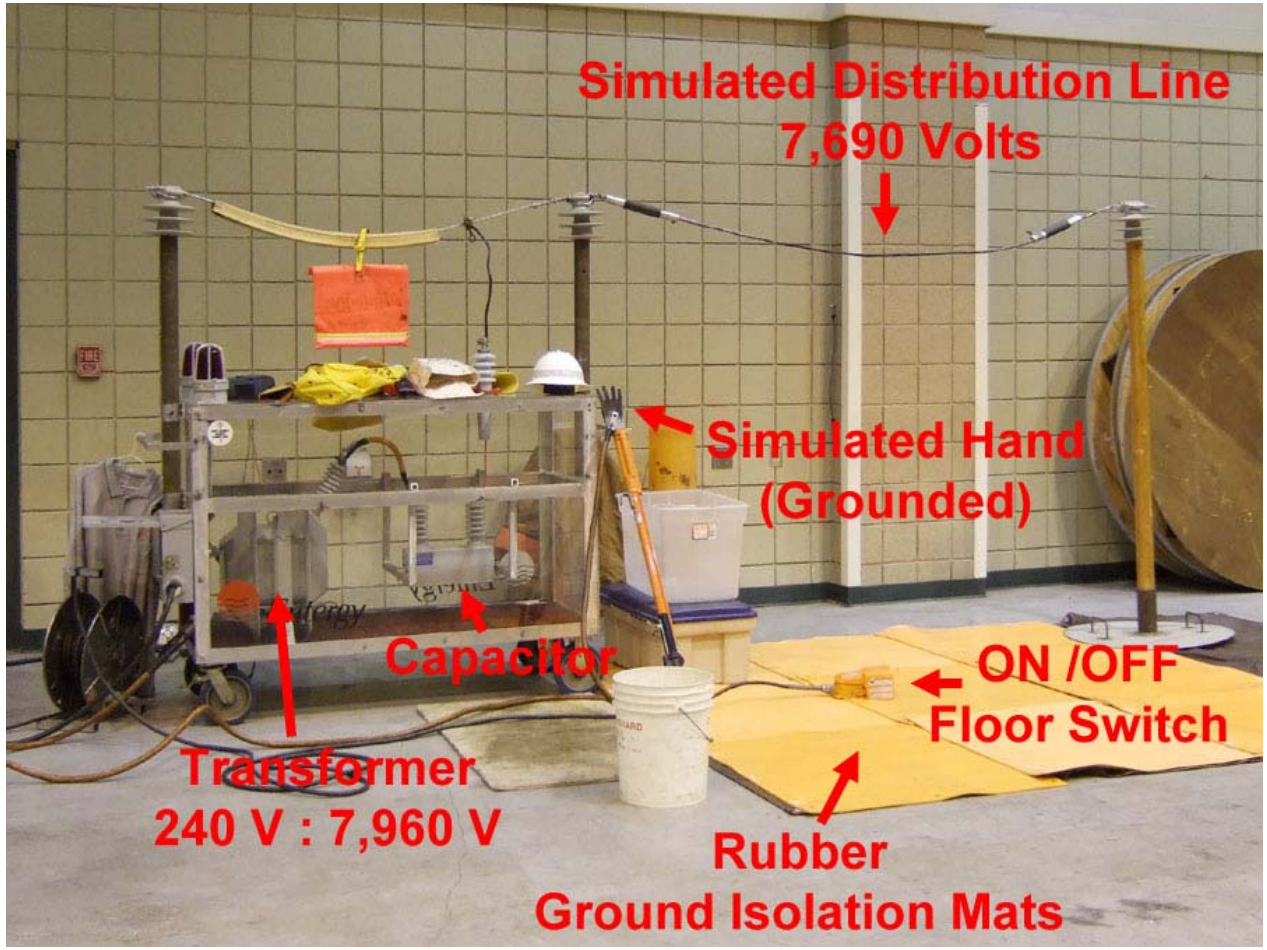


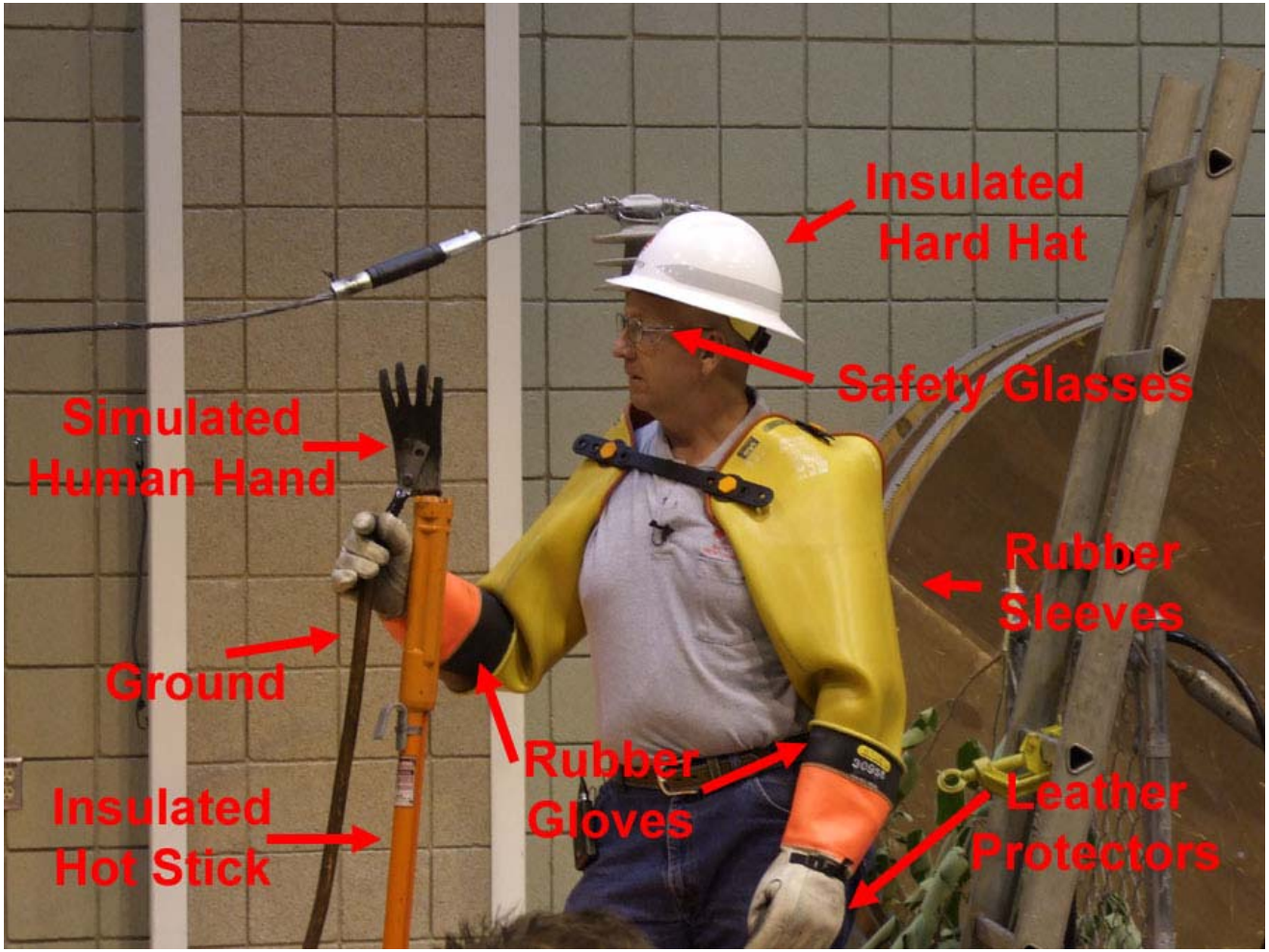
The breakdown strength of air depends on the shape of the electrodes and the waveform applied. A typical value is: 72.6 kV per inch.

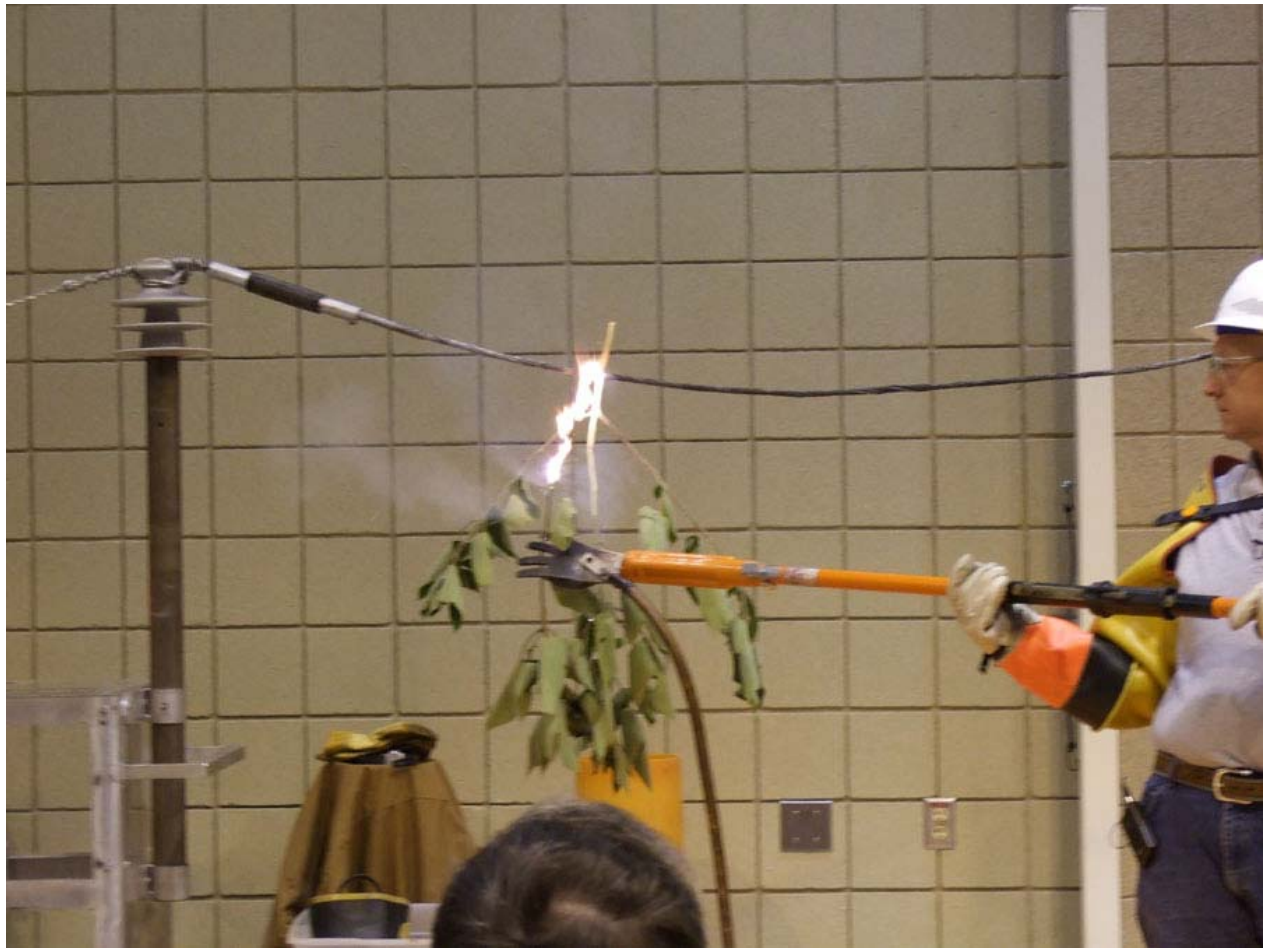
Distribution lines are typically one-tenth of this. So, at distribution line voltages, electricity can jump approximately one-tenth of an inch.

However, once the arc is initiated, only 50 volts per inch is required to maintain it.

No matter how close you get the electrodes, you can not create an arc through air with less than 350 volts (NFPA 921 – 9.12.4).


Simulated Distribution Line
7,690 Volts
Simulated Hand
(Grounded)
Capacitor
ON /OFF
Floor Switch
Transformer
240 V : 7,960 V
Rubber
Ground Isolation Mats

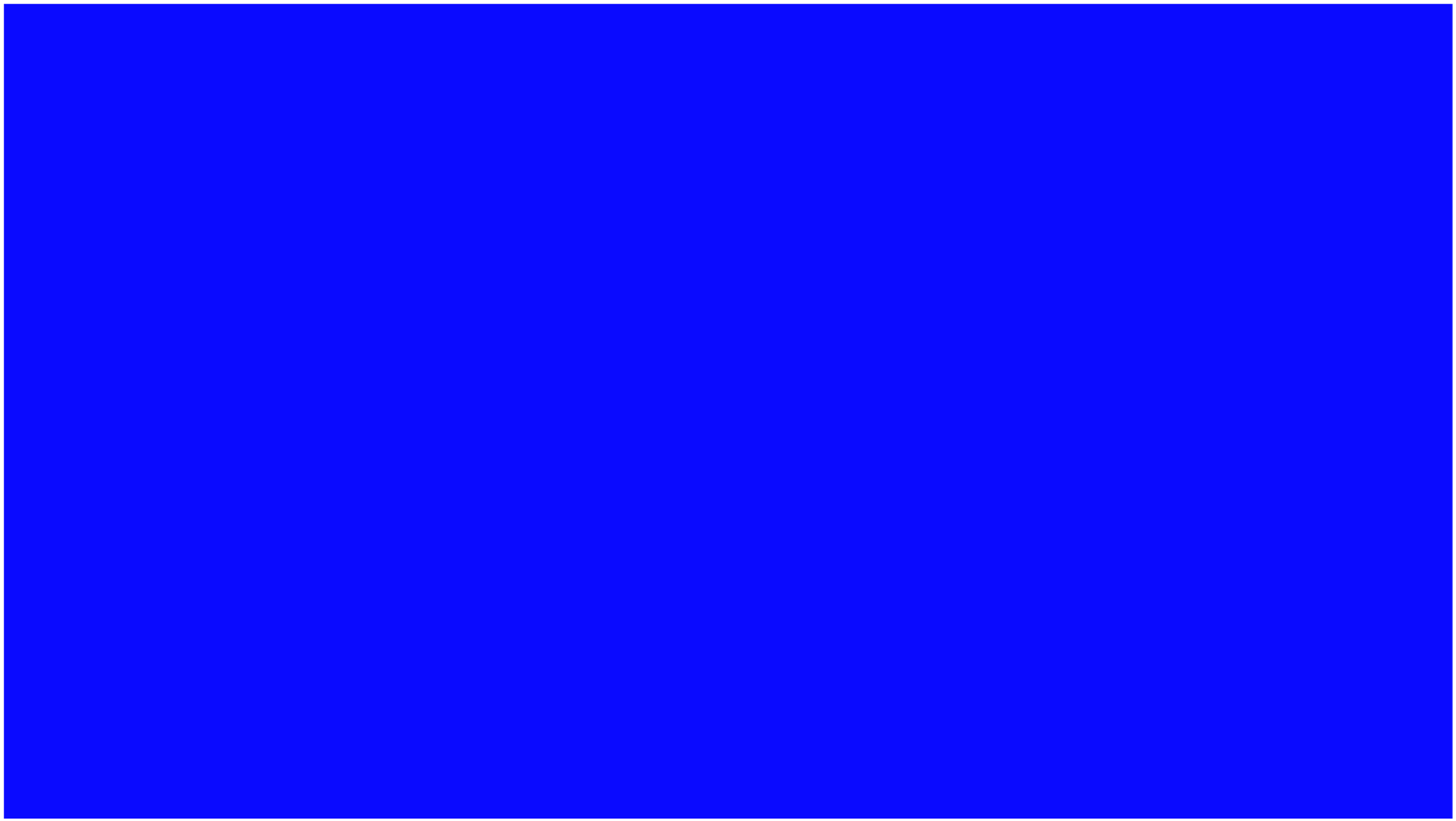

Insulated
Hard Hat
Safety Glasses
Simulated
Human Hand
Rubber
Sleeves
Ground
Rubber
Gloves
Leather
Protectors
Insulated
Hot Stick



Firefighter’s Pike Pole

Firefighter’s Pike Pole

https://www.youtube.com/watch?v=2Xoyb9M5-EA



COOPER Bussmann

Handbook for Electrical Safety

Electrical Safety 1 mA = 1/1,000 amp

Current (60 Hz)	Physiological phenomena	Feeling or lethal incidence
<1 mA	None	Imperceptible
1 mA	Perception threshold	Mild sensation
1–3 mA		Painful sensation
3–10 mA		
10 mA	Paralysis threshold of arms	Cannot release hand grip; if no grip, victim may be thrown clear (may progress to higher current and be fatal)
30 mA	Respiratory paralysis	Stoppage of breathing (frequently fatal)
75 mA	Fibrillation threshold 0.5%	Heart action discoordinated (probably fatal)
250 mA	Fibrillation threshold 99.5% (≥ 5-s exposure)	
4 A	Heart paralysis threshold (no fibrillation)	Heart stops for duration of current passage. For short shocks, may restart on interruption of current (usually not fatal from heart dysfunction)
≥5 A	Tissue burning	Not fatal unless vital organs are burned

Table II. Human Resistance Values for Various Skin-contact Conditions

Condition	Resistance, (ohms)	
	Dry	Wet
Finger Touch	40,000 to 1,000,000	4,000 to 15,000
Hand Holding Wire	15,000 to 50,000	3,000 to 6,000
Finger-Thumb Grasp	10,000 to 30,000	2,000 to 5,000
Hand Holding Pliers	5,000 to 10,000	1,000 to 3,000
Palm Touch	3,000 to 8,000	1,000 to 2,000
Hand Around 1 1/2 Pipe	1,000 to 3,000	500 to 1,500
Two Hands Around 1 1/2 Pipe	500 to 1,500	250 to 750
Hand Immersed		200 to 500
Foot Immersed		100 to 300
Human Body, Internal, Excluding Skin	200 to 1,000	

This table was compiled from data developed by Kouwenhoven and Milnor.

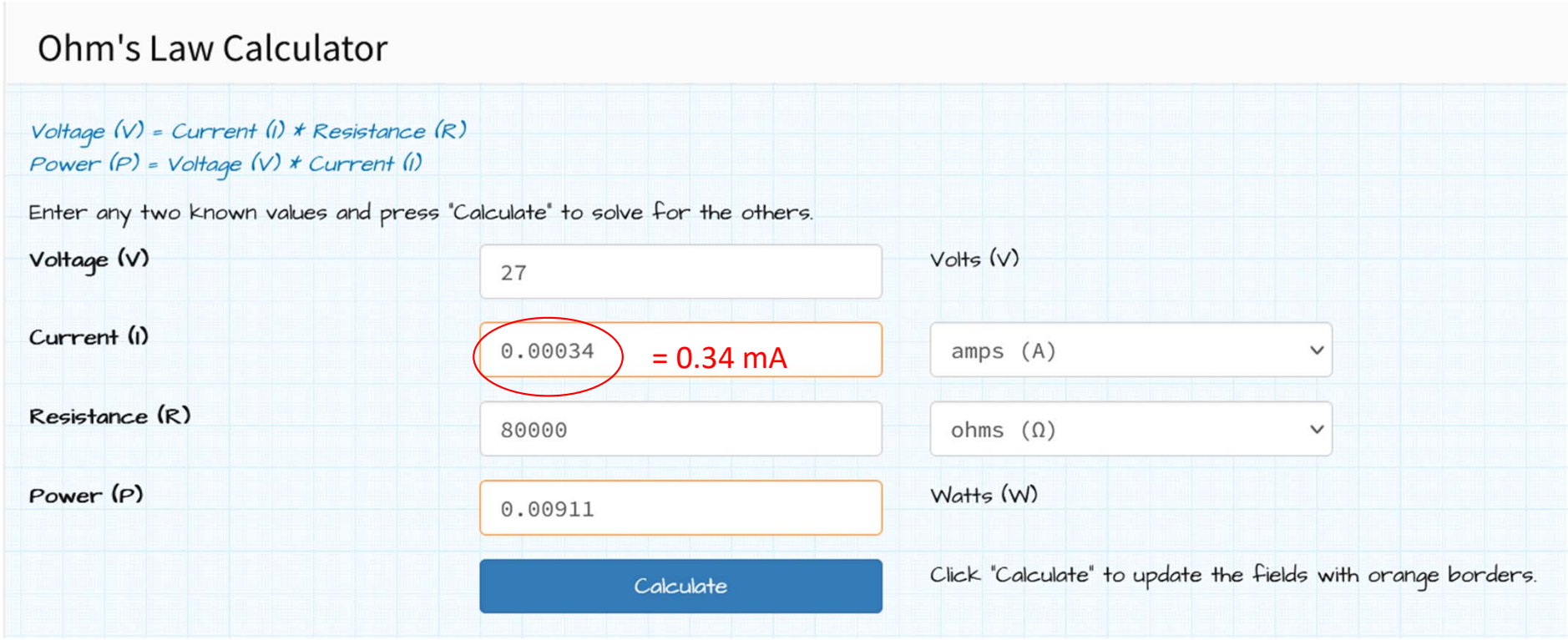
27 volt battery demo

Ohm's Law Calculator

*Voltage (V) = Current (I) * Resistance (R)*
*Power (P) = Voltage (V) * Current (I)*

Enter any two known values and press "Calculate" to solve for the others.

Voltage (V)	27	Volts (V)
Current (I)	current	amps (A)
Resistance (R)	80000	ohms (Ω)
Power (P)	power	Watts (W)
	Calculate	Click "Calculate" to update the fields with orange borders.



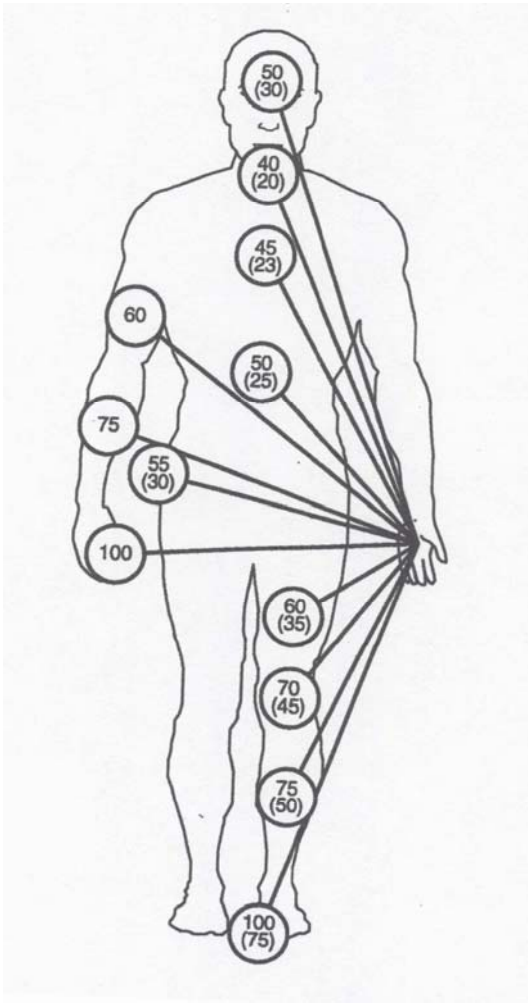
We generally do not have batteries over 48 volts

Most of the human body's resistance is from the dry skin.

Voltages above 500 will punch through or breakdown the human skin. Above 500 volts, we ignore the skin resistance.

The internal body resistance is between 200 to 1,000 Ω.

Above 500 volts electricity will punch the skin.



Internal Human Body Resistances

From hand-to-hand or hand-to-foot is typically 200 - 500Ω.

Numbers is the circles are % of hand-to-hand.

Numbers in brackets are when both hands are joined.

$$I_{max} = \frac{E}{R} = \frac{240\ volts}{200\Omega} = 1.2\ \text{amps}$$

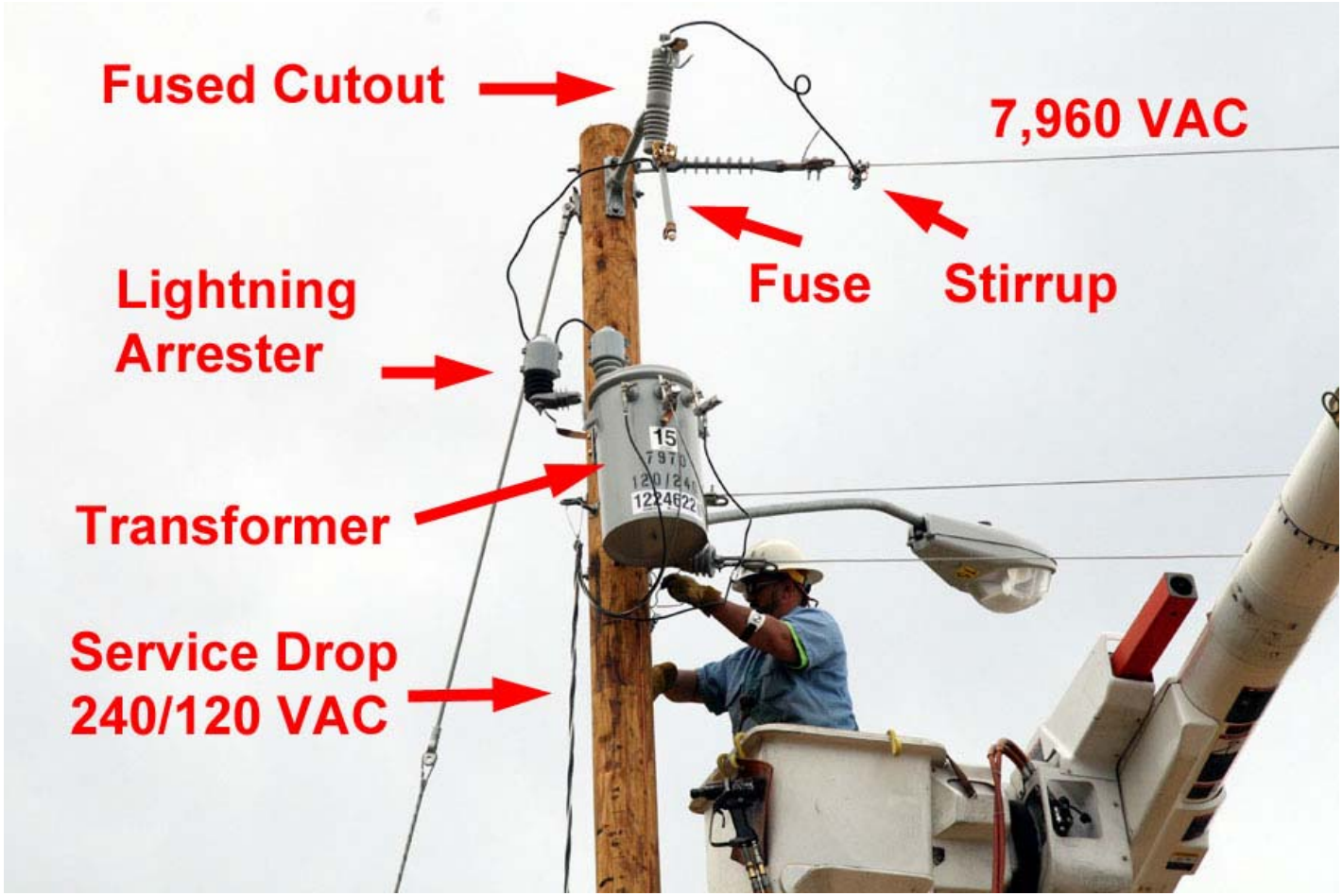
Will not trip a Circuit Breaker!

Test Question

The majority of electrocution deaths occur because of ventricular fibrillation, where the heart beats in a very rapid and uncoordinated manner.

A) True
B) False

Is the Power Off?


Fused Cutout
7,960 VAC
Fuse
Stirrup
Lightning Arrester
Transformer
Service Drop 240/120 VAC

Completely Self-Protected Transformers use a Circuit Breaker on the Inside of the transformer in lieu of a fuse.

The fuse is inside the transformer cabinet

- Pad mounted transformer
- Can be single or three phase
- Accompanied by underground lateral

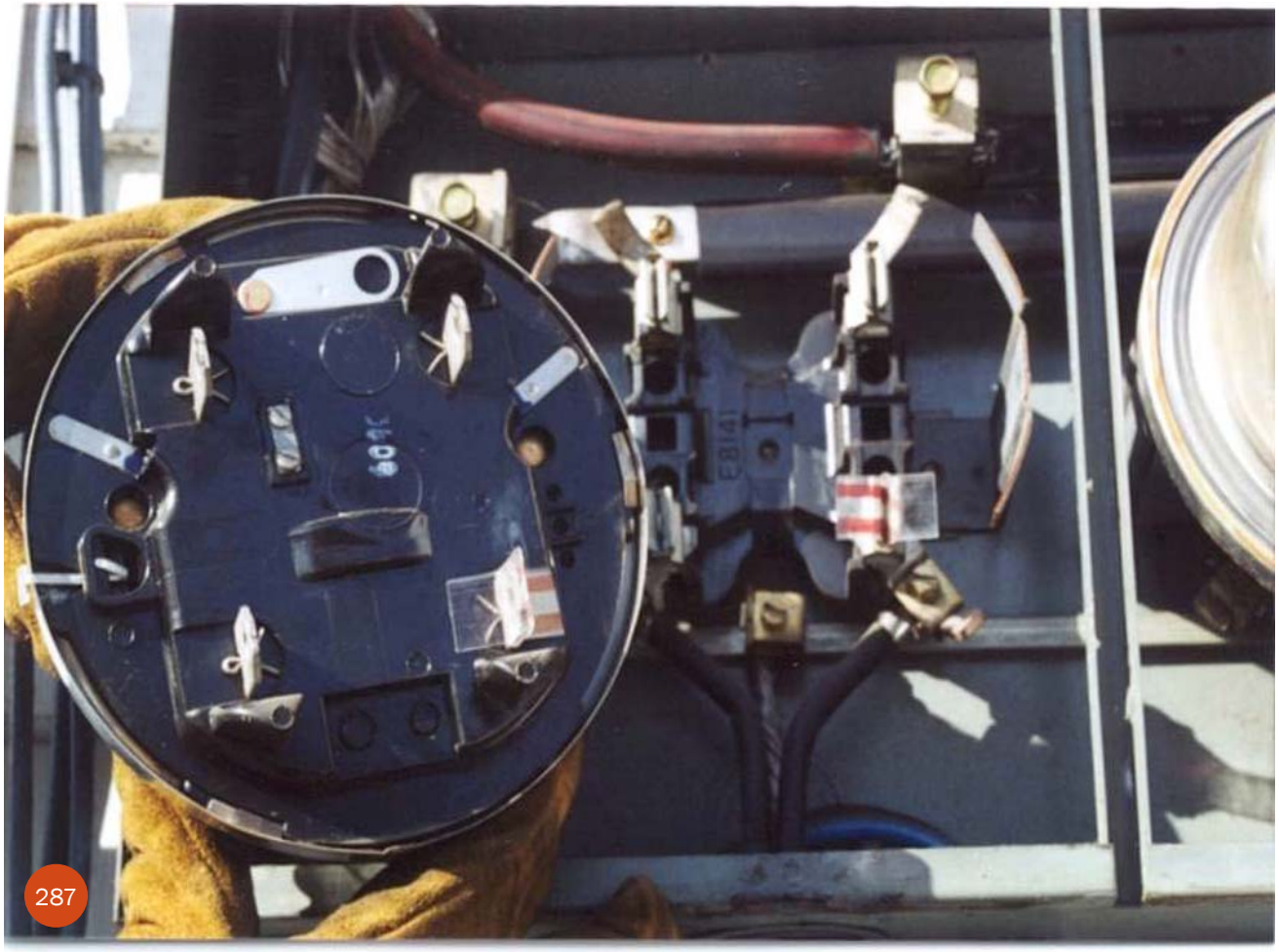
Is the meter plugged In?

METER BASE

101

The Ground or Neutral cable does not pass through the meter

Meter Insulation Boots



Meter Insulation Boot

- Meter Sockets are rated up to 320/400 amps.
- Above 400 amps, current transformers are used to measure the energy.
- Commercial building use current transformer to meter the amount the amount of energy (kWh) used by a building.

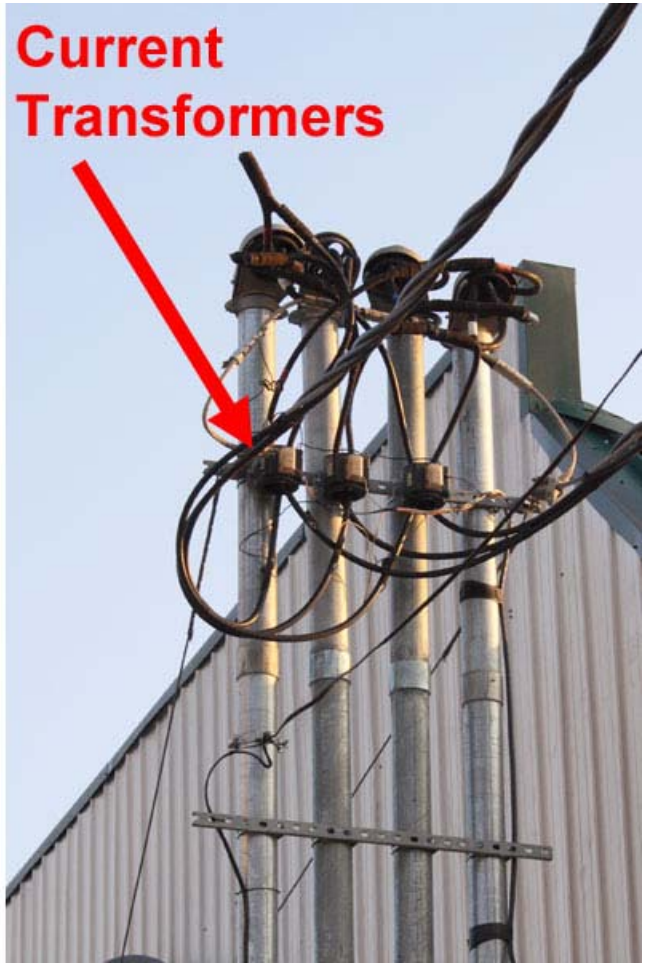
Current Transformer Demo

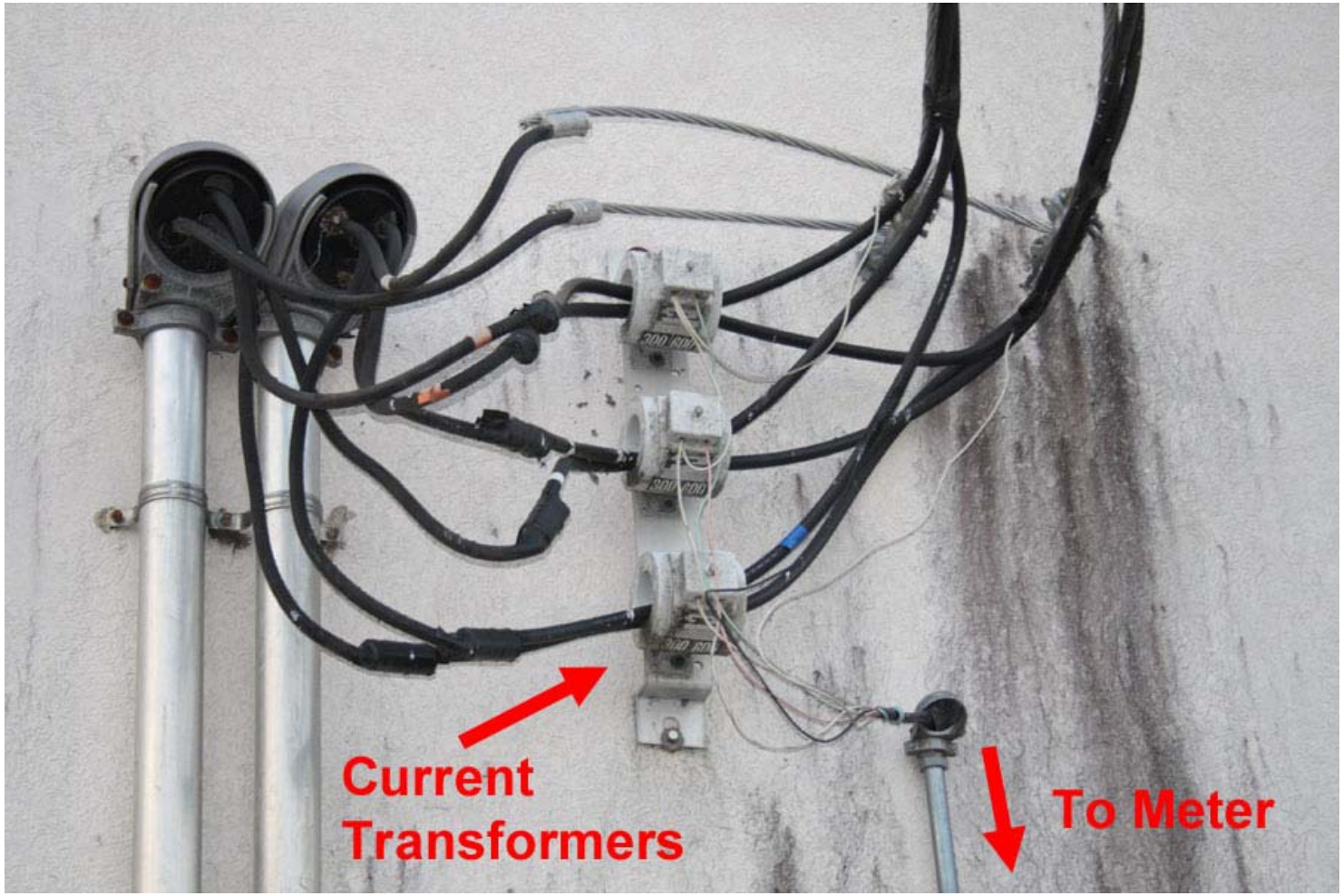
Current Transformer with 1 turn

Current Transformer with 2 turns

We changed the turns ratio by a factor of 2, which decrease the voltage by a factor of 2, and increased the current by a factor of 2.


3-Ø Power


Current
Transformers


Current
Transformers
To Meter


Current
Transformers

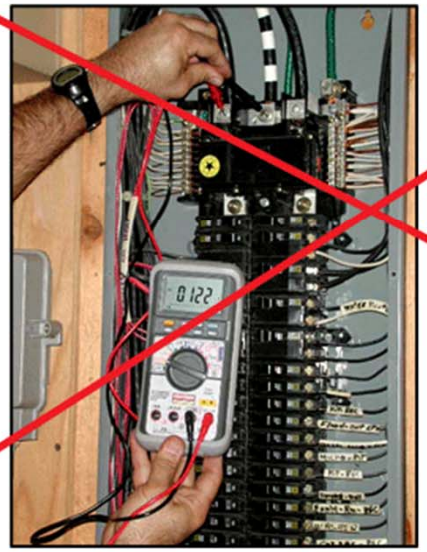
Test Question?

Pulling the electric meter at a commercial building will always disconnect power to the building?

True or False

Skip

DIGITAL METER



- Checking the Main service entrance conductors.
- One lead on the "hot" conductor the other to the Neutral Conductor
- 120 Volts

82

Never Do This! The only thing between you and the transformer is the transformer fuse !

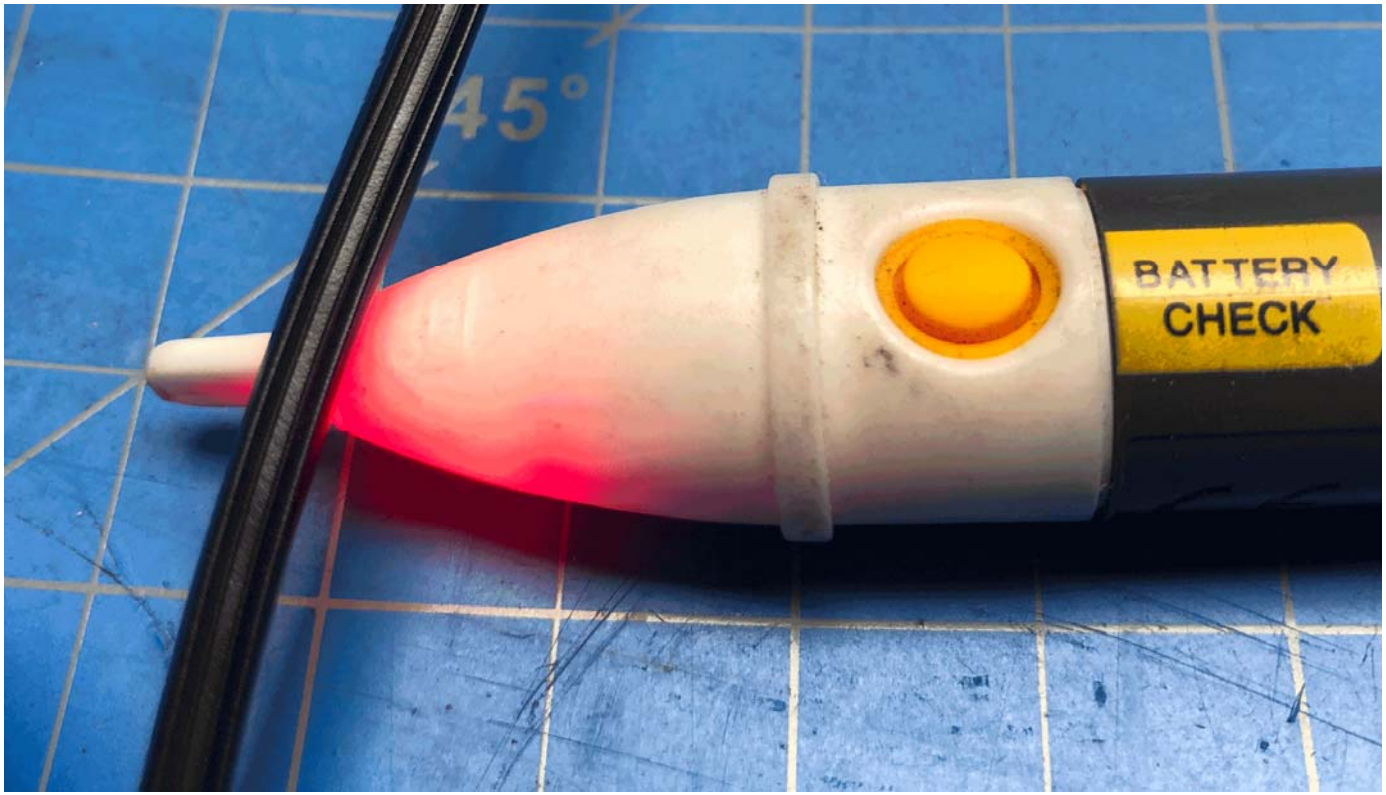
Test Question

A qualified person ~~You~~ should never measure the voltage at a circuit breaker box without a face shield, rubber gloves with leather protectors and fire-retardant clothing.

A. True
B. False

Non-Contact Voltage Tester

Proximity Non-Contact Voltage Tester - Fluke



:s

Roll over image to zoom in

Fluke 2AC Alert Voltage Tester

Visit the Fluke Store

4.6 ★★★★½ 1,953 ratings | 27 answered questions

1K+ bought in past month

-10% $37.77

List Price: ~~$41.99~~

FREE Returns

Get $60 off instantly: Pay $0.00 ~~$37.77~~ upon approval for the Amazon Store Card. No annual f

Available at a lower price from other sellers that may not offer free Prime shipping.

Brand	Fluke
Power Source	Battery Powered
Style	Tester
Item Weight	0.1 Kilograms
Item Dimensions LxWxH	10.25 x 3 x 1.2 inches

About this item

- Voltbeat technology and continuous self test so you always know it is working
- Upon detection, tip glows and beeper sounds ?
- Non-contact voltage detection from 90 to 1000 V ac
- Battery Check' ensures battery is in good condition
- Suitable for a wide range of residential, commercial and industrial needs

Internet # 317460355 Model # NCVT1PR Store SKU # 10065

Best Seller

Klein Tools

Non Contact Voltage Tester Pen, 50-1000V AC

★★★★½ (2076) Questions & Answers (22)

Hover Image to Zoom

$19.97

- Non-contact voltage tester detects voltage 50 to 1000V AC
- Volt pen has red LED lights and audible tones to indicate voltage
- Not recommended for tamper-resistant outlets
- View More Details

Vicksburg Store

✓ 5 in stock Aisle 06, Bay 018

Pickup at Vicksburg | Delivering to 39180

Pickup
Today
5 in stock
FREE

Delivery
Friday, Oct 27
192 available
FREE

Get it as soon as today. Schedule your delivery in checkout.

Protect This Item

Select a Home Depot Protection Plan by Allstate for:

- ○ 2 Year / **$3.00**
- ◉ No thanks

What to Expect

Klein Non-Contact Voltage Tester

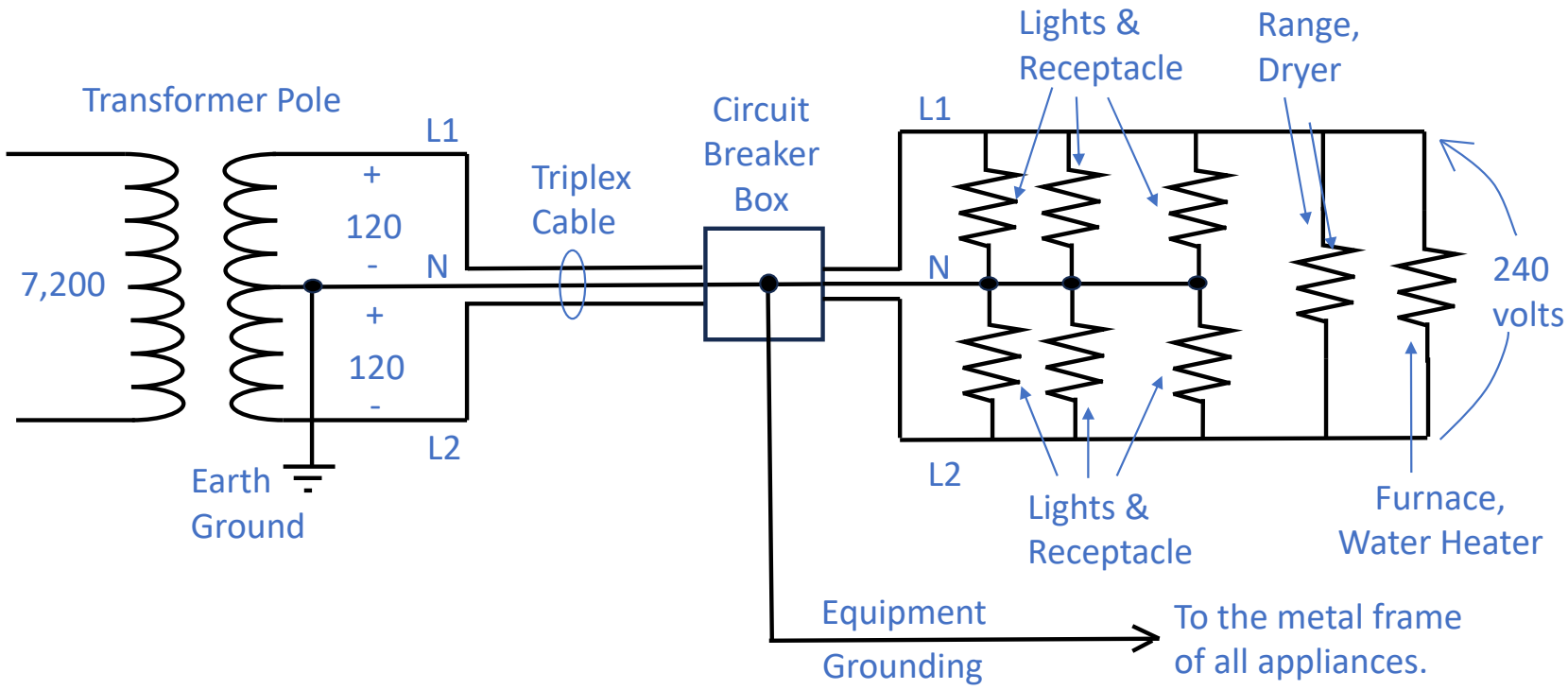
Demo Non-Contact Tester.

Test Question:

To ensure that the electricity is off, the best tool a fire investigator can have is:

A) A voltmeter
B) A clamp on current meter
C) A magnetometer
D) A non-contact voltage proximity tester

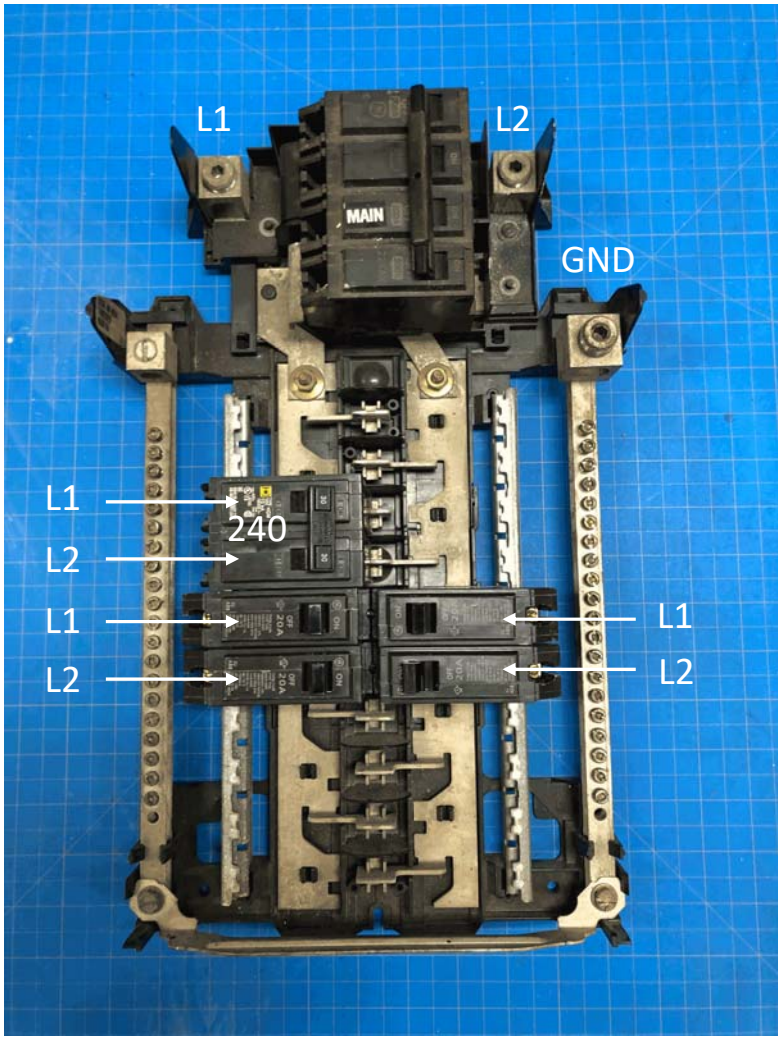
THREE-WIRE Single Phase



Lighting and receptacles are on 120 volt circuits. Because of the greater current requirements, dryers and furnaces are on 240 volt circuits. No current flows in the equipment grounding conductor (EGC) unless there is a fault.

National Electrical Code (NEC)

NEC Terminology	Layman Terms
Ungrounded Conductor	Hot Legs L1 and L2
Grounded Conductor	Neutral
Grounding Conductor	Equipment Grounding Conductor / Ground


L1
L2
MAIN
GND
L1
240
L2
L1
L2
L1
L2

CIRCUIT BREAKERS

Typical residential and commercial style circuit breakers operate on two trip mechanisms:

- **Thermal** *(overloads)*

and

- **Electromagnetic** *(short circuits)*

Circuit breakers are at “rest” in the **OFF** position and are held in the **ON** position by a latching mechanism that is spring-loaded.

Circuit Breakers

- Circuit breakers are sized to protect the integrity of the wire insulation; they are not sized to protect human life.

Thermal Trip Mechanism

- If a circuit breaker is overloaded to a value of 135% it rated current, it must trip within one hour.

- If a circuit breaker is overloaded to a value of 200% it rated current, it must trip within two minutes.


550 °F
I/ON
20
O/OFF
10 kA
120/240V~
450 °F
I/ON
20
O/OFF
10 kA
120/240V~
10 26 05

Circuit Breakers

The electromagnetic trip mechanism is almost instantaneously, but it requires between 9 and 15 times the rating on the circuit breaker for it to trip. It is for short circuits and other catastrophic failures.

For example, it requires approximately 200 amps to activate the electromagnetic trip mechanism of a 20-amp circuit breaker.

Test Question

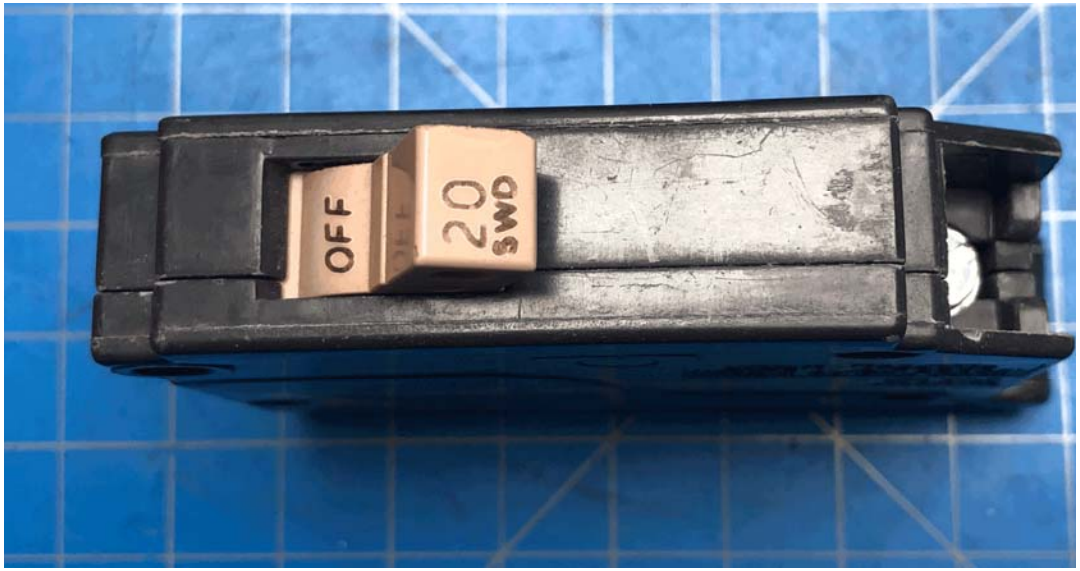
Circuit breakers have:

A) a slow thermal trip mechanism to prevent overloads (excessive currents) from overheating and damaging the wire insulation.

B) A fast electromagnetic trip mechanism in case of a catastrophic failure such as a short circuit.

C) Both A and B.

All circuit breakers do not trip to the center position. The following circuit breakers do not have a center position, and they trip to the "off" position: Cutler Hammer, Bryant and Murray.



Cutter Hammer circuit breaker have a light brown handle.

Test Question

All circuit breaker trip to the center position.

A) True
B) False

ATF - Jeremy Neagle, PE EE

Circuit Breakers

Never stand directly in front of a circuit breaker when you cut it off. Stand to the side of it. Bad things can happen.

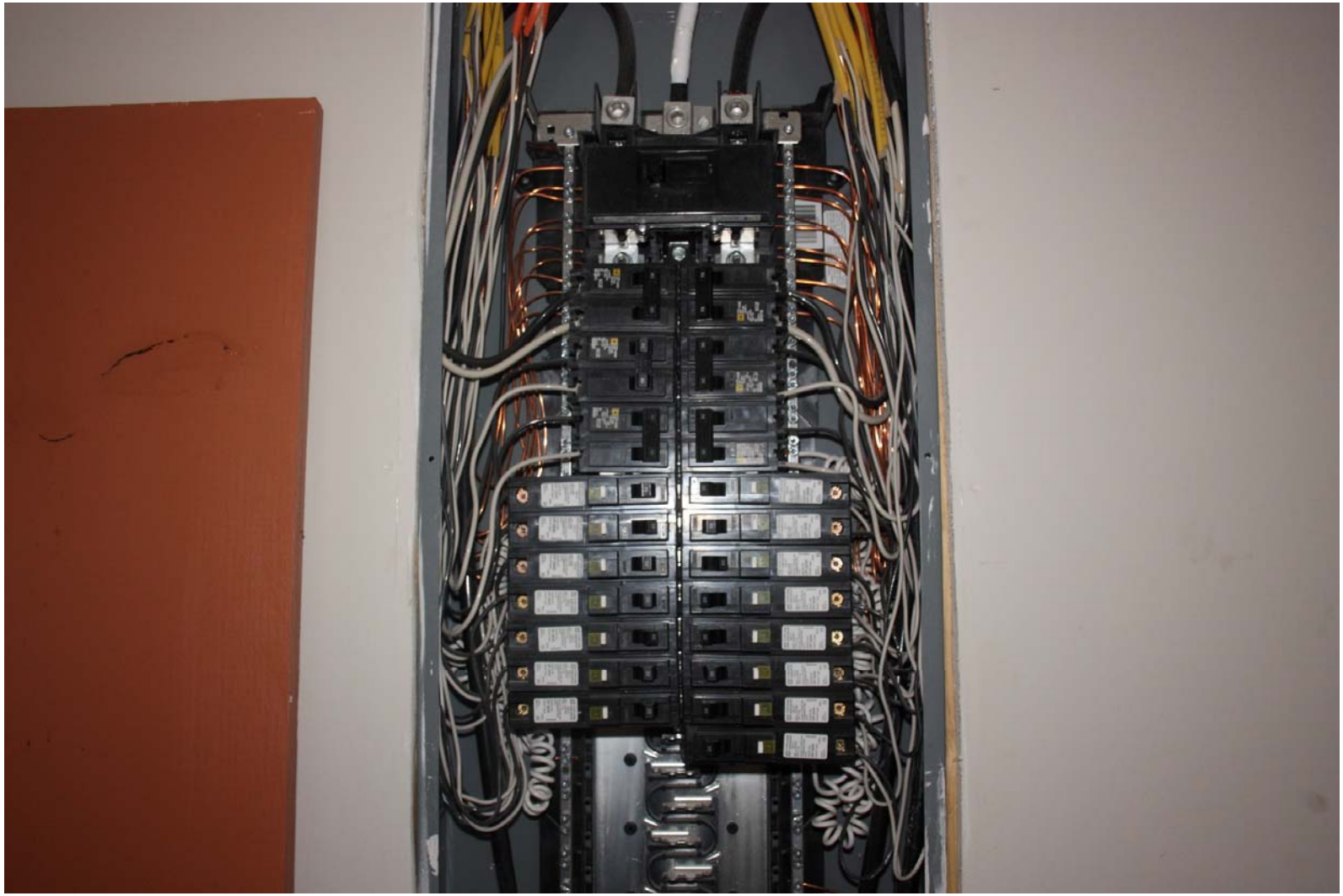
When electricity start to flow, it wants to continue to flow. When you interrupt it, a parting arc will occur.

If the load is a motor the parting arc will be worst. Energy will be stored in the motor windings and this energy will be released as part of the parting arc.

The parting arc is proportional to the current. If you need to cut off the main circuit breaker, first cut the individual circuit breakers off one at a time.

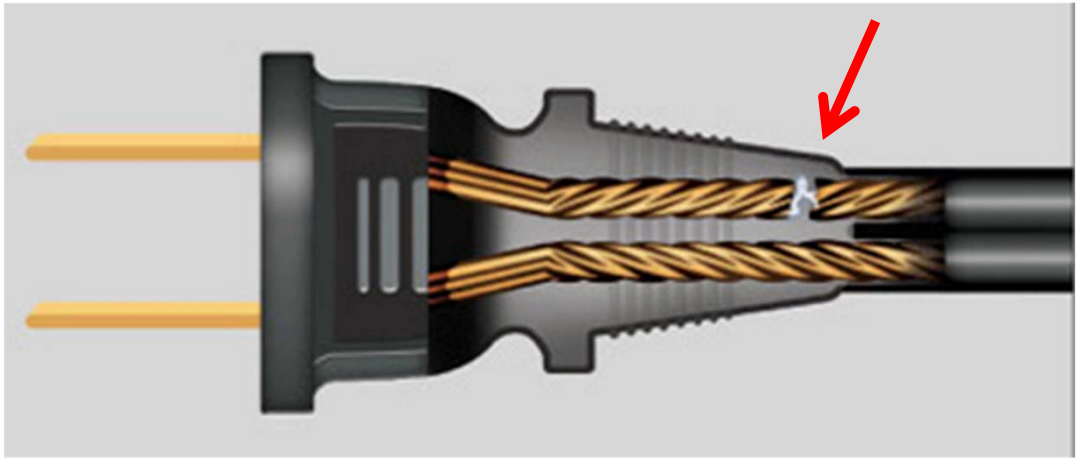
ARC-FAULT CIRCUIT-INTERRUPTERS

- AFCI: a device intended to provide protection from the effects of arcing type faults
- Recognizes the electrical waveform characteristics that are unique to arcing
- Required for all 125-volt, single phase 15- and 20-ampere branch circuits supplying outlets installed in living and activity areas (NEC 2014)
- Also available in feed-through outlets:

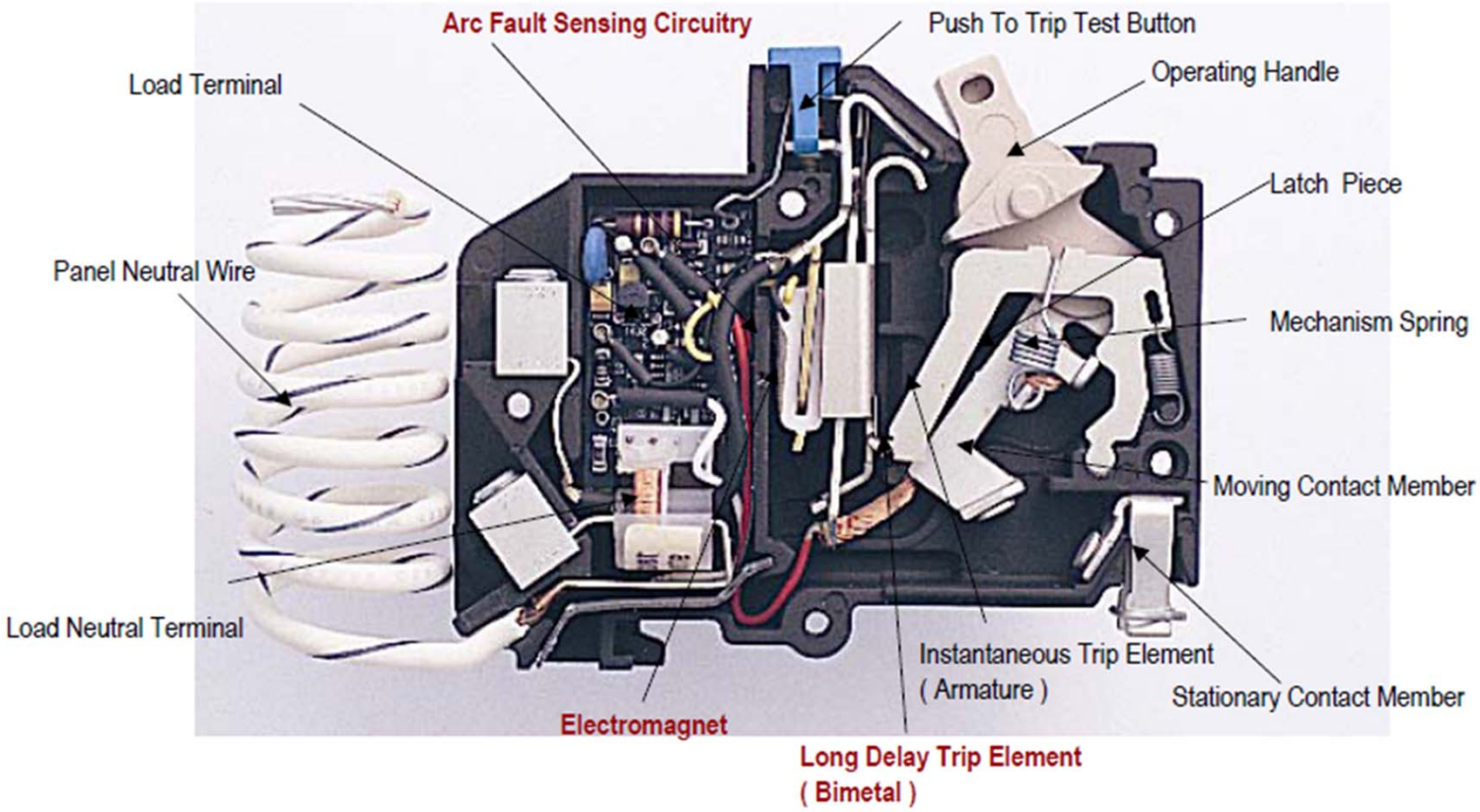


ARC-FAULT CIRCUIT-INTERRUPTER BREAKERS

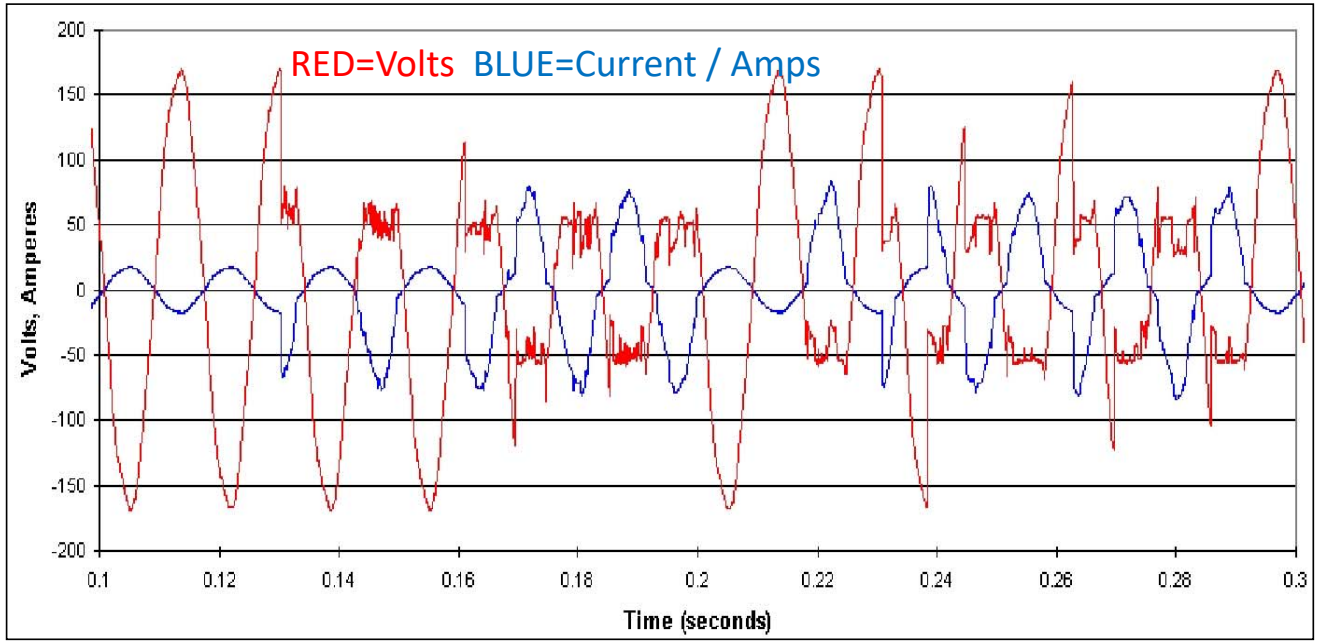
Series Arcing: Arcing between ends the same conductor at a break



Usually self-current-limiting – once conductor is severed, current flow and arcing stops.


Arc Fault Sensing Circuitry
Push To Trip Test Button
Load Terminal
Operating Handle
Latch Piece
Panel Neutral Wire
Mechanism Spring
Moving Contact Member
Load Neutral Terminal
Instantaneous Trip Element
(Armature)
Stationary Contact Member
Electromagnet
Long Delay Trip Element
(Bimetal)

ARC-FAULT CIRCUIT INTERRUPTER PROTECTION



Graph courtesy of 'The Arc-Fault Circuit Interrupter, An Emerging Product,' by George D. Gregory and Gary W. Scott, IEEE Transactions on Industry Applications, Vol. 34, No. 5, Sept/Oct. 1998, Publication 0093-9994/98

Ground Fault Protection

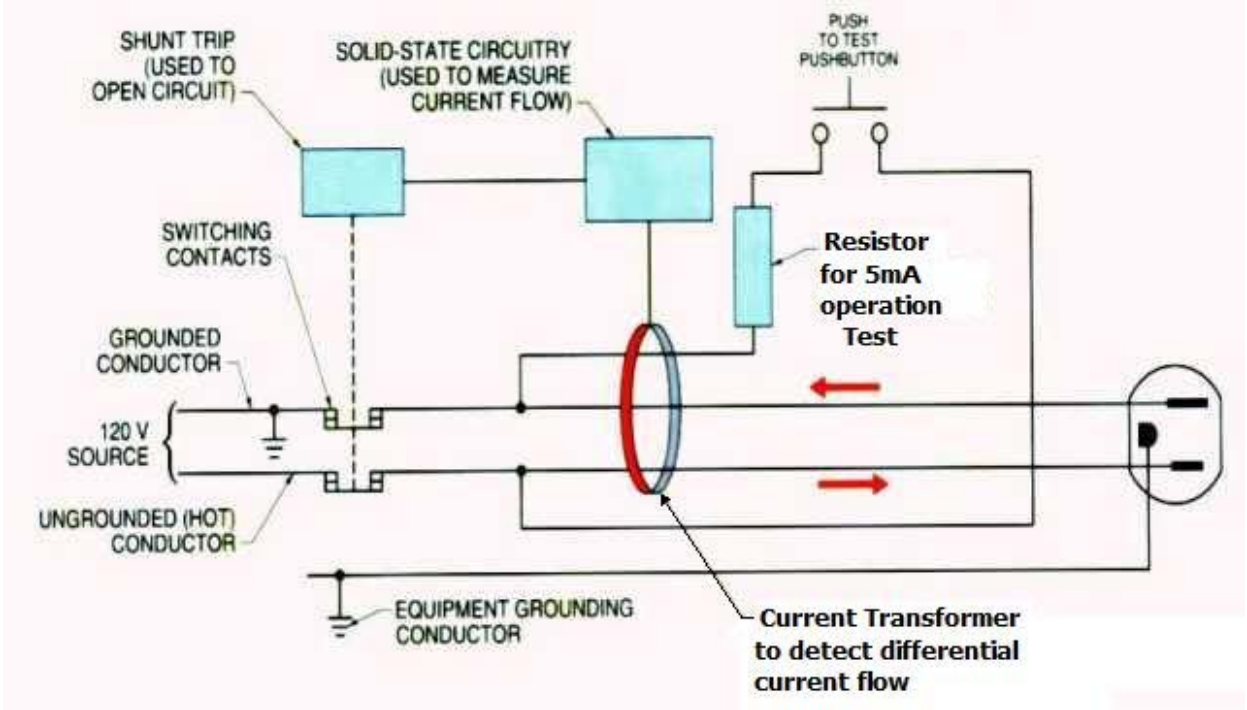
A ground fault is when current is return through some other path than the neutral – possible through you.

Ground fault circuit breakers and receptacle are extremely sensitive. They will trip if the difference is the supply current and the return current is greater than 6 mA (6/1,000 amp).

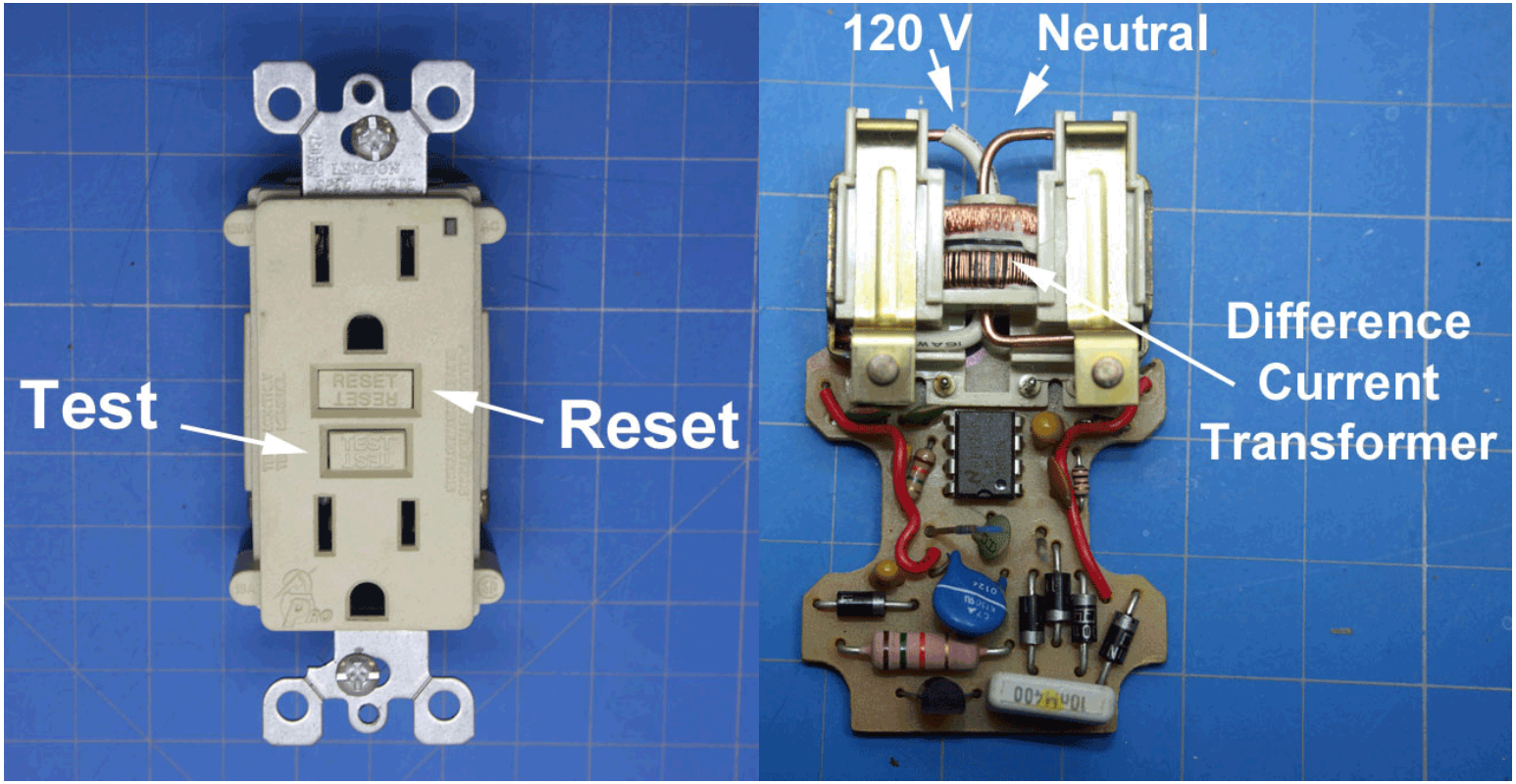
The National Electrical Code (NEC) requires them in any wet or damp location: kitchen, bathroom, garages, outside areas, etc.

GFCI CIRCUIT BREAKERS

GFCI CIRCUIT BREAKERS



If the return current does not equal the entering current, that means the return current is finding another path to take!


Test
Reset
120 V
Neutral
Difference
Current
Transformer

Circuit Breakers & Wire Sizes

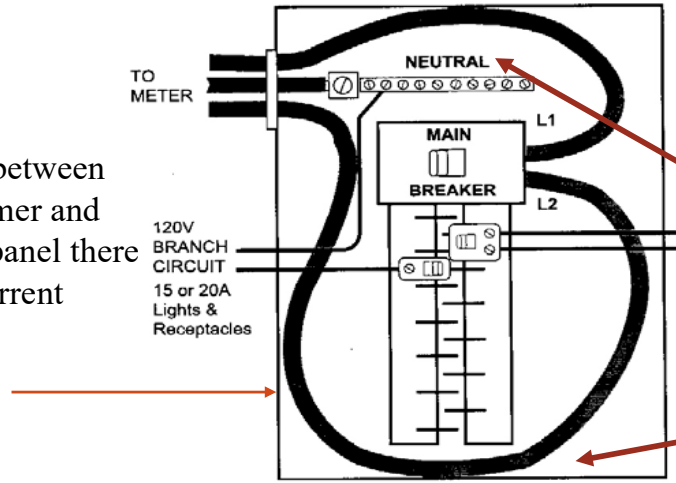
Circuit Breaker	American Wire Gage (AWG)	Color After 1999	Appliance
15	14	White	Lights
20	12	Yellow	Receptacles
30	10	Orange	Water Heater & Dryer
40	8		Range & Furnace
50	6		Range & Furnace

10 AWG wire is 0.1 inch in diameter and has a resistance of 1ohm per 1,000 feet.

As the AWG size get larger the diameter gets smaller.

ARC FAULT DAMAGE-FLAME IMPINGEMENT

Remember between the transformer and the service panel there is no overcurrent protection



Notice how the supply conductors are routed against the metal enclosure.

As the fire attacks the panel the metal begins to heat up. The insulation between the metal enclosure and the supply conductors melts. This allows the conductor to arc to the enclosure. Since there is no overcurrent device the arcing can occur in multiple locations and for long periods. The result is long, snaky arc burn holes in the enclosure adjacent to the conductors. The conductors exhibit arcing and melting. This type of damage is commonly mistaken for fire causation, but, is almost always the result of an external attack by fire.

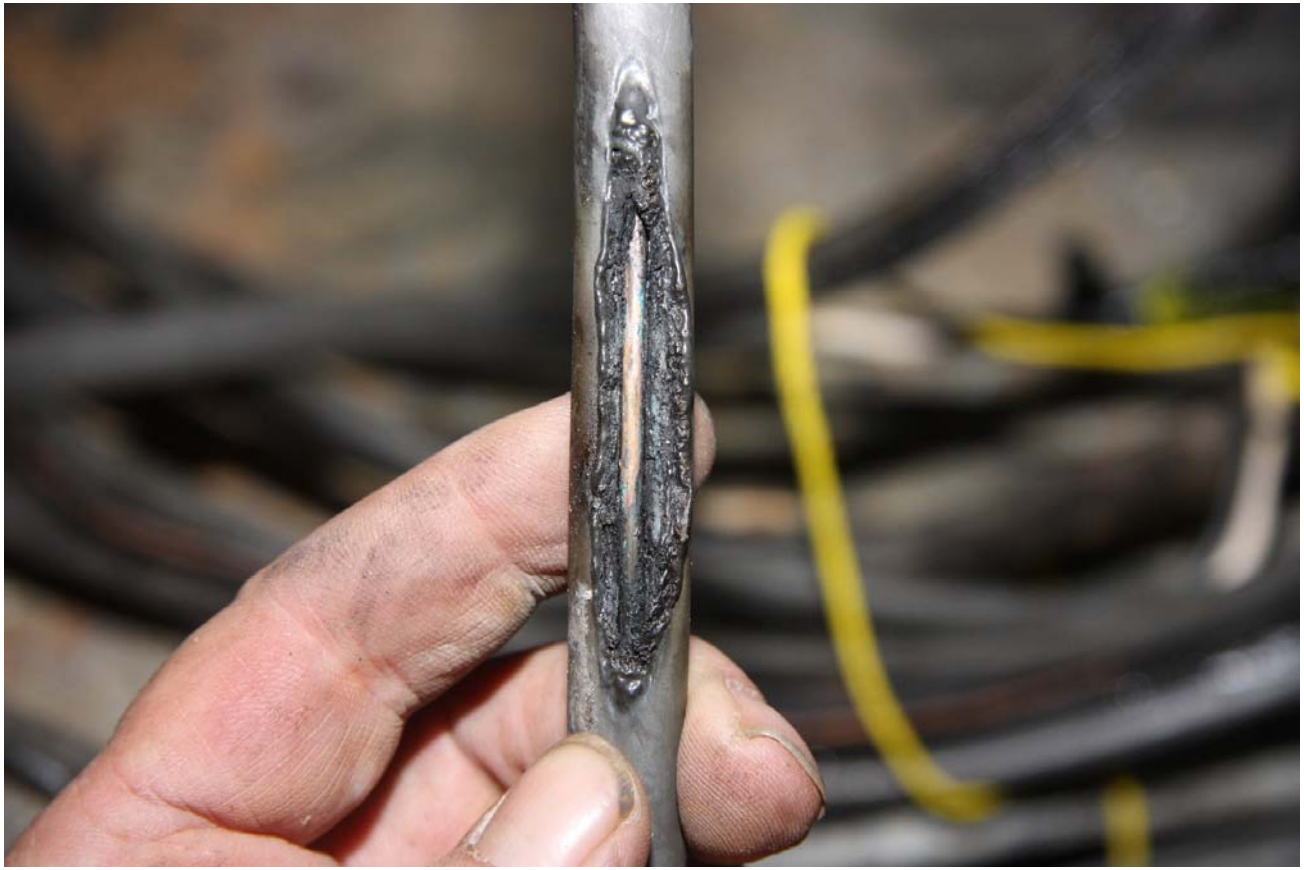
DOCUMENT THE PANELBOARD

- **Note the positions of circuit breakers (on, tripped, off)**
  - **Remember, some breakers trip to "off"**
- **Note what fuses are blown**
- **Copy any legend**
- **Find out which, if any, breakers were disturbed during or after the fire**
- **Determine if any breakers tripped often**
- **Find out if recent work has been performed**
- **Determine if breakers were regularly used as switches**
- **Remove cover and document interior**
- **Look for burned or melted insulation on wiring**
- **Verify panelboard/enclosure is properly grounded**
- **Check main connections ???**
- **Look for modifications or poor workmanship**
- **DO NOT MOVE BREAKER HANDLES!**

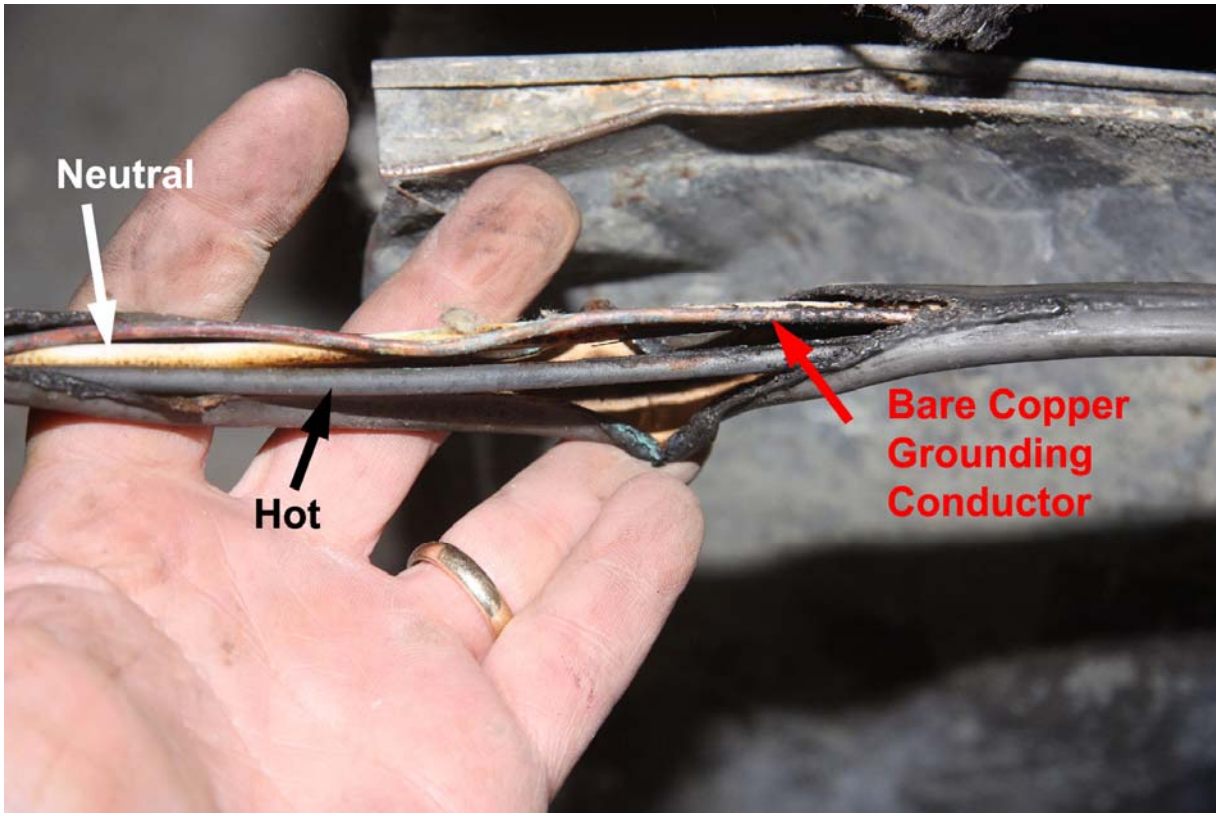
Romex Cable

F08-049 – In Attic, Cable to Furnace.

F08-049: Localized Melting at the Grounding Conductor



F08-049: Cable Burned from the Inside out. Hot and Neutral Wire Insulation Undamaged



Energized Neutral

- If the primary line of the transformer (≈ 8,000 volts) or one of the 120 volt secondary lines comes in contact with the neutral (non-insulated), electrical current can flow into the house without passing through a circuit breaker and find a path to earth ground. There has to exist a path to ground or no current will flow. The usual path is through a metal water or gas pipe. You must have a complete path.

- Tree limbs
- Vehicles hitting poles
- Down power lines.
- Animals (squires and racoons)

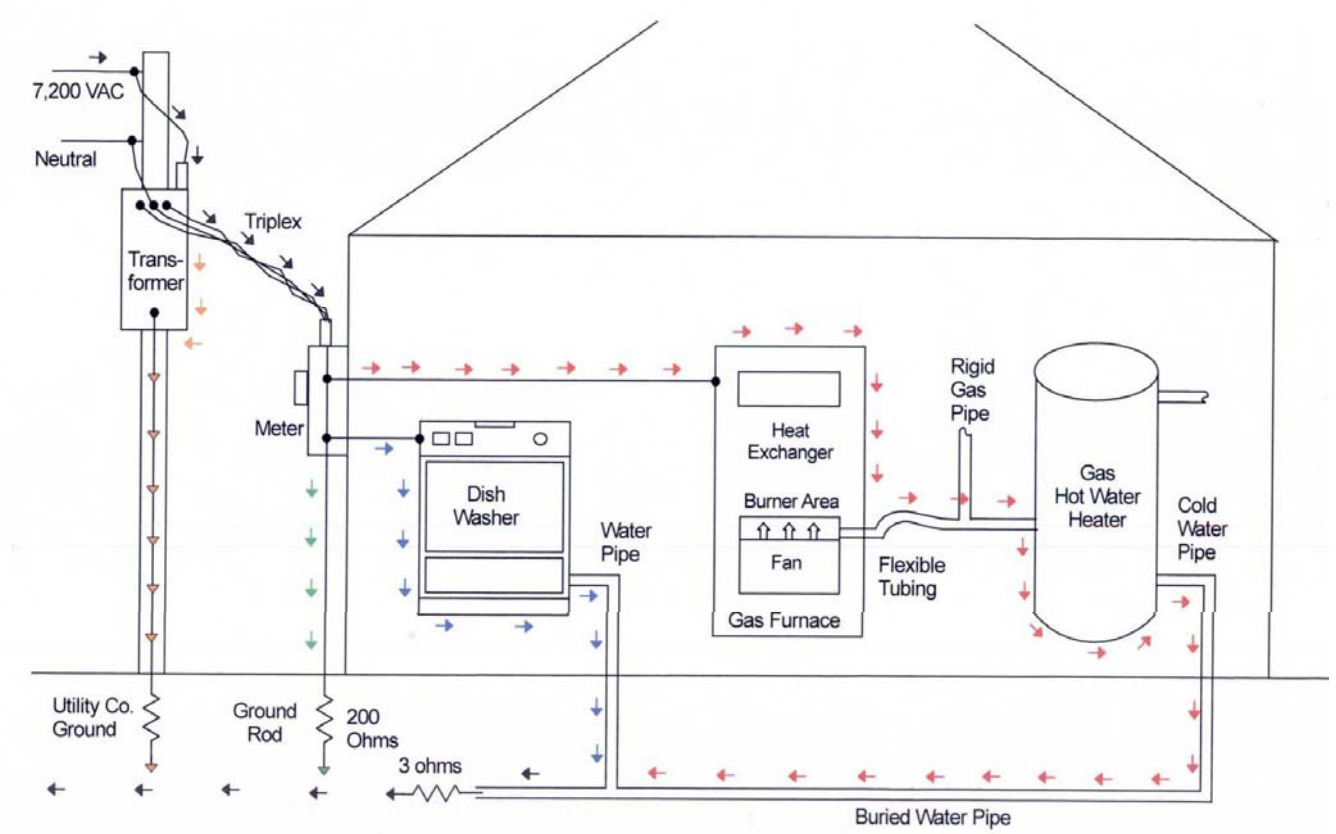
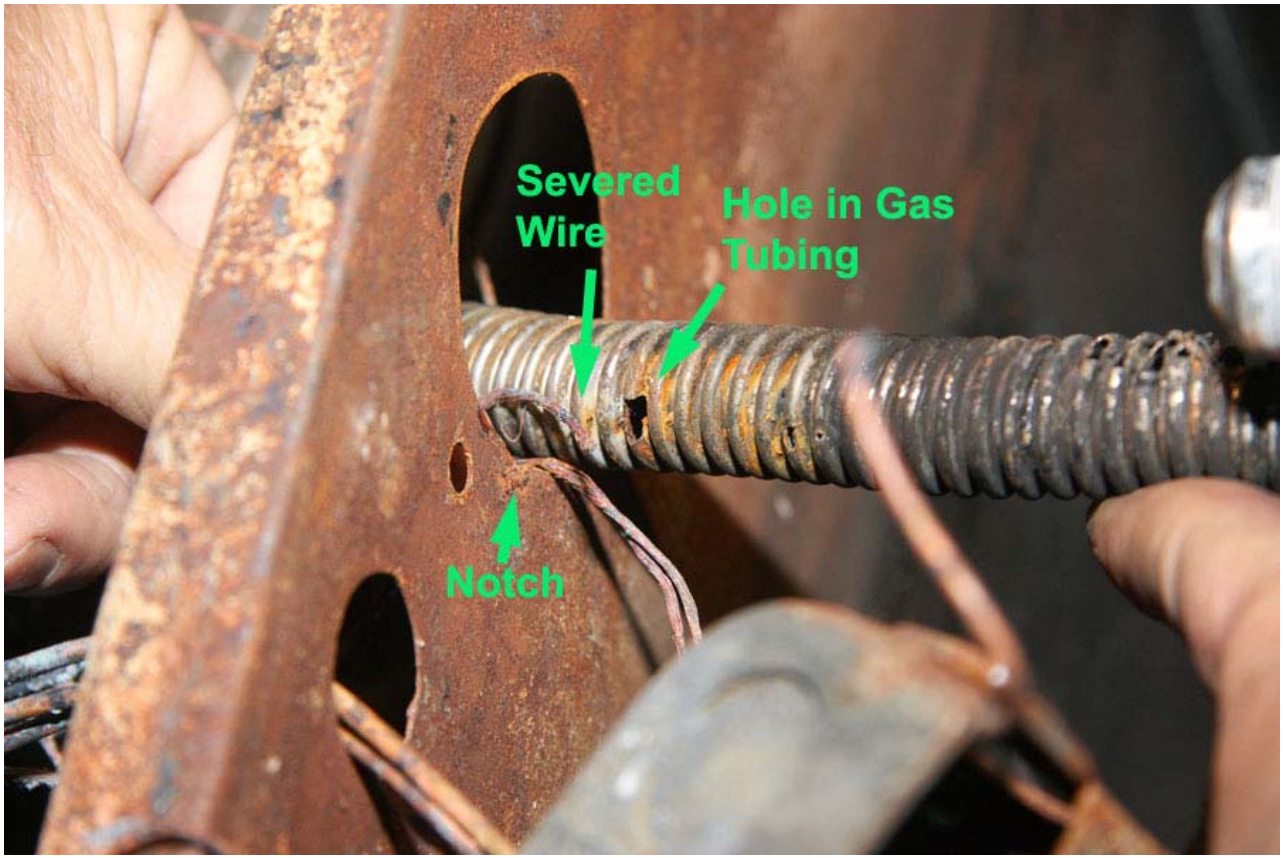


Figure 1. Multiple Fault Current Paths.

Case No.: F08-049

F08-049



F08-049: Transformer Examination

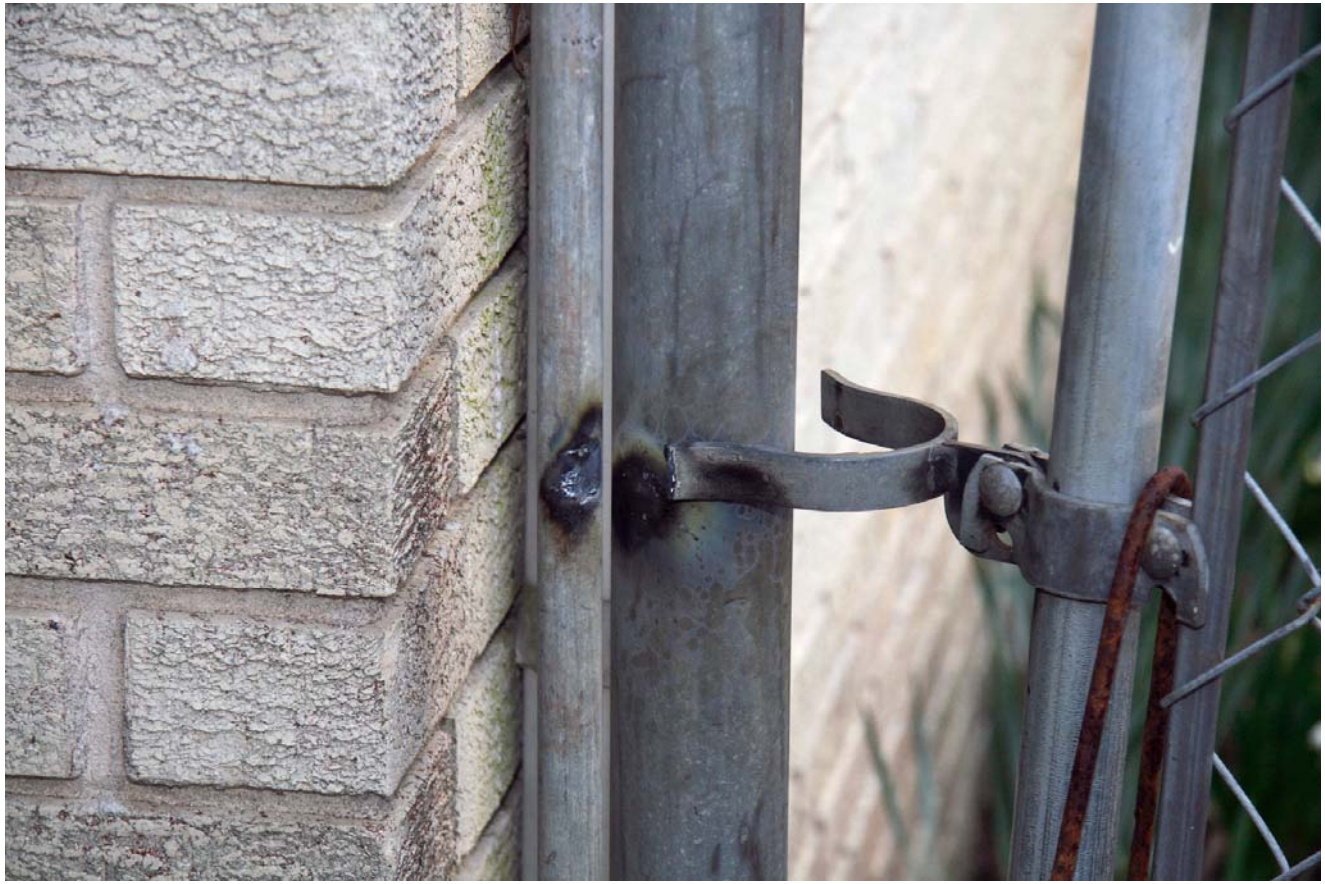
F08-049: Transformer Examination

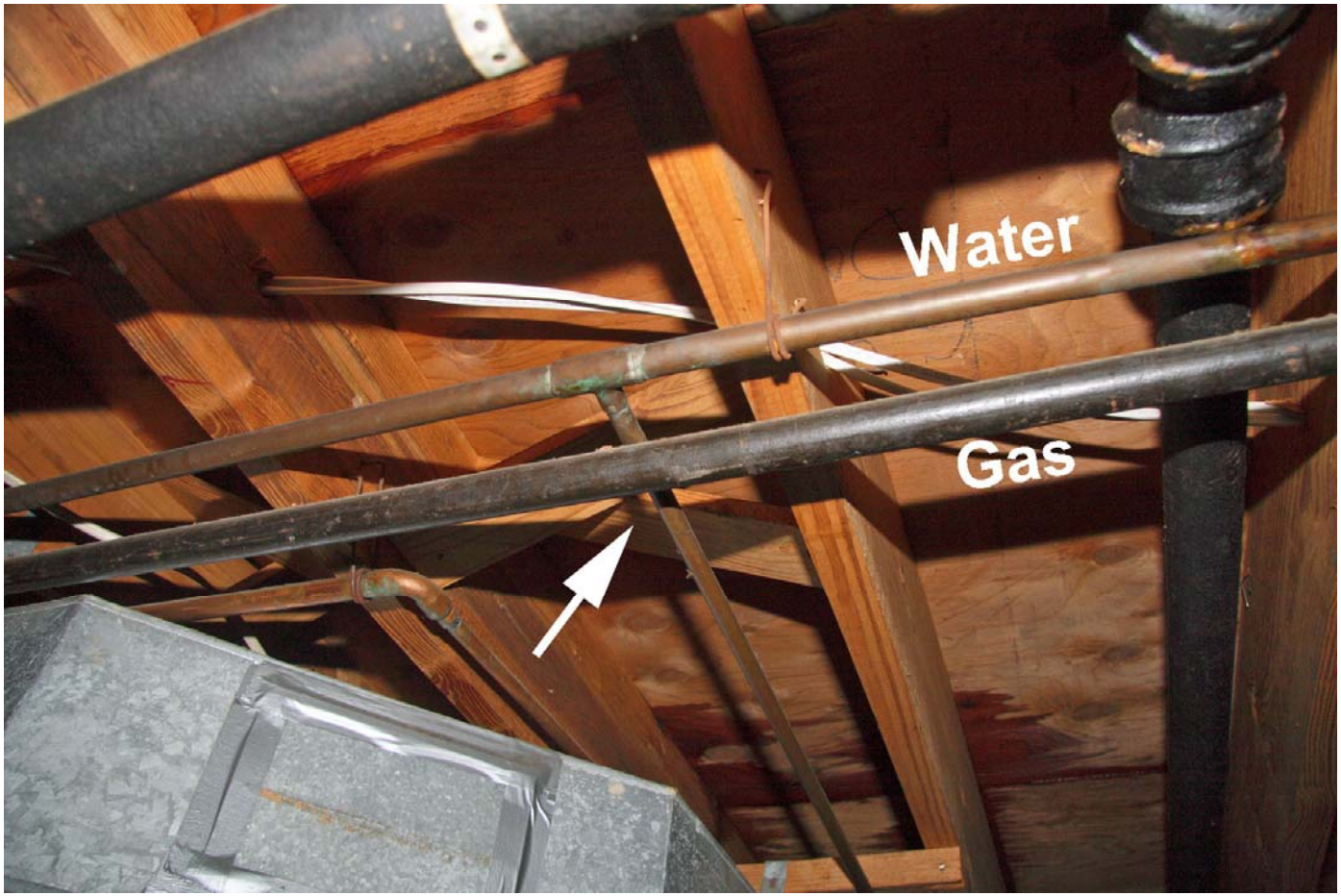
Crossville, AL

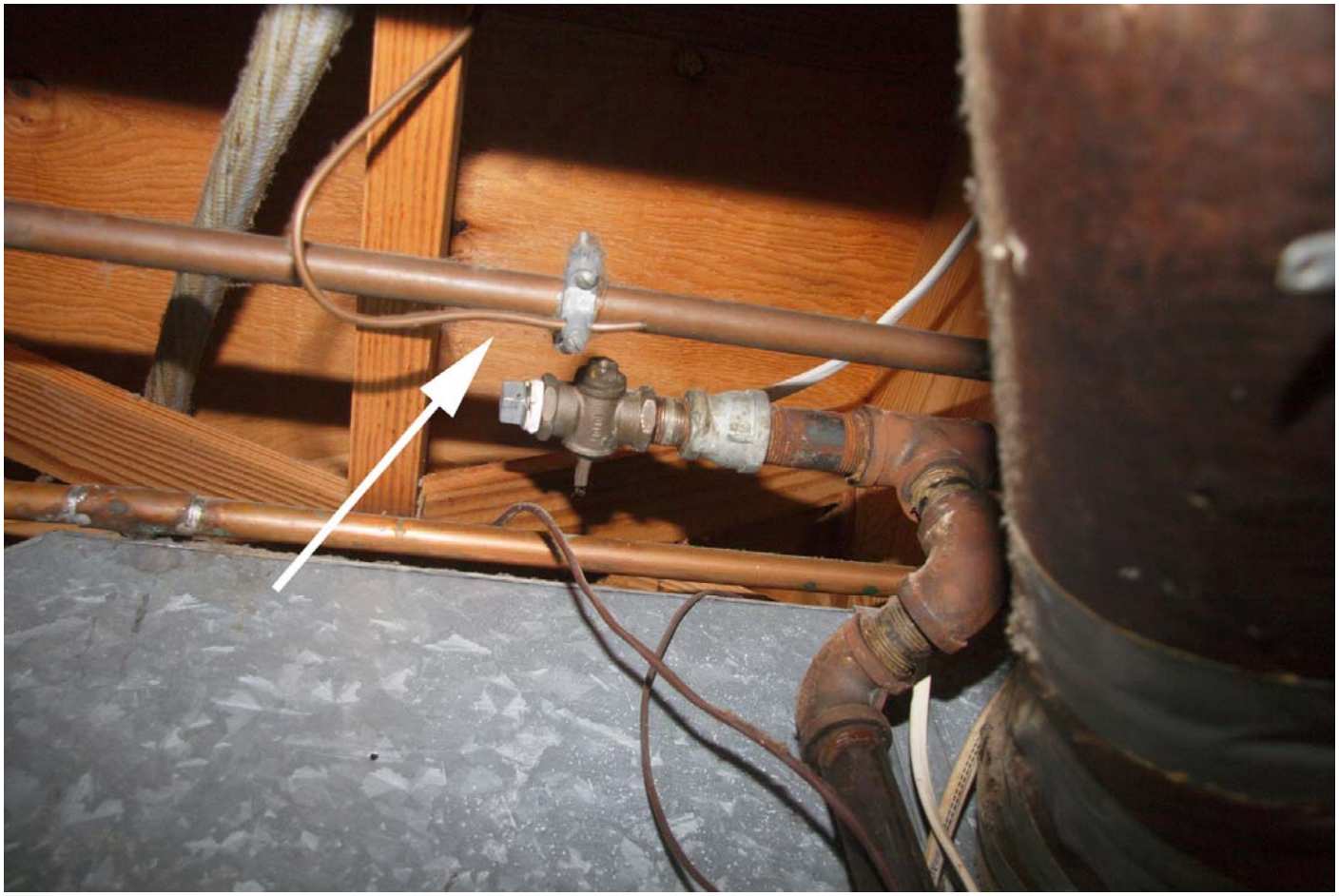

TEREX
UTILITIES
TEREX
UTILITIES

Vestavia Hill, AL

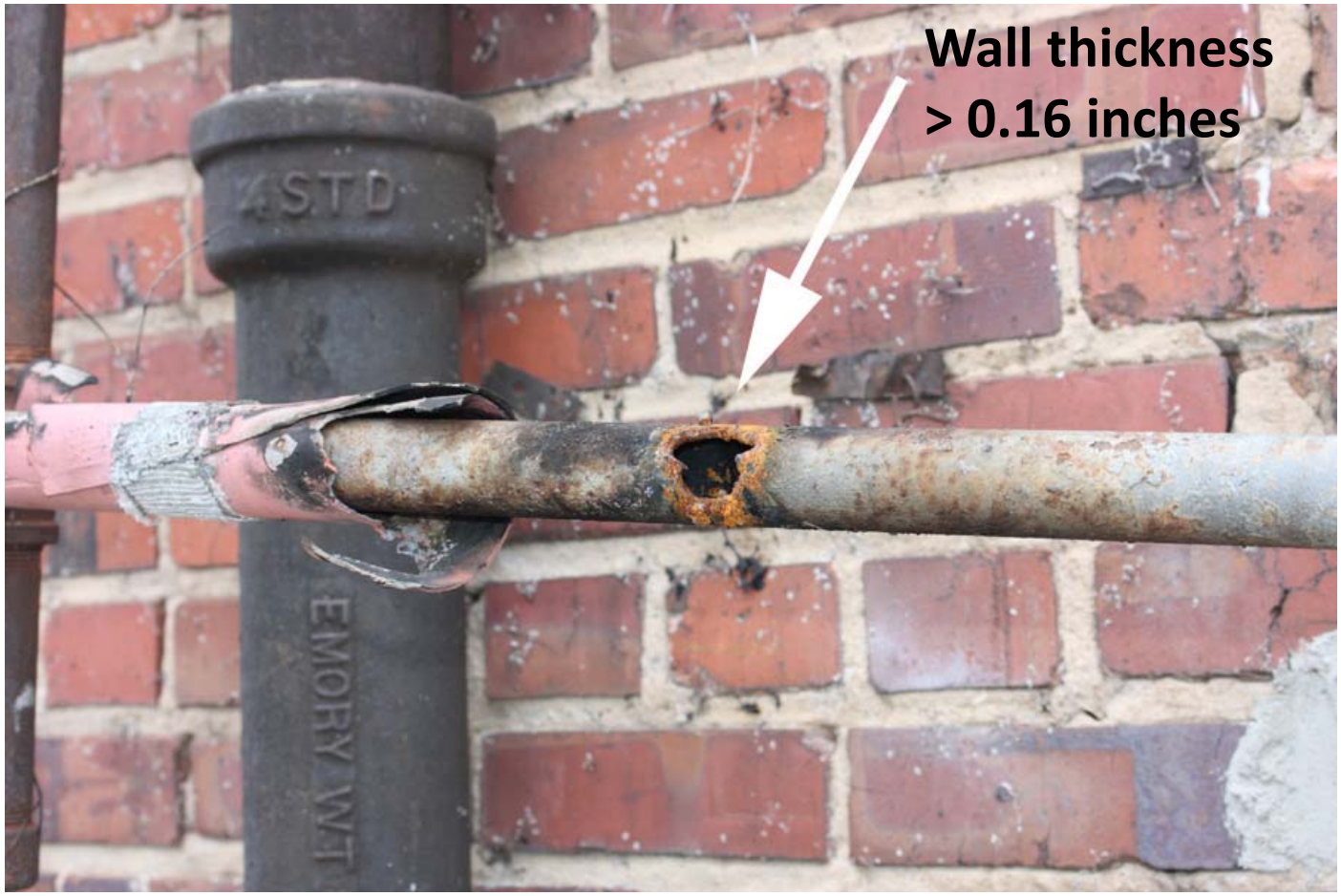
Electrical-Forensics.com



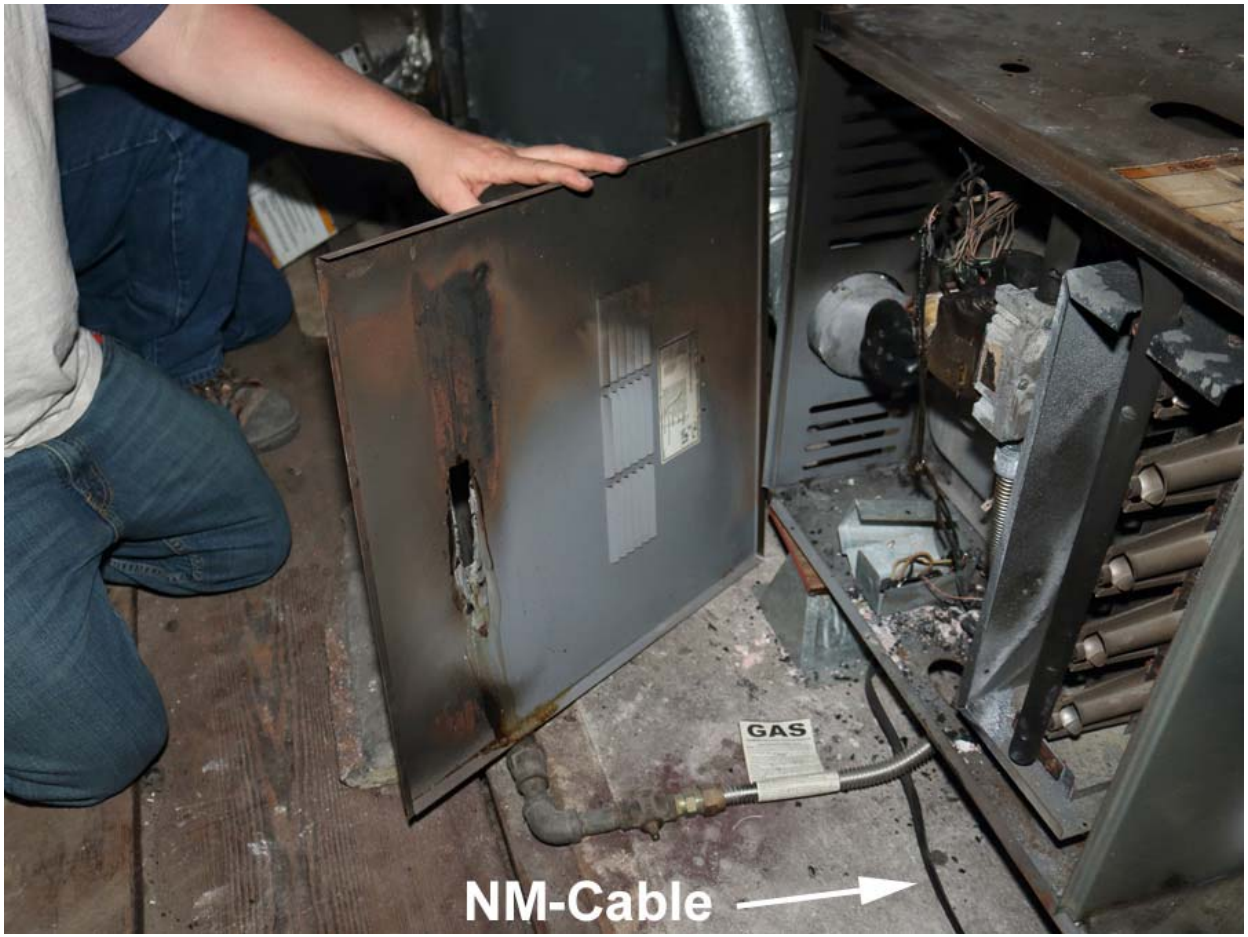

Water
Gas

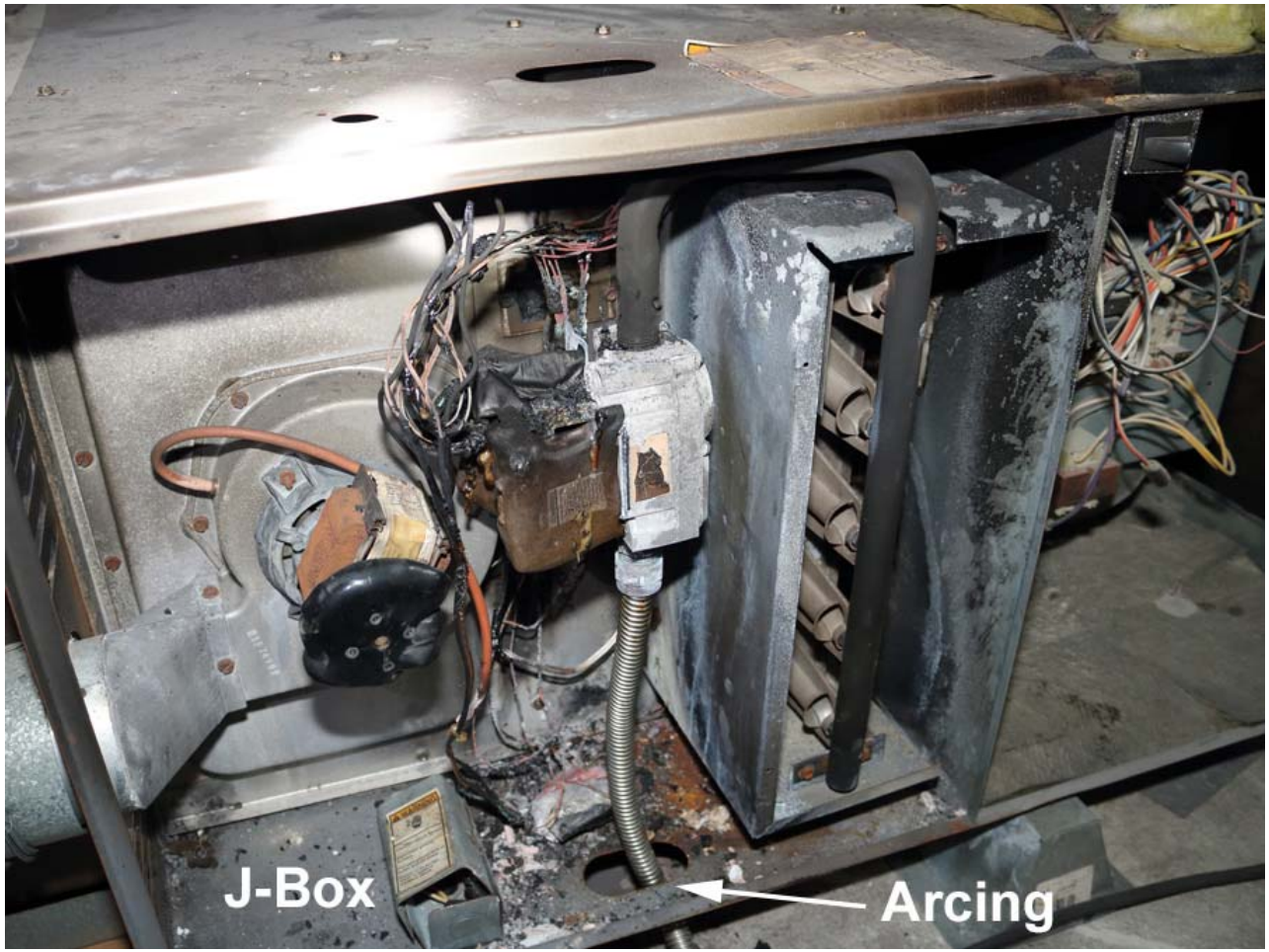


Selmer TN


Wall thickness
> 0.16 inches
4STD
EMORY WT

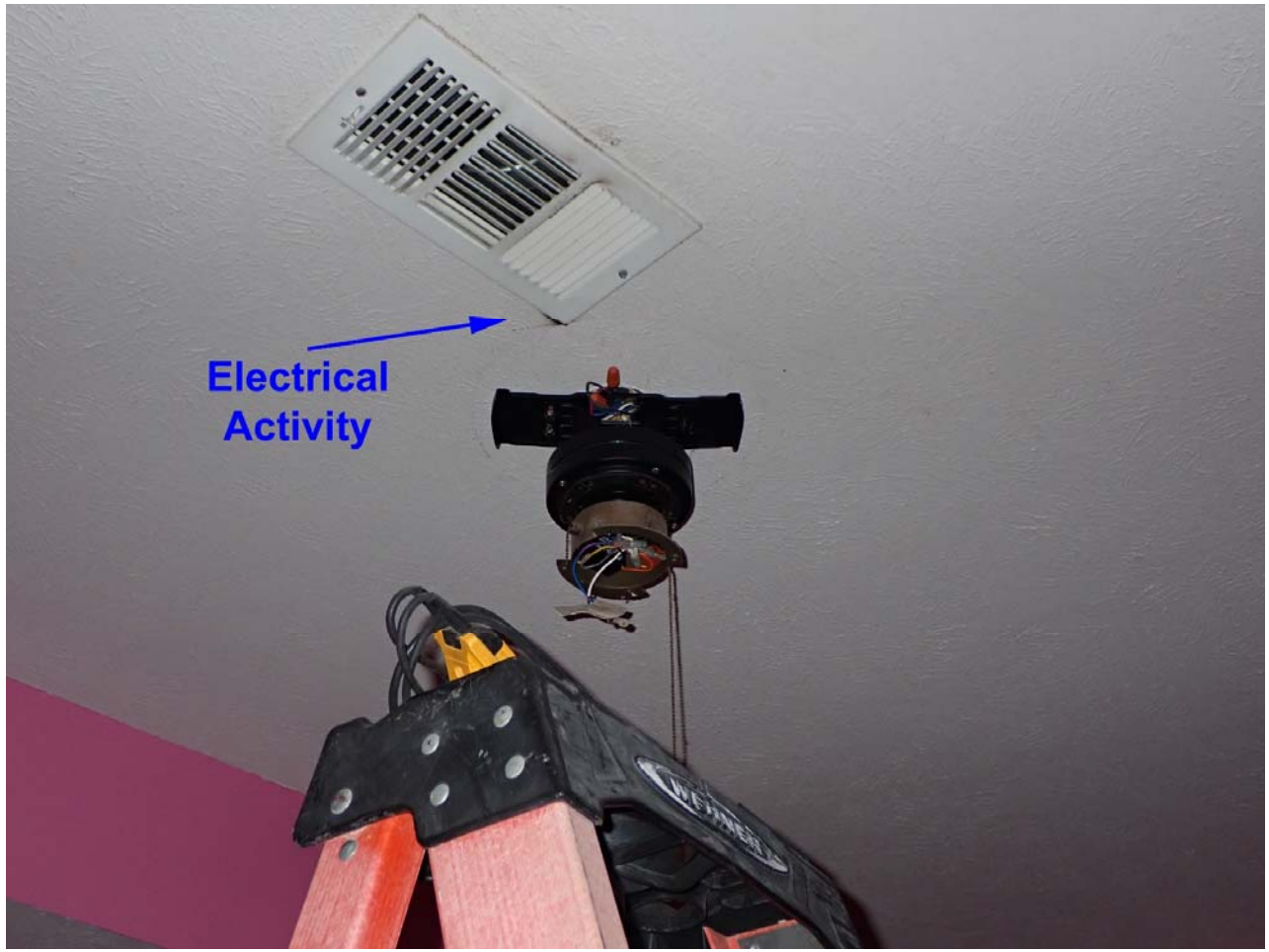
New Orleans, LA


GAS
NM-Cable


J-Box
Arcing

F20-042 Vicksburg MS


Damaged Water Supply Line
Dishwasher

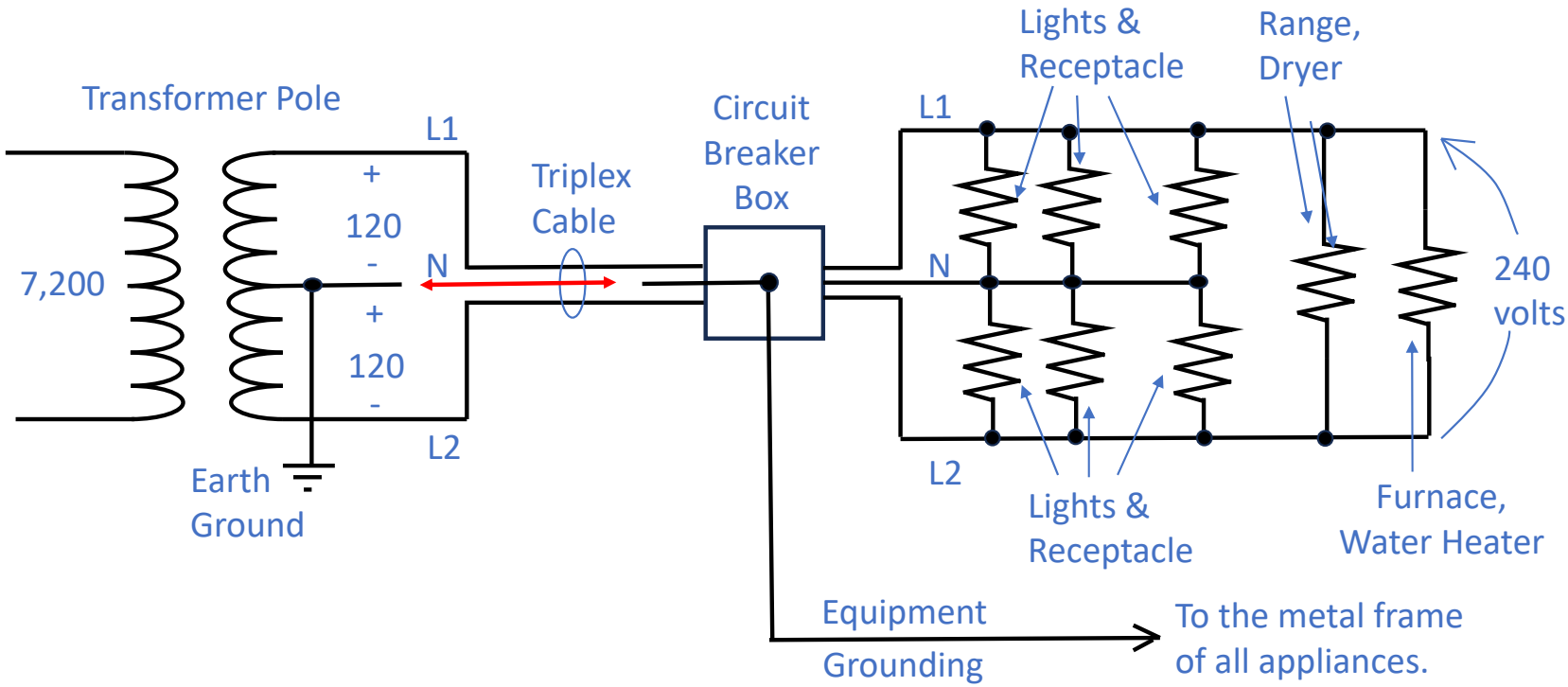

Electrical
Activity

Test Question

A cable that is damaged from excessive heat from the ground conductor is a sign of:

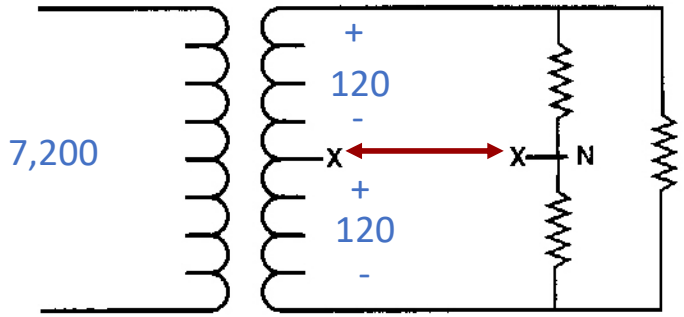
A) Overvoltage
B) A Floating neutral
C) An Energized Neutral
D) A bad flux capacitor

Open Neutral



Neutral breaks somewhere between the transformer and the circuit breaker box. Could occur because of an energized neutral.

OPEN NEUTRAL FAILURE



A failure or loss of neutral results in the 120 volt loads being subjected to voltages between 0 to 240 volts. The actual voltage depends on how the system is balanced. I.e. how much load is on one leg of 120 volt compared to the other. The more the unbalance the more the unbalance of voltage. The 240 volt loads are not affected.

~~Since the effects are very noticeable this type of condition does not persist long.~~ Some effects of an open neutral are:

Lights - Burn bright and hot. Burn out very quickly

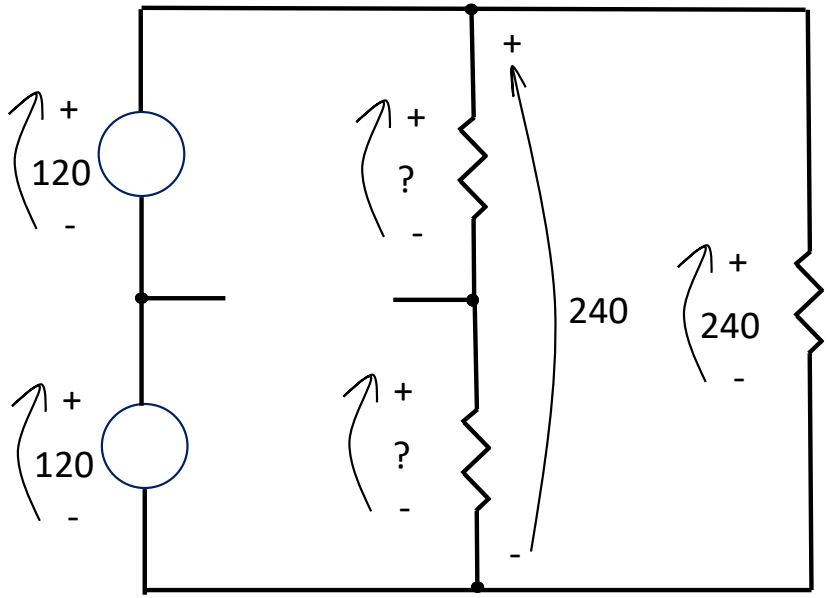
Heaters - May overheat, thermal protection shuts down heater

Motors - Overheat, some types may increase speed

Transformers - Overheat, devices connected to output may overheat or fail due to increased voltage

Wiring - No effect. Building wiring is rated for 600 volts.

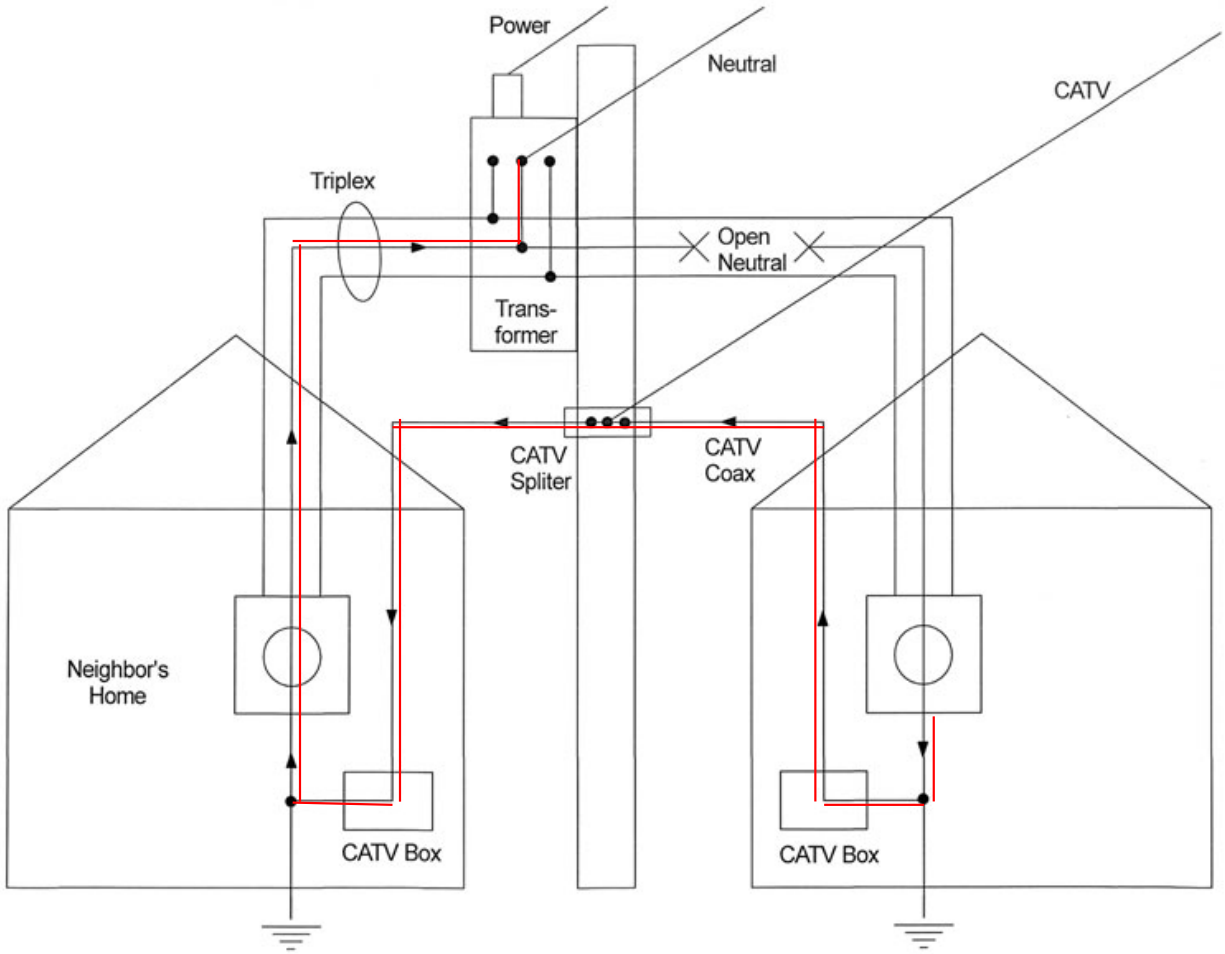
Kirchhoff's Voltage Law: "The sum of the voltages around any closed loop is zero".



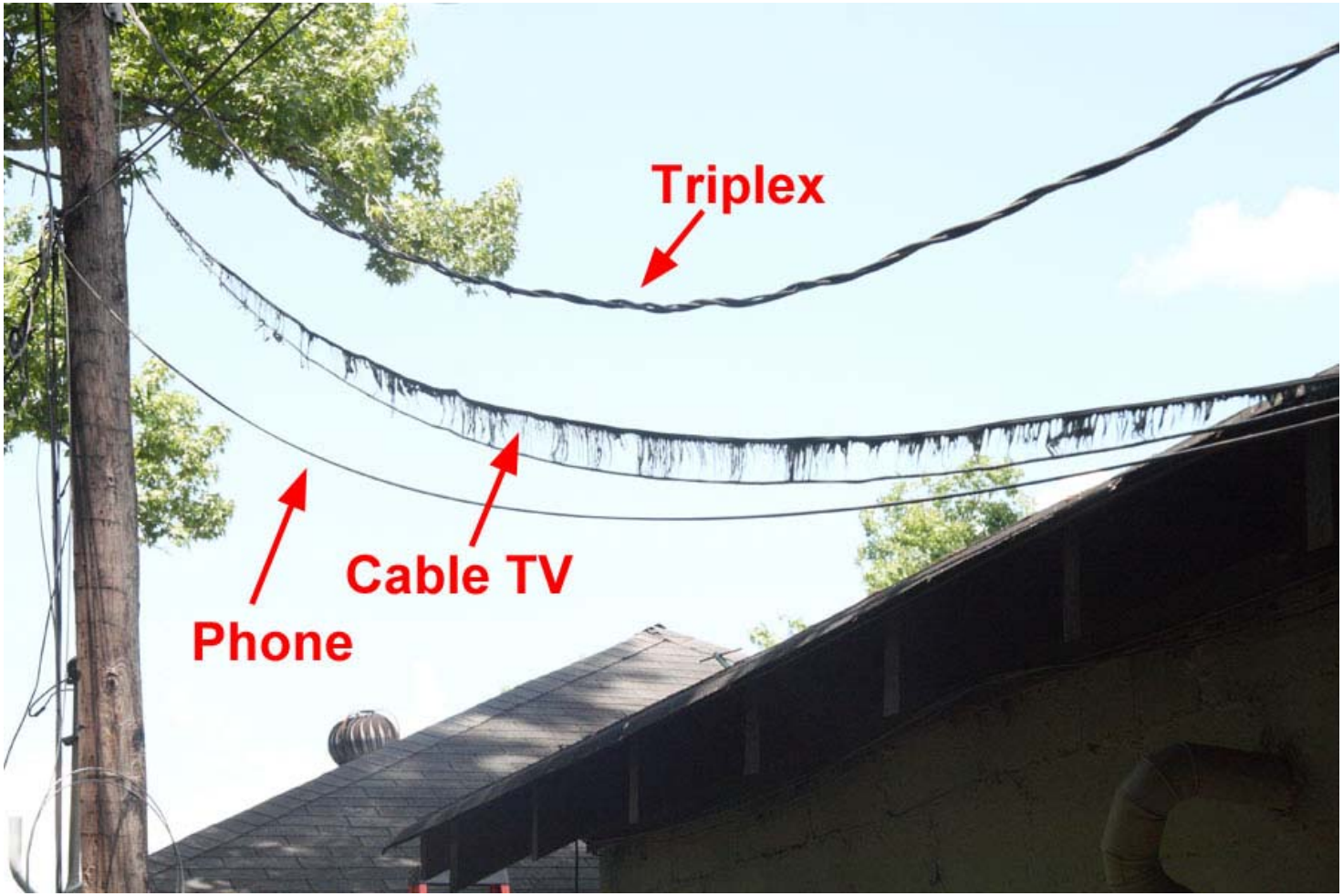
Open or Floating Neutral

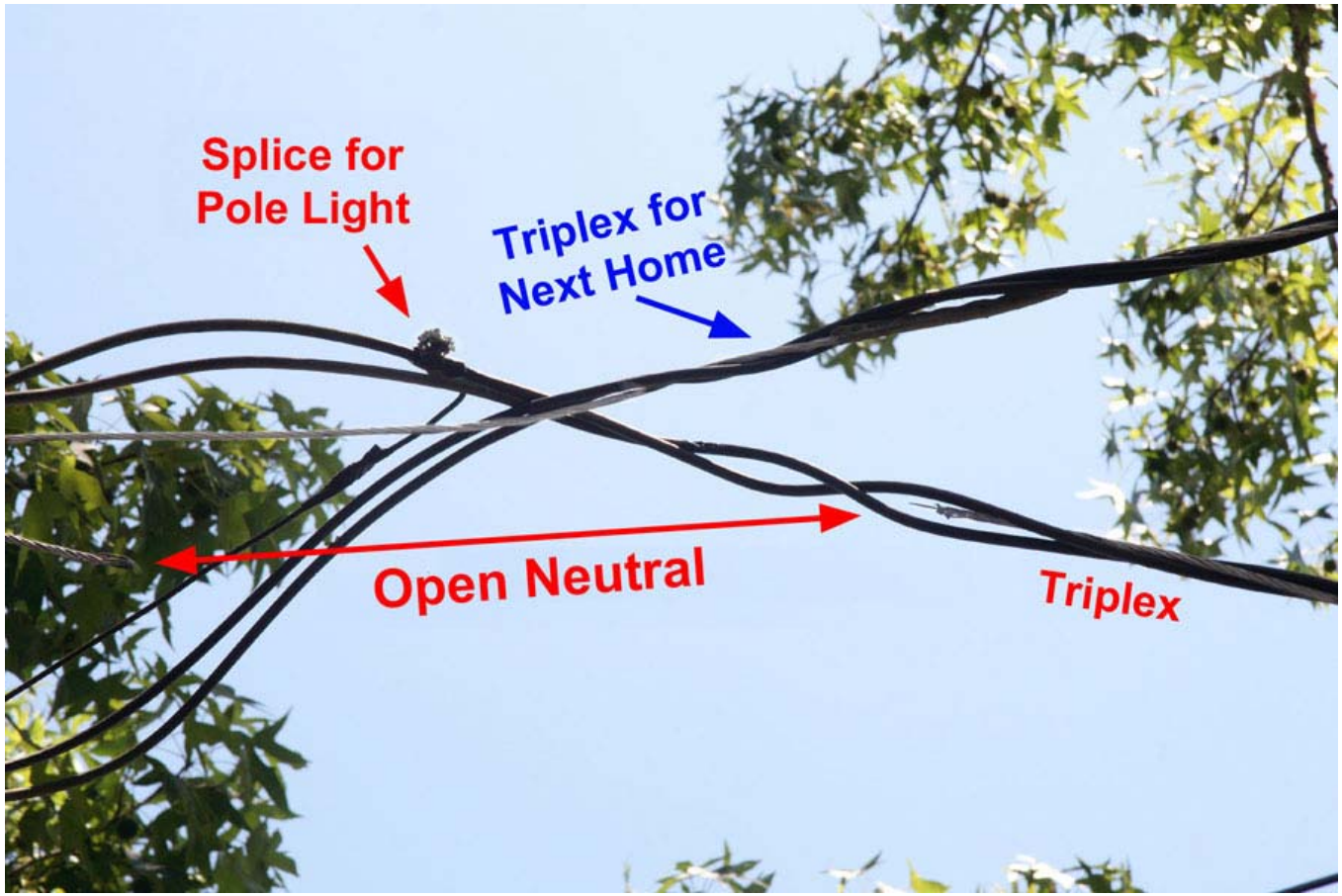
Floating or Open Neutral

- NFPA 921 2021, Section 9.5.2
- An electrical installation with an open neutral conductor will not have a fixed 120 V between each hot leg and the neutral. There will be 240 V between the two legs, but instead of the voltage of the two legs being fixed at 120 V to neutral each. The voltage may vary to some other values that add up to 240 V. The actual voltages in the legs will depend on the load on the two legs at any time. For example, the voltages might be 60 and 180.


Power
Neutral
CATV
Triplex
Open
Neutral
Trans-
former
CATV
Spliter
CATV
Coax
Neighbor's
Home
CATV Box
CATV Box


Triplex
Cable TV


Triplex
Cable TV
Phone


Splice for
Pole Light
Triplex for
Next Home
Open Neutral
Triplex

Brookhaven, MS

Inside the home

Electrical Arcs

2021 NFPA 921 - Section 9.9.4 Arcs.

9.9.4.1 General. An arc is a high-temperature luminous electric discharge across a gap or through a medium such as charred insulation. Temperatures within the arc are in the range of several thousand degrees, depending on circumstances, including current, voltage drop, and metal involved. For an arc to jump even the smallest gap in air spontaneously, there must be a voltage difference of at least 350 V. In the 120/240 V systems being considered here, arcs do not form spontaneously under normal circumstances. *(See Section 9.12.)* In spite of the very high temperatures in an arc path, arcs may not be competent ignition sources for many fuels. In most cases, the arcing is so brief and localized that solid fuels such as wood structural members cannot be ignited. Fuels with high surface-area-to-mass ratio, such as cotton batting, tissue paper, and combustible gases and vapors, may be ignited when in contact with the arc.

2021 NFPA 921 – Section 9.9.5 Sparks.

9.9.5.2 When just copper and steel are involved in arcing, the spatters of melted metal begin to cool immediately as they fly through the air. When aluminum is involved in faulting, the particles may actually burn as they fly and continue to be extremely hot until they burn out or are quenched by landing on some material. Burning aluminum sparks, therefore, may have a greater ability to ignite fine fuels than do sparks of copper or steel. However, sparks from arcs in branch circuits are inefficient ignition sources and can ignite only fine fuels when conditions are favorable. In addition to the temperature, the size of the particles is important for the total heat content of the particles and the ability to ignite fuels. For example, sparks spattered from a welding arc can ignite many kinds of fuels because of the relatively large size of the particles and the total heat content. Arcing in entry cables can produce more and larger sparks than can arcing in branch circuits.

Melting Temperatures of Metals

Zinc	707°
Aluminum	1220°F
*Yellow Brass	1710°F
Copper	1984°F
*Carbon Steel	2760°F

Yellow Brass is an alloy – 60% Copper and 40% Zinc
Carbon Steel is alloy of Iron and Carbon (<2%)

Electrical Arcing

ATF - Jeremy Neagle, PE EE

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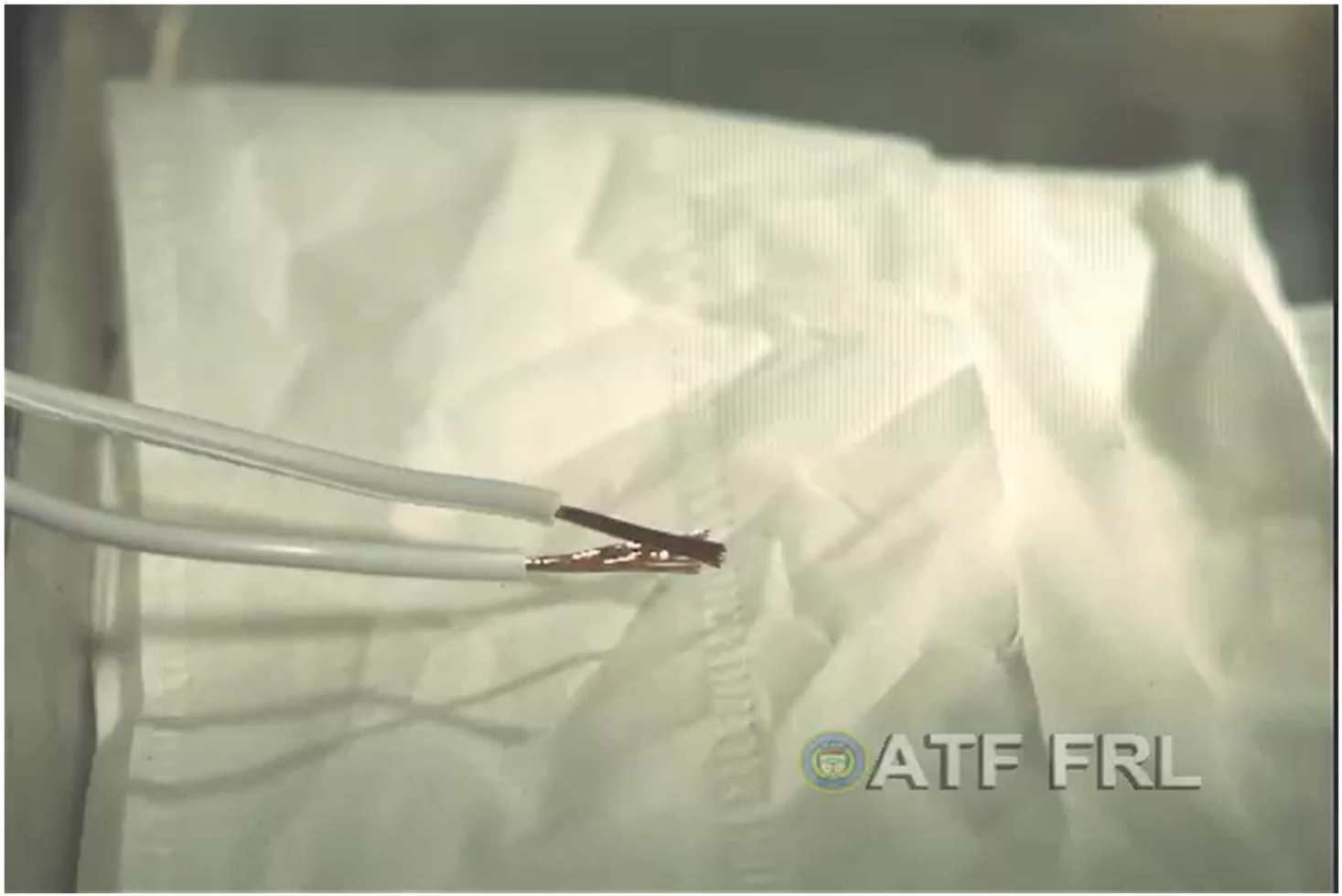


IGNITION ENERGY OF AN ARC

- The ignition energy of an arc, or its potential to cause ignition, is the equivalent of one lit match for one second.

Can not ignite a wood beam 2x4

Electrical beading indicates that the circuit was energized.

Beading on a conductor is NOT a sole indicator the fire was electrical in nature.

Arcing verses Fire Melting

- Arcing
  - Usually last less than 1 second
  - Temperatures between 3,600°F & 7,200°F

  Fire Melting
  - Usually last minutes or longer
  - Max Temperature between 1,600°F & 2,000°F

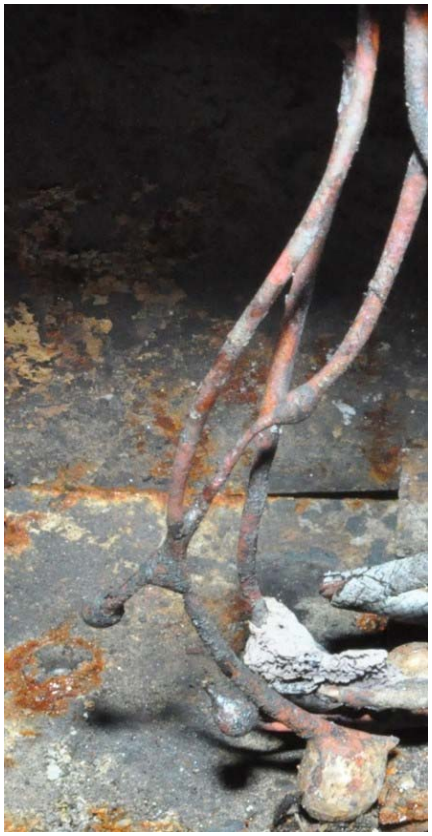
Melting Caused by Fire

2021 NFPA 921, Section 9.11.2

1. Visible effects of gravity on artifact
2. Extended area of damage without a sharp demarcation from undamaged material.
3. Gradual necking of the conductor - assuming this is not due mechanical break).
4. Low internal porosity when viewed in a cross-section (little air trapped in the bead – metallurgist.

ATF - Jeremy Neagle PE
Fire Melting

ATF Jeremy Neagle, PE
Fire Melting



ATF – Jeremy Neagle, PE
Fire Melting

Melting Caused by Electrical Arcing

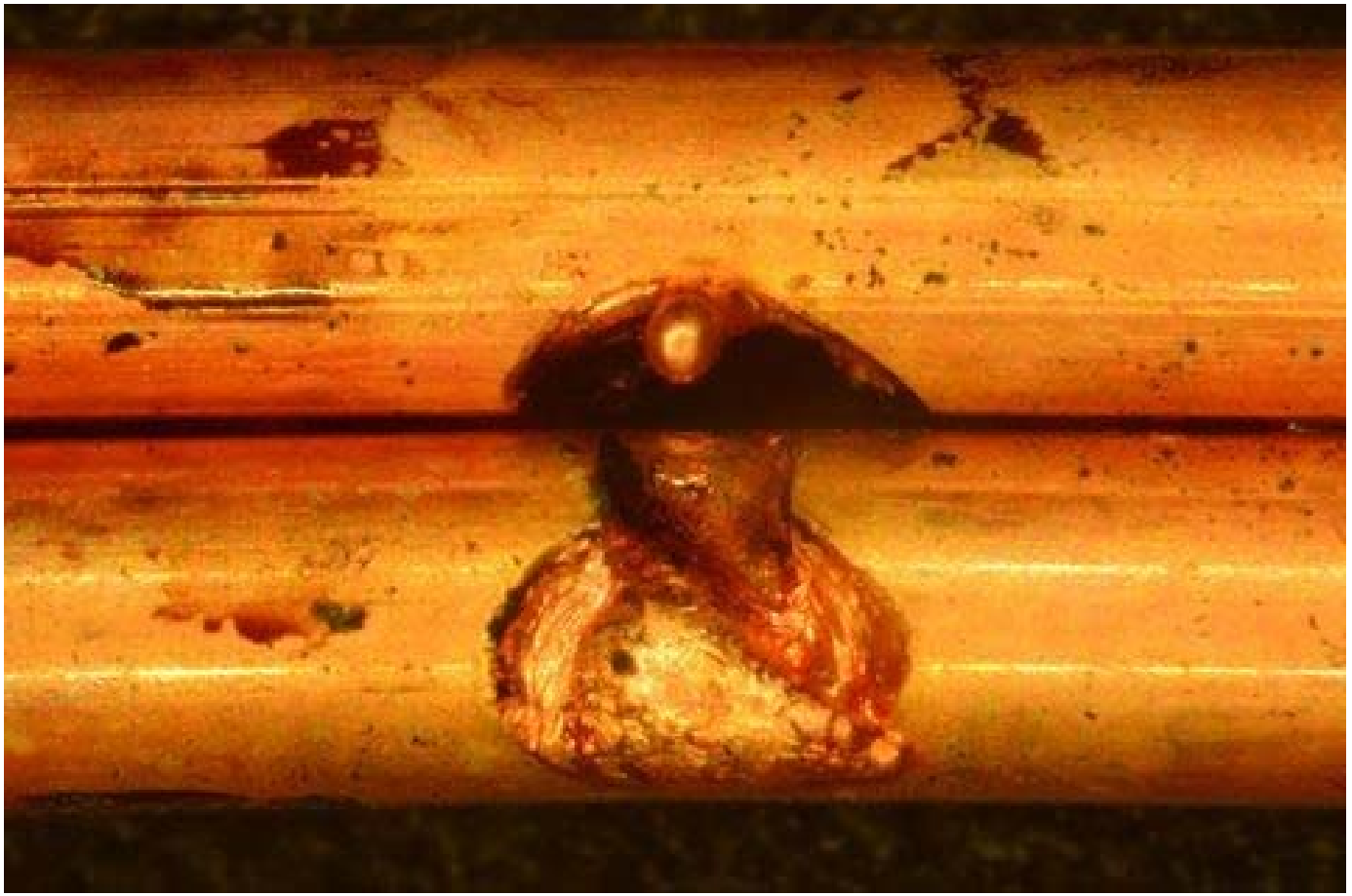
2021 NFPA 921, Section 9.11.1

1. Sharp demarcation between damaged and undamaged area
2. Round, smooth shape of artifact
3. Localized Point of contact
4. Identifiable corresponding area of damage on the opposing wire.
5. Locally enlarged gain size (metallurgist).
6. Resolidifcation of waves
7. Copper drawing lines visible outside of damaged area
8. Localized round depressions.
9. Small beads and divots over a limited area
10. High internal porosity when viewed in a cross-section (metallurgist)

ATF - Jeremy Neagle, PE
Arcing

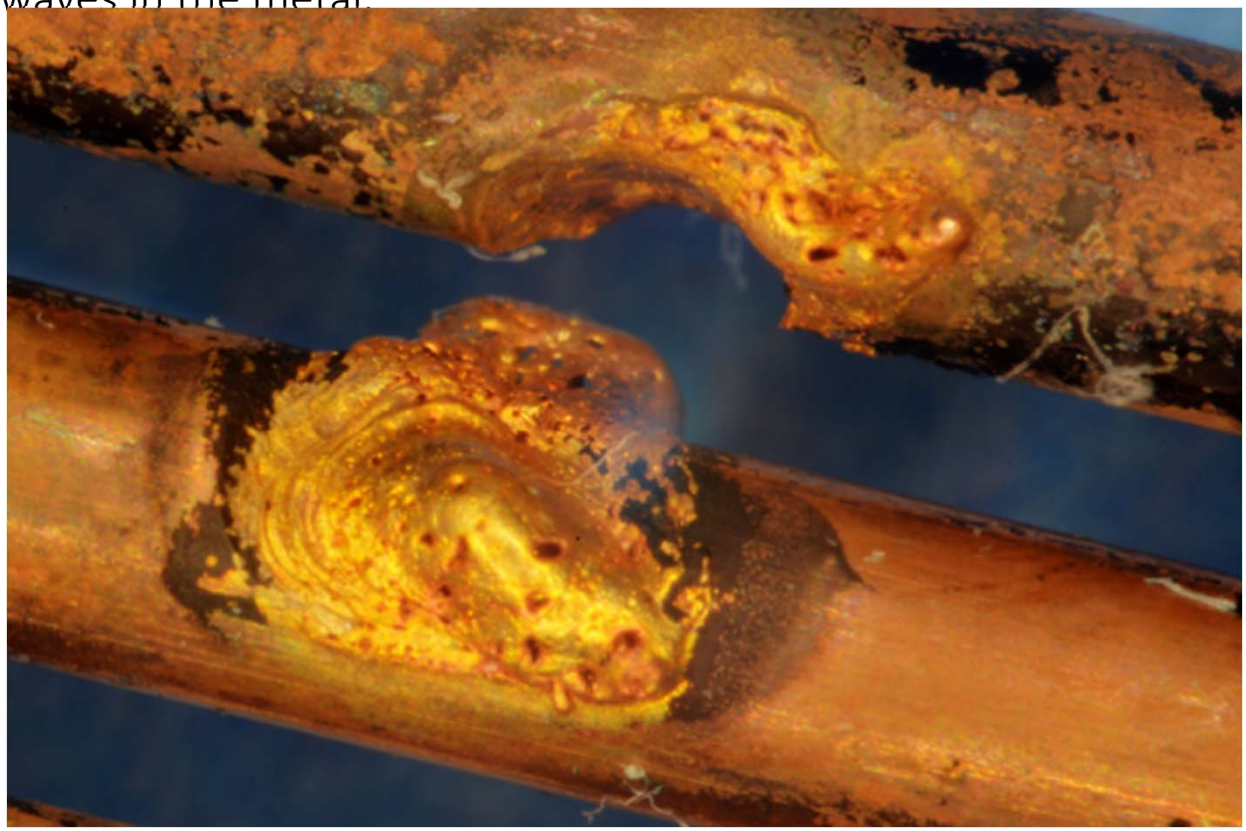
ATF - Jeremy Neagle, PE

arcing



ATF – Jeremy Neagle PE

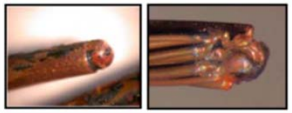
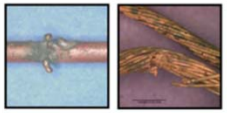
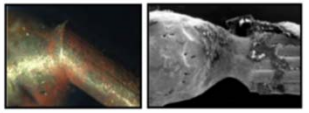
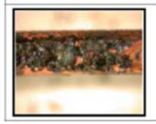
Resolidifcation Waves – The metal was molten and cooled quickly "freezing" the waves in the metal.



ATF – Jeremy Neagle, PE
arcing

ATF Technical Bulletin 001 September 28, 2012
Visual Characteristics of Fire Melting on Copper Conductors

Table 1
Characteristics of Arc Beads

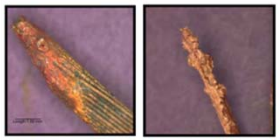
	Sharp Line of Demarcation between damaged and undamaged area (Photos by Kevin Lewis / E. C. BUC)
	Round Smooth Shape (Photos by Nick Cary / Kevin Lewis)
	Localized Point of Contact (Photos by Kevin Lewis / E.C. Buc)
	Identifiable Corresponding Area of Damage on Opposing Conductor (Photo by Kevin Lewis)
	Copper Drawing Lines Visible Outside the Damaged Area (Photos by Kevin Lewis)
	Localized Round Depressions (Photos by David Reiter / Kevin Lewis)
	Small Beads and Divots Over a Small Area (Photo by Nick Carey)

NFPA 2014 – 9.11.1.1
Adds:

- Resolidification Waves
- Locally enlarged grain size
- High internal porosity when viewed in cross-section

ATF Technical Bulletin

Table 2
Characteristics of Melt Globules

	Extended Area of Damage Without a Sharp Line of Demarcation from Undamaged Material (Photos by Yasuki Hagimoto / E. C. Buc)
	Visible Effects of Gravity in the Artifact (Photo by Stephen Andrews)
	Blisters on the Surface (Photos by E. C. Buc)
	Gradual Necking of the Conductor (Photo by Jeremy Neagle)
	Non-Localized Loss of Integrity of Individual Strands on a Stranded Conductor (Photo by Michael Keller) (NOTE: This characteristic was not included in Dr. Babrauskas' proposal but is included here since it is part of the ATF training curriculum.)

- If electricity is on and there is a fire, the fire will consume the wire insulation and the conductors will come in contact with each other. If the wires are solid conductors, this usually causes the circuit breaker to trip.

- But where is the arc bead? If it is somewhere in the middle of a wire run. Why would a wire fail in the middle of a run and cause a fire?

- Wires usually fail at the end points due to poor connections and resistive heating.

- Test Question

- The usually failure points of a wire are at the terminal points where connections are made, and not in the middle of a wire run.

  - A) True
  - B) False

Arc Fault Mapping

Arc Mapping is the identifying and documenting a fire pattern derived from the identification of arc sites used to aid in determining the area of fire origin or spread.

2017 NFPA 921, Section 18.1.2 – Arc mapping is one of the four ways of determining the origin of a fire.

2021 NFPA 921, Section 18.1.2 – Arm mapping was removed as one of the 4 pillows for determining the origin.

In the 2021 edition of NFPA 921 arc mapping was moved from section 9 to section 8.

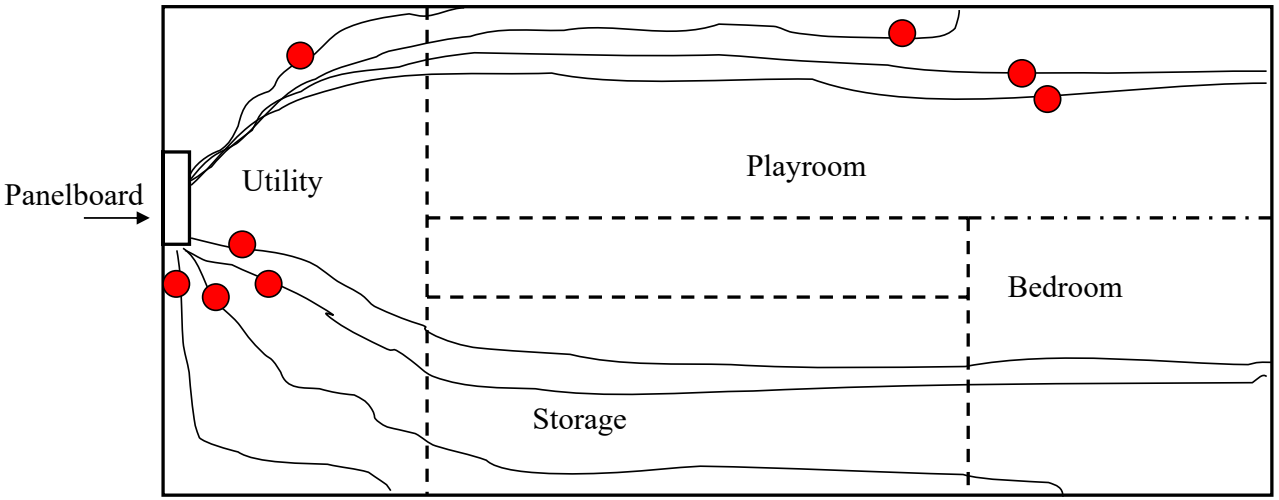
Arc Site Mapping – Case F19-031/-32

Arc Site Mapping – Case F19-031/032

•Knowing how many tripped breakers or blown fuses gives an idea of how many faults you can expect to find

•Locate all faults and tag with tape

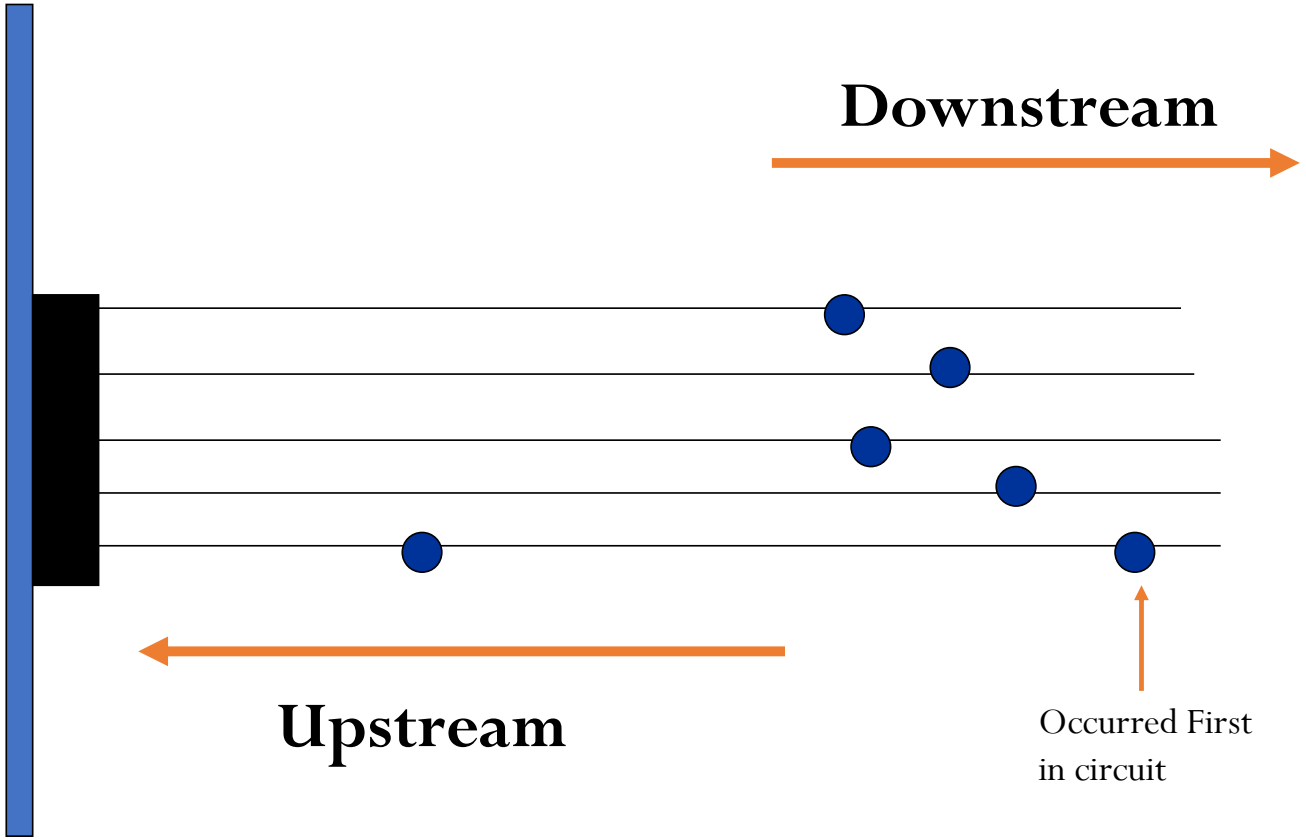
•Plot the location of faults on a drawing of each floor



In this case, the fire could not have started in the utility room. Taking into account concealment of wires, etc. the arc faults in the playroom indicate the fire first attacked the energized conductors here first. Had the fire started in the utility room first, those conductors would have been de-energized there and no downstream arcing would have been found in the playroom.

UPSTREAM VS. DOWNSTREAM DAMAGE

NFPA 921



One of the Problems with Arc Mapping

If only one or two circuit breakers are tripped, the fire is usually small enough that you will not have a problem determining the origin.

If five or six circuit breakers are tripped, you are going to spend a considerable amount of time and effort looking for all of the arcs. You will have to search out of your area of origin and inside fixtures and appliances where you know the fire did not start.

For example, I had a case in which only three circuit breaker were tripped. One was in the area of origin, and the other two were in another room. One was inside a light fixture and the other inside a ceiling fan. Who in here has had a ceiling fan fire?

SO WHAT CAUSES ELECTRICAL FIRES?

Short Circuits ??

Overloads ??

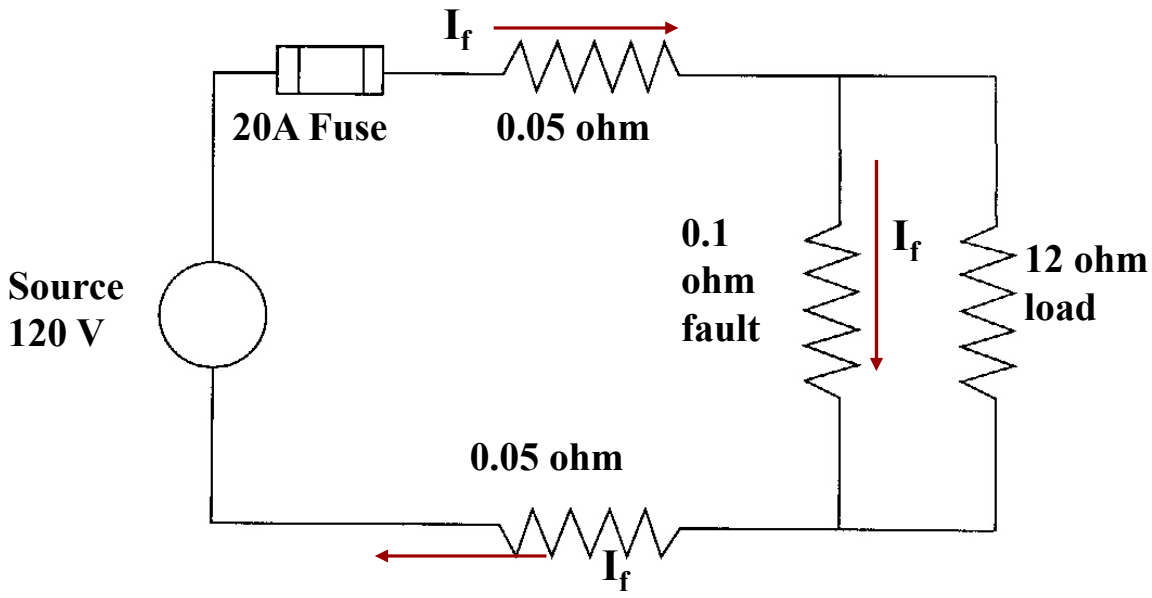
Loose or Failed Connections??

Product Failure ??

Pinched Cords ??

Etc.

MYTH: SHORT CIRCUITS CAUSE FIRES



I_f = 120V/0.2 ohm = 600 Amps

At 600 amps the fuse blows (or circuit breaker trips) instantly. Even if a penny was placed in the fuse holder, the 60 amp-main fuse would trip. Short circuits rarely cause fires. They are short duration events that cause overcurrent devices to operate.

MYTH – OVERLOADED CONDUCTORS CAUSE FIRES

The tables for wire sizing from the National Electrical Code are extremely conservative.

Insulation temperature rating

12 AWG wire

Rated for 30 amps

Table 310-16. Allowable Ampacities of Insulated Conductors Rated 0 through 2000 Volts, 60°C through 90°C (140°F through 194°F) Not More than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)

Size	Temperature Rating of Conductor (See Table 310-13)						Size
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
AWG or kcmil	Types TW, UF	Types FEPW, RH, RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RH, RHW, THHW, THW, THWN, XHHW, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	AWG or kcmil
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18	—	—	14	—	—	—	—
16	—	—	18	—	—	—	—
14*	20	20	25	—	—	—	—
12*	25	25	30	20	20	25	12*
10*	30	35	40	25	30	35	10*
8	40	50	55	30	40	45	8
6	55	65	75	40	50	60	6
4	70	85	95	55	65	75	4
3	85	100	110	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	150	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	190	230	255	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	355	420	475	285	340	385	600
700	385	460	520	310	375	420	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	450	800
900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	520	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	560	665	750	470	560	630	2000
	CORRECTION FACTORS						
Ambient Temp. (°C)	For ambient temperatures other than 30°C (86°F), multiply the allowable ampacities shown above by the appropriate factor shown below.						Ambient Temp. (°F)
21–25	1.08	1.05	1.04	1.08	1.05	1.04	70–77
26–30	1.00	1.00	1.00	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	—	0.58	0.71	132–140
61–70	—	0.33	0.58	—	0.33	0.58	141–158
71–80	—	—	0.41	—	—	0.41	159–176

*See Section 240-3.

A 12AWG wire will not even begin to smoke until it is carrying 100 amps. However, you cannot connect 100 Amps to a properly protected branch circuit wired with 12AWG. The breaker or fuse will trip long before the wire burns.

Overcurrent damage to a wire occurs along the entire length from the panelboard to the load. If the overcurrent protective device is incorrectly sized, or fails to operate, a fire can result from an overloaded conductor.

Poor Connections - Resistive Heating

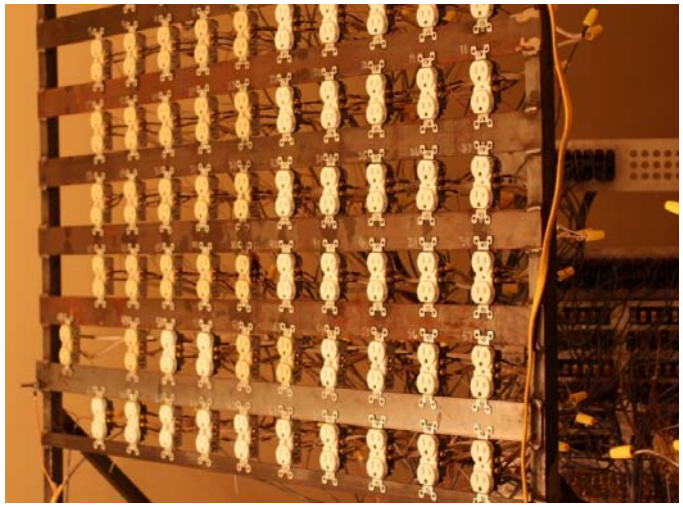
- NFPA 921 (2021) – Section 9.10.4 – Overheating Connections: Connection points are the most likely place for overheating to occur on a circuit. The most likely cause of the overheating will be a loose connection or the presence of resistive oxides at the point of the connection.

Resistive Heating

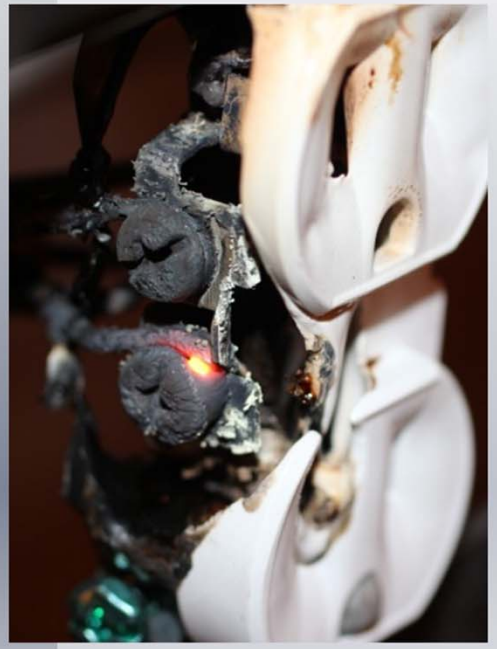
- Begins with a loose connection having a larger contact resistance.
- The increased contact resistance causes resistive heating at the connection.
- Copper Oxide (Cupric oxide – CuO) will form as the heated copper reacts with oxygen in the air. CuO is typically Black in color.
- Copper Oxide being semi-conductive will further increase the resistance.
- The cycle continues until a glowing connection and/or failure occurs.
- Above 1,600°F, an oxide of Cu_2O forms which is typically a red-orange color.

Jensen Hughes - Laboratory Receptacle Testing: Setup

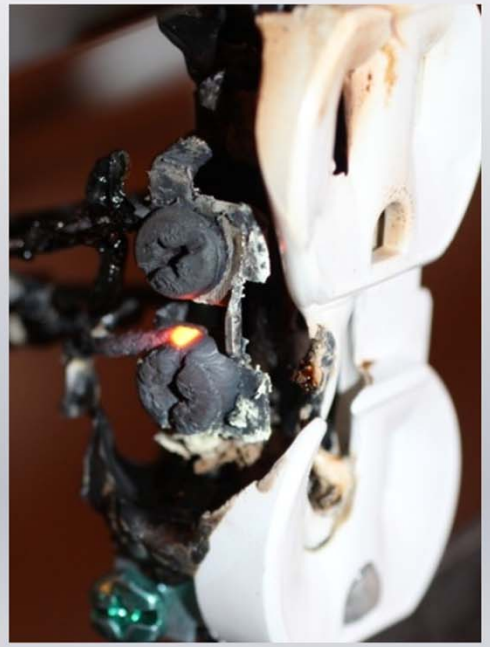
- Each rack with up to 78 receptacles
- Wired using the feed-through method
- Dedicated load banks
- Seven test racks; 528 receptacle trials
- Some receptacles with temperature and voltage measurements



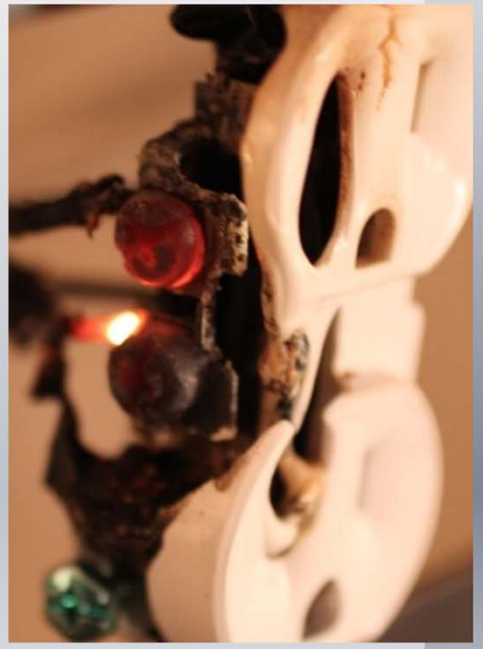
Movement of Glow Spot: Welding of Conductor



T = 0 hours

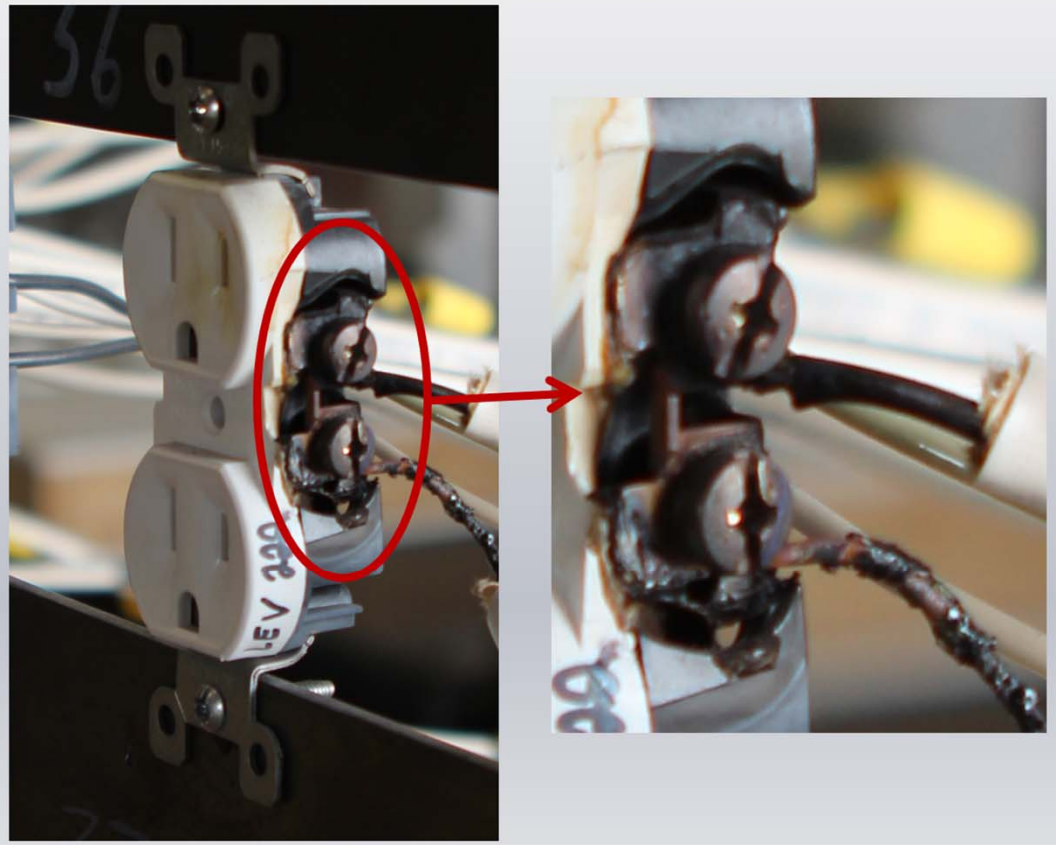


T = 2.7 hours



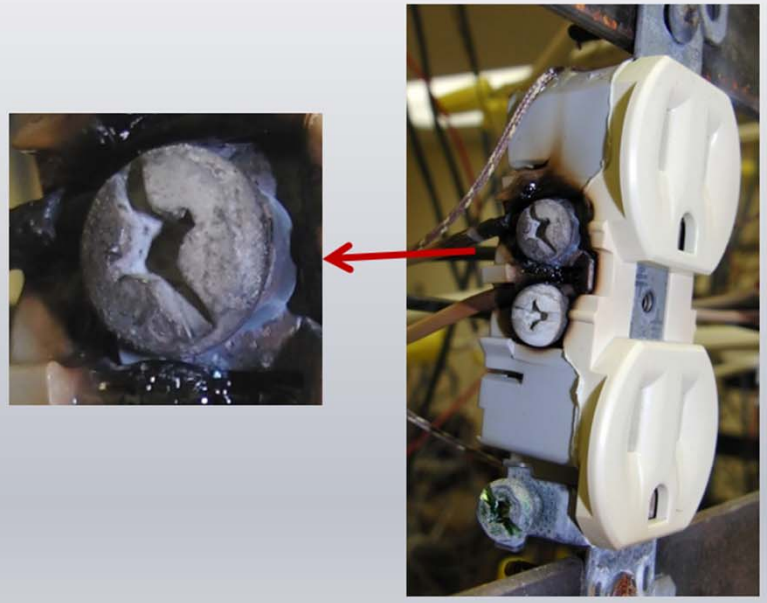
T = 5.5 hours

Overheating Connections



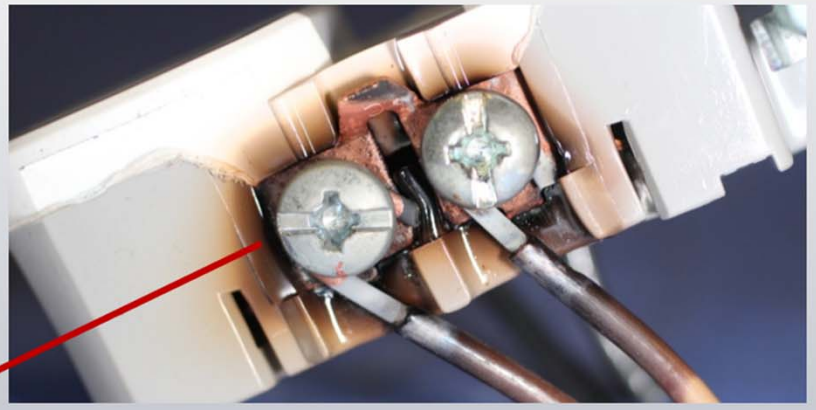
Melting of plastic near screw terminals.

Overheating Connections



Discoloration/charring of plastic, loss of plating on screw, black oxidation of copper conductor.

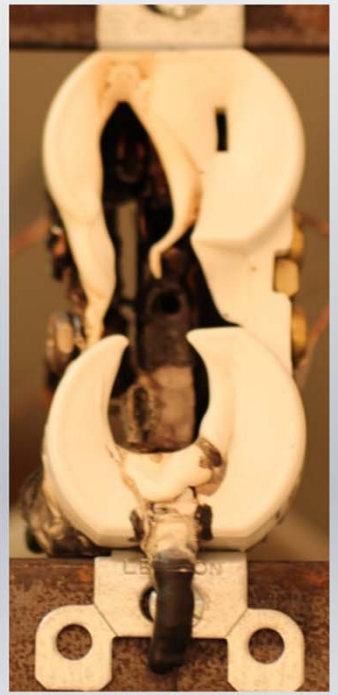
Overheating Connections



Discoloration/charring of plastic, white corrosion of copper conductor, and dezincification of brass contacts. ?

Overheating Connections

Polypropylene



Melting, running and dripping

PVC

Softening, deforming, and charring

Phenolic

Cracking and localized crumbling

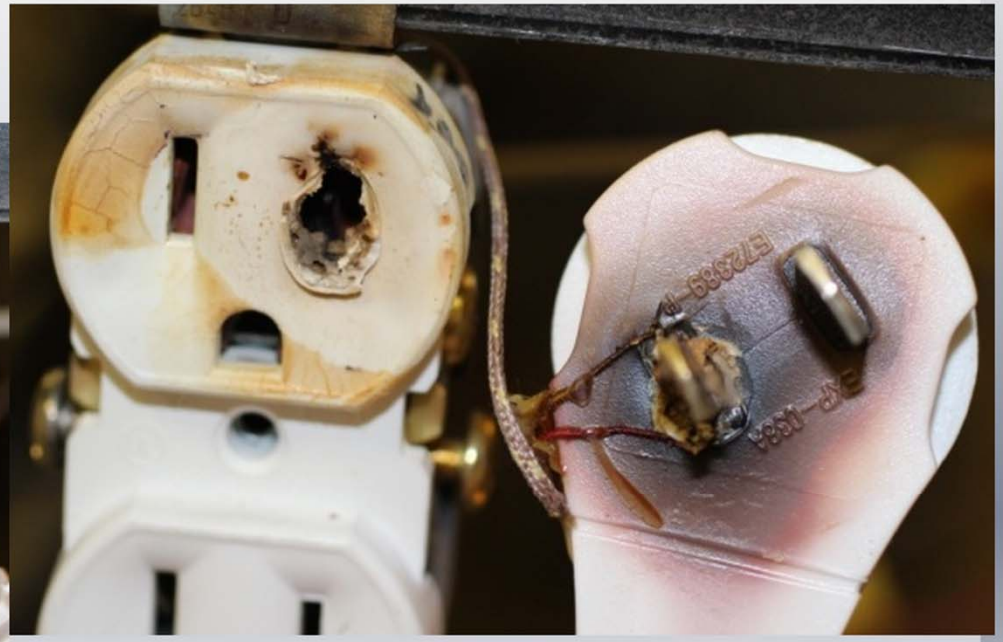
Evidence of Glowing Connections

Welded Conductor w/Curved Striations

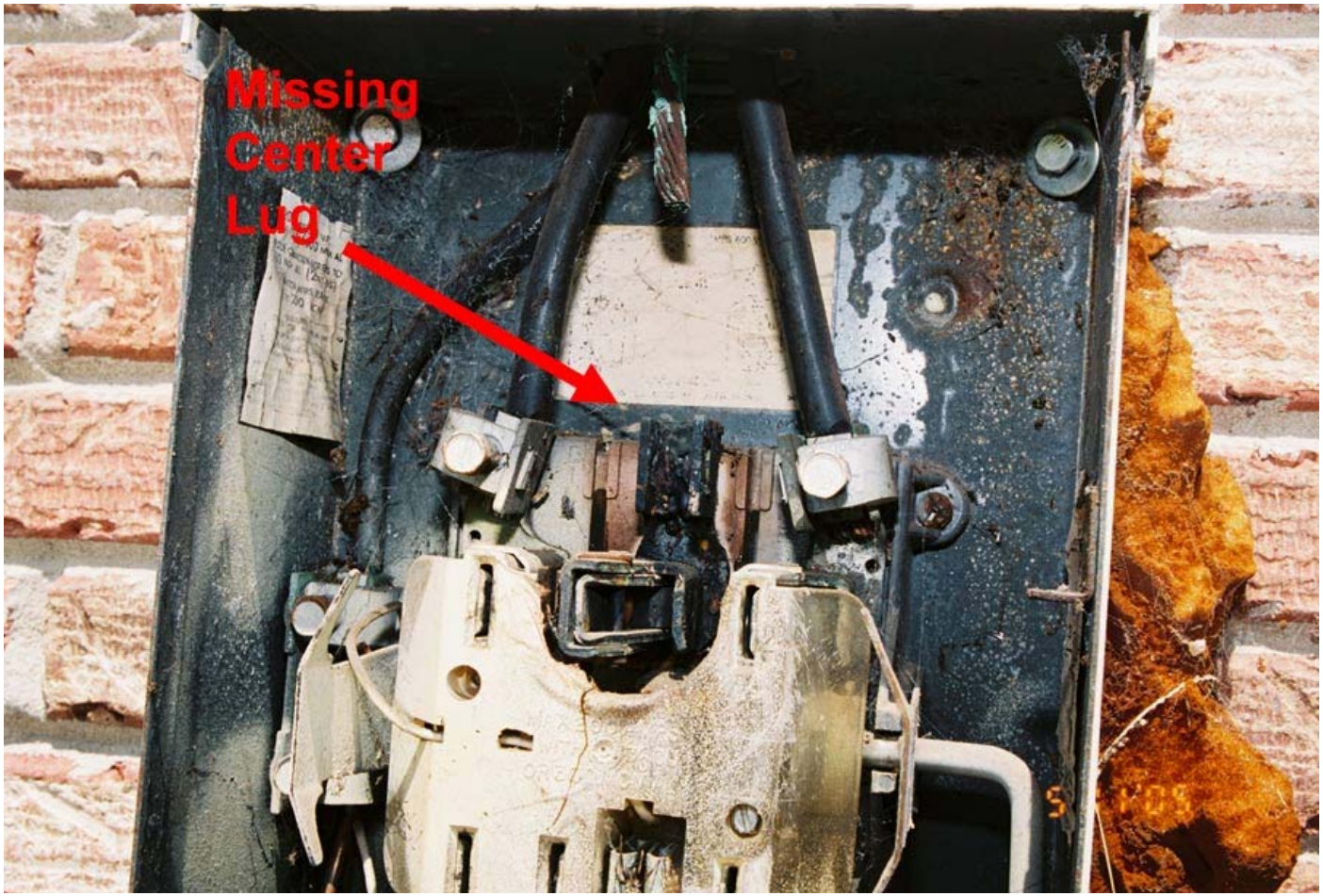
Severed Conductor (Welded w/Curved Striations)

Enlarged Screw Head

Overheating Connections

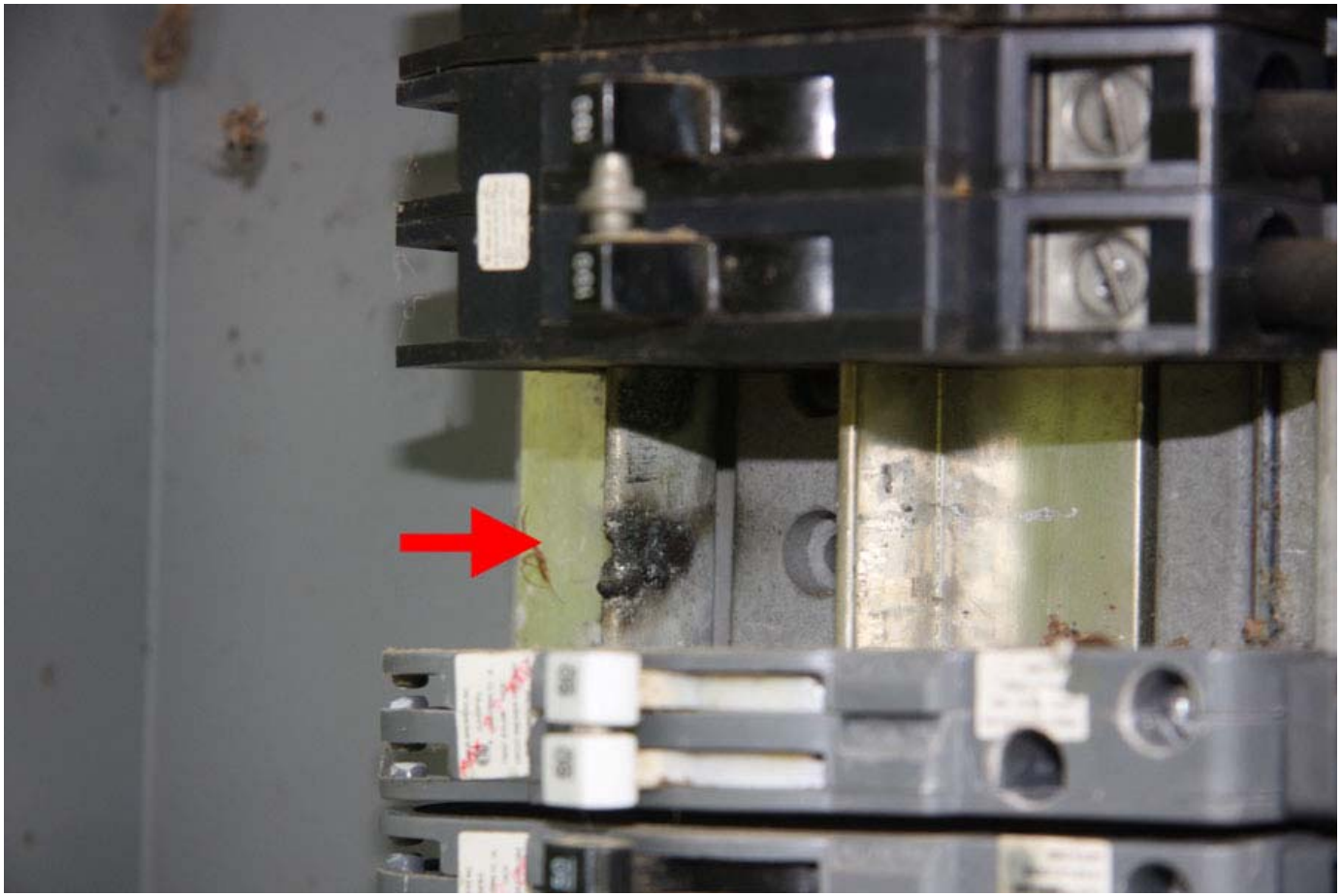


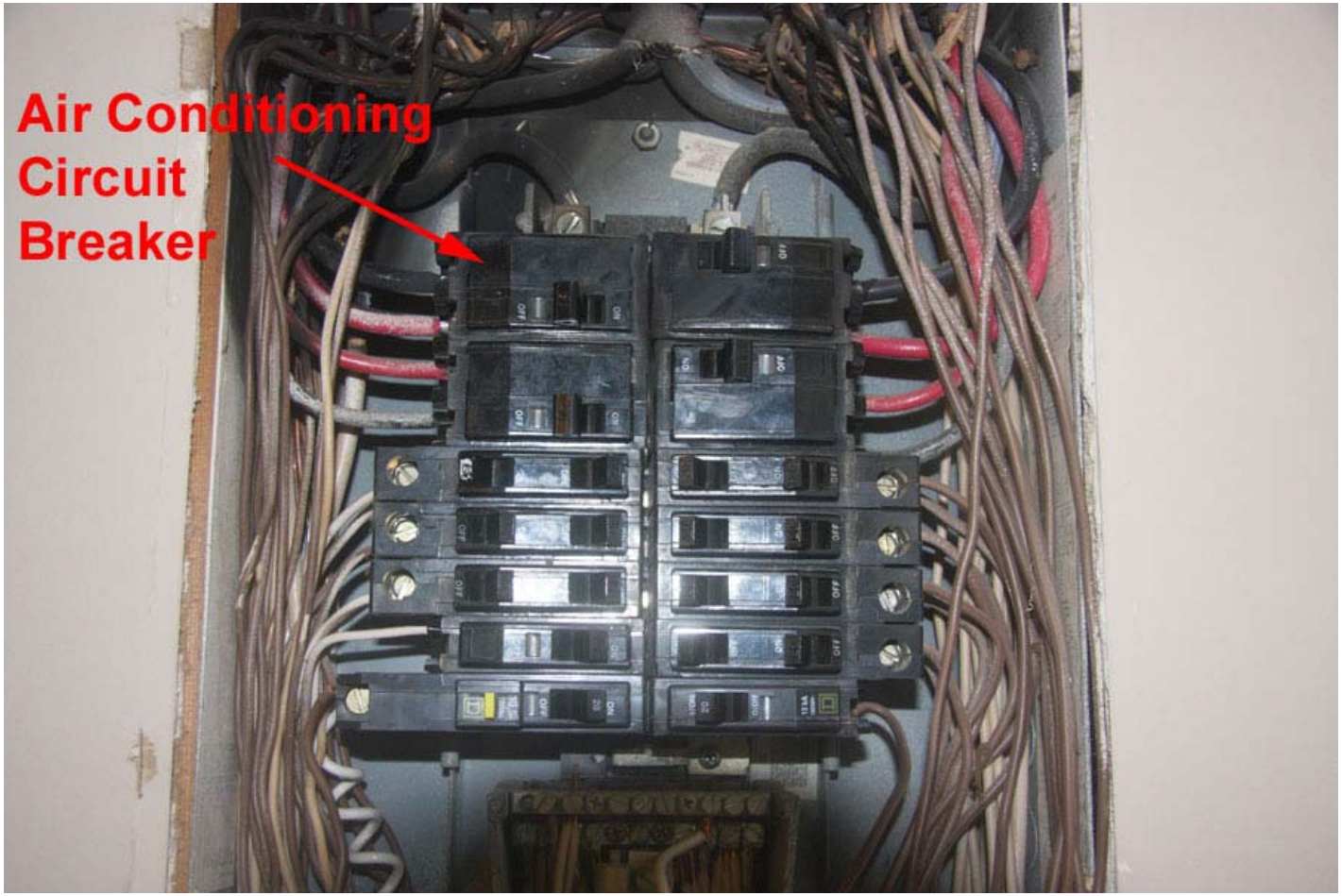

60°
0828

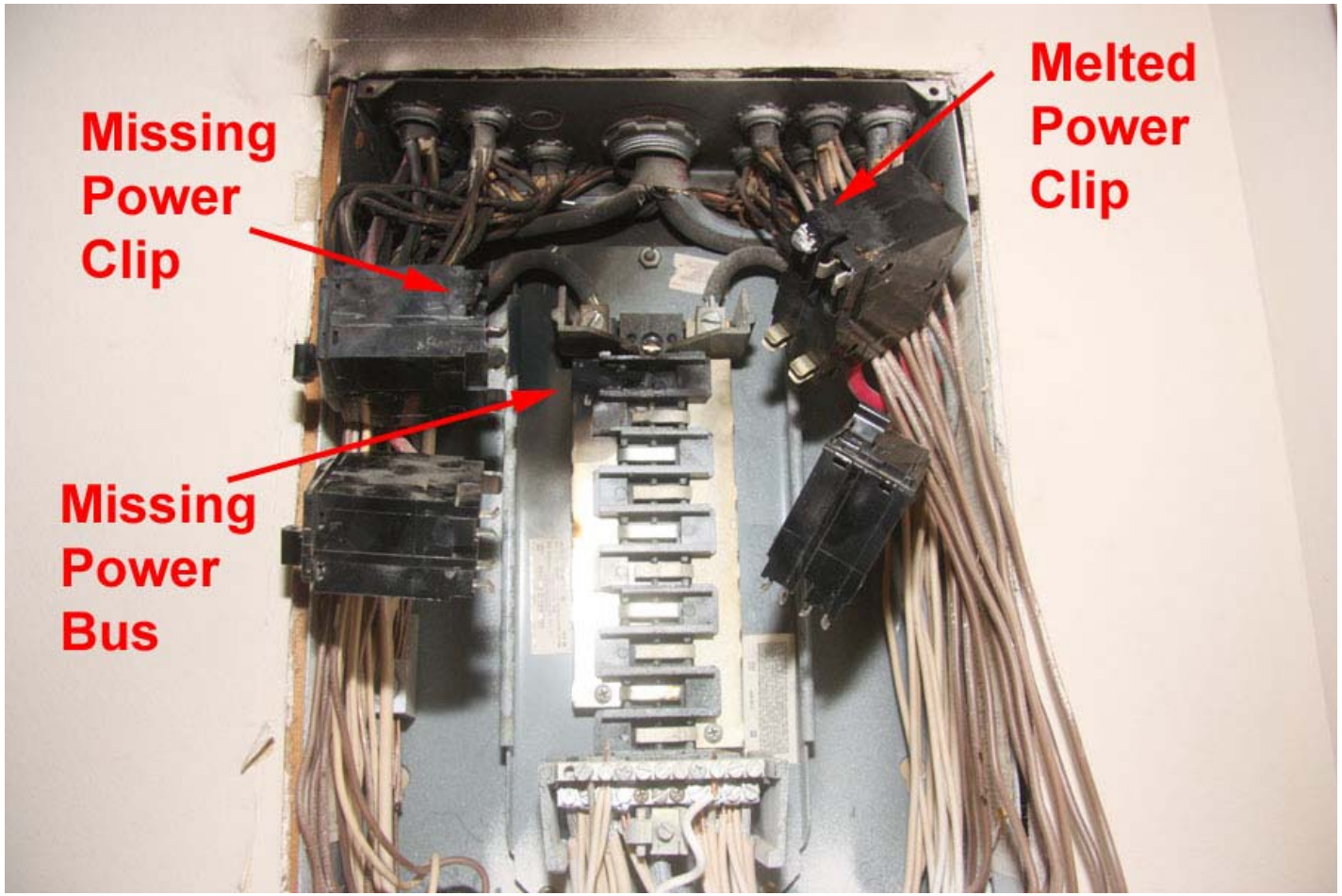

Missing
Center
Lug

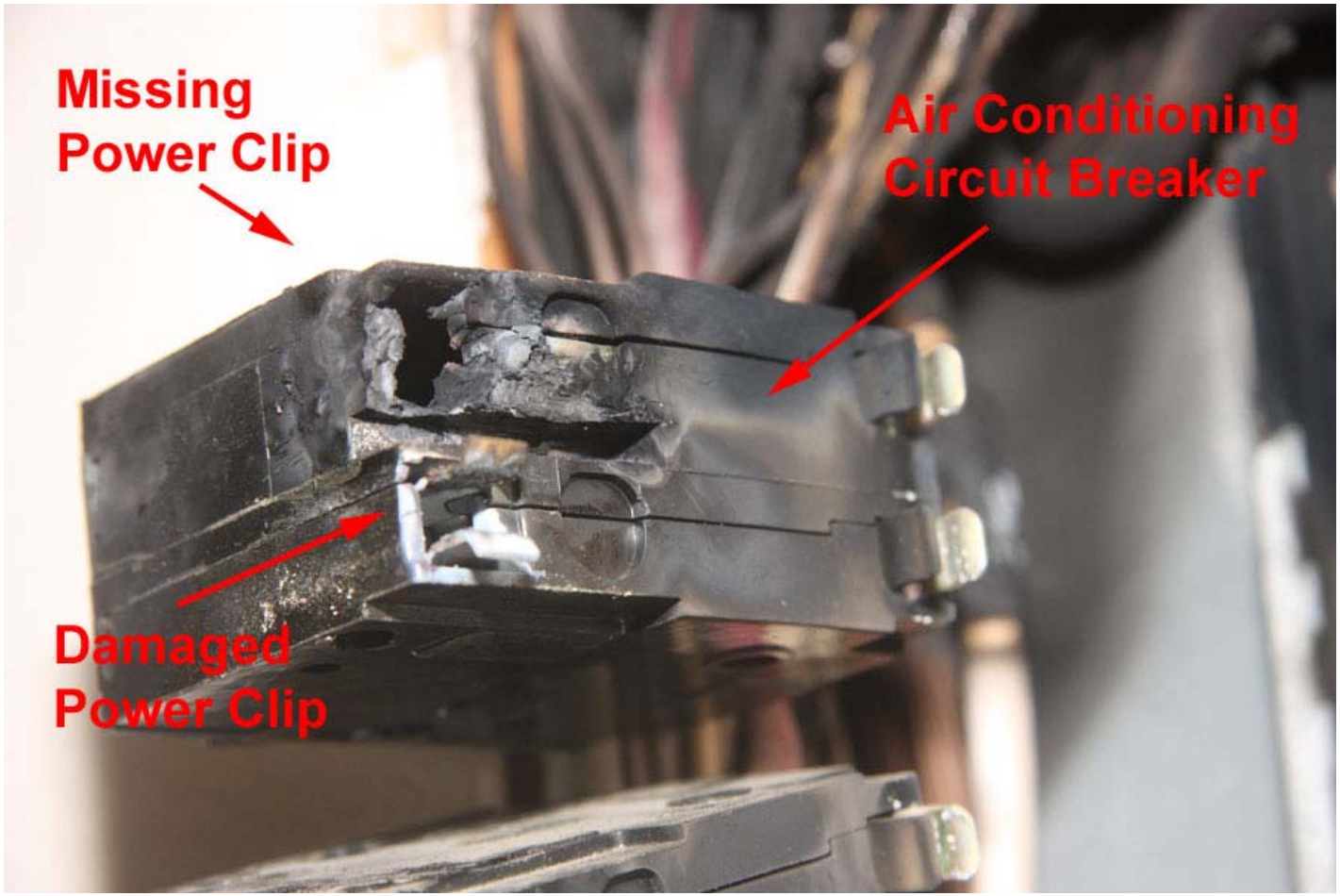
Zinsco Circuit Breakers

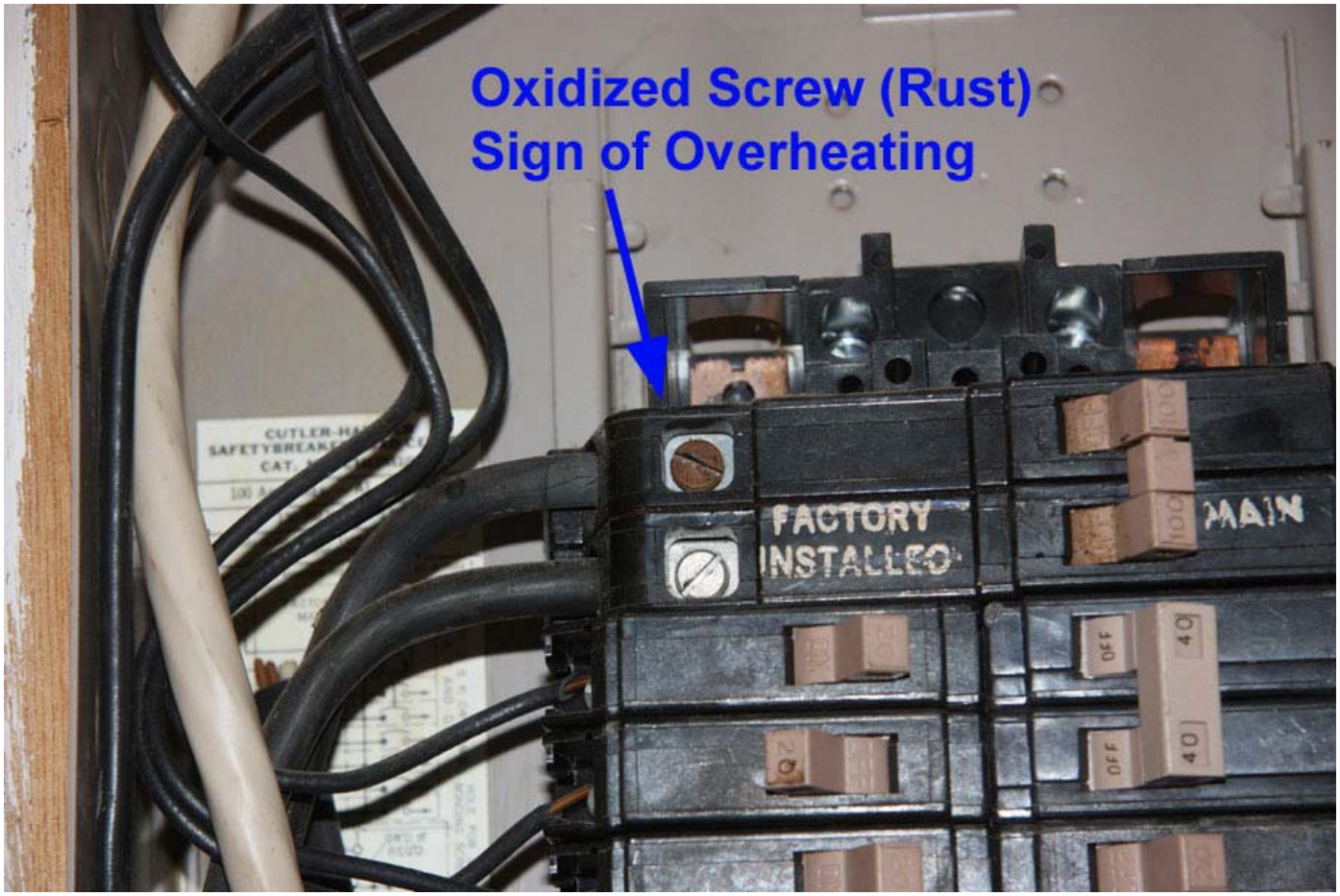

STRIP
GAGE
TYPE
CIRCUIT

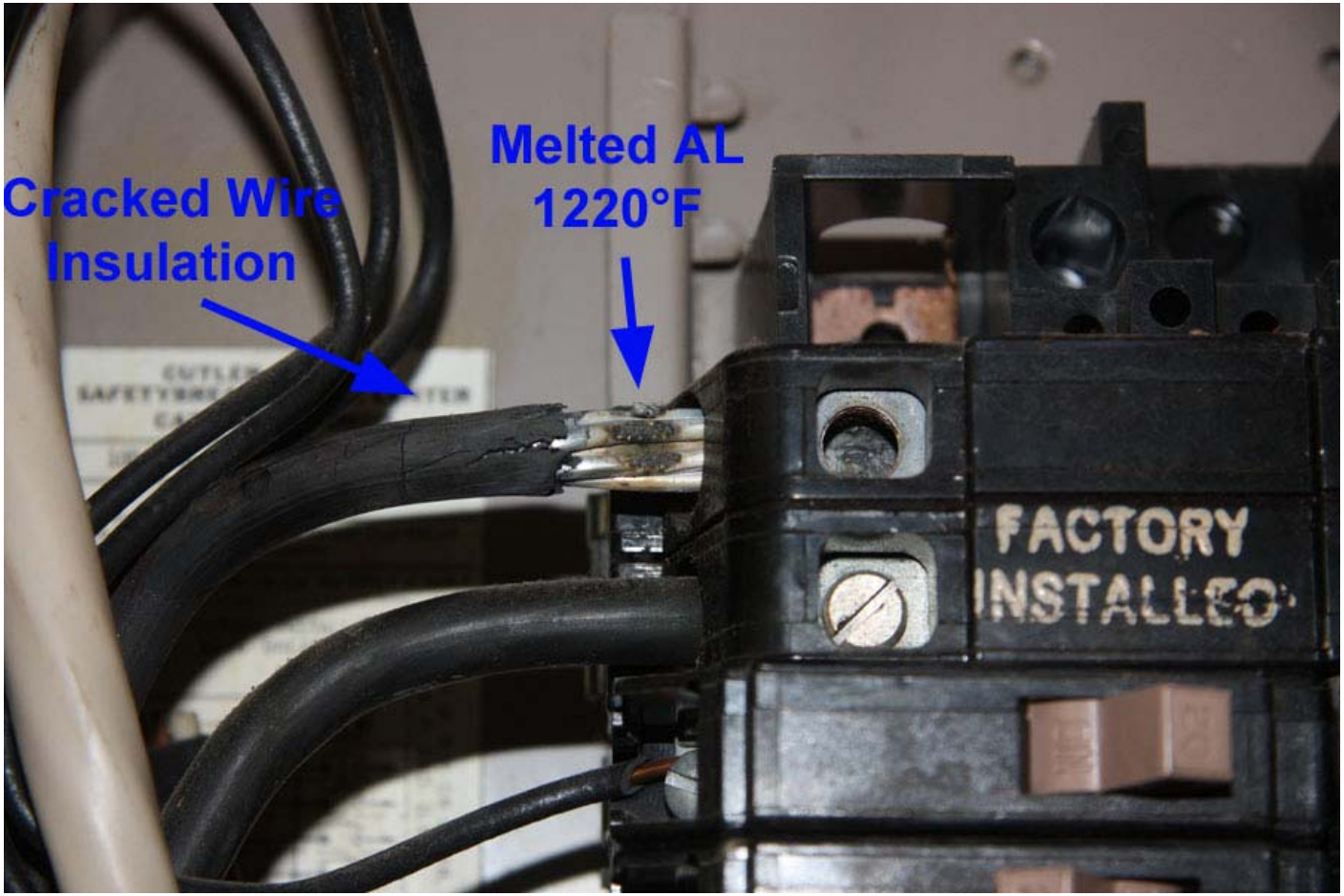


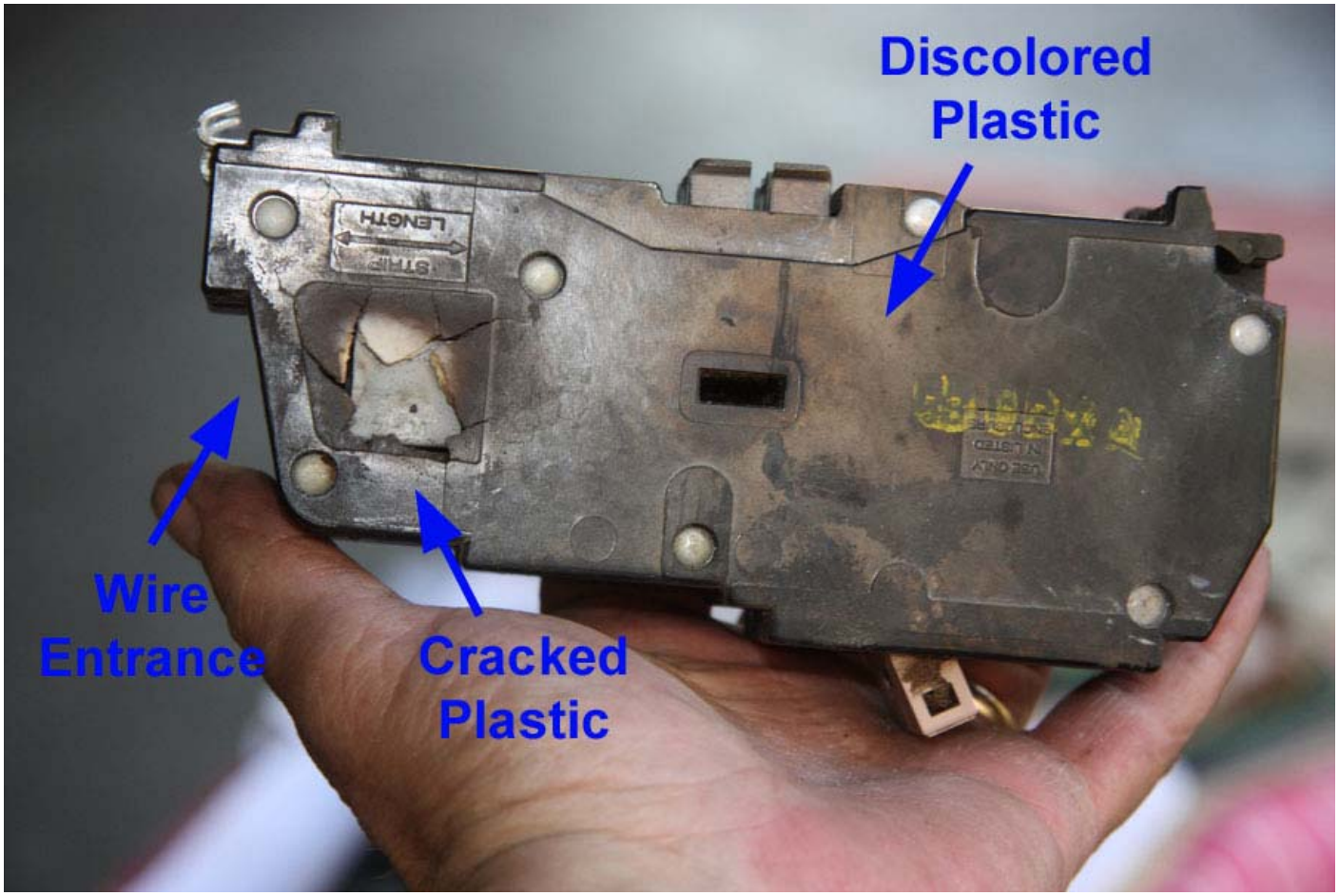

Air Conditioning
Circuit
Breaker


Missing
Power
Clip
Melted
Power
Clip
Missing
Power
Bus


Missing
Power Clip
Air Conditioning
Circuit Breaker
Damaged
Power Clip

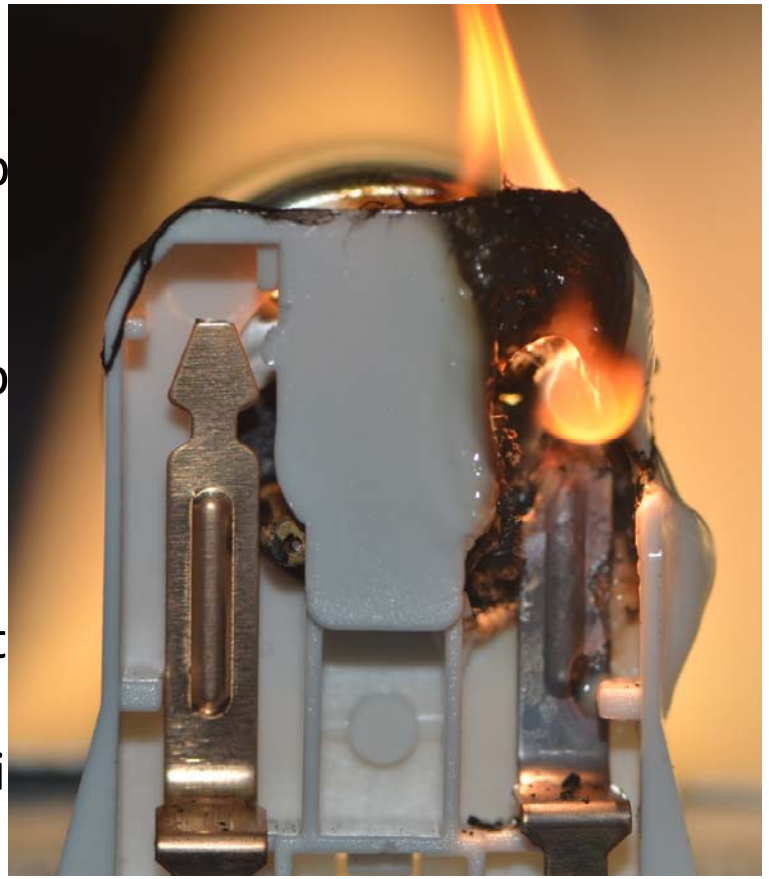

Oxidized Screw (Rust)
Sign of Overheating
FACTORY
INSTALLED
MAIN


Cracked Wire
Insulation
Melted AL
1220°F
FACTORY
INSTALLED


Discolored
Plastic
Wire
Entrance
Cracked
Plastic

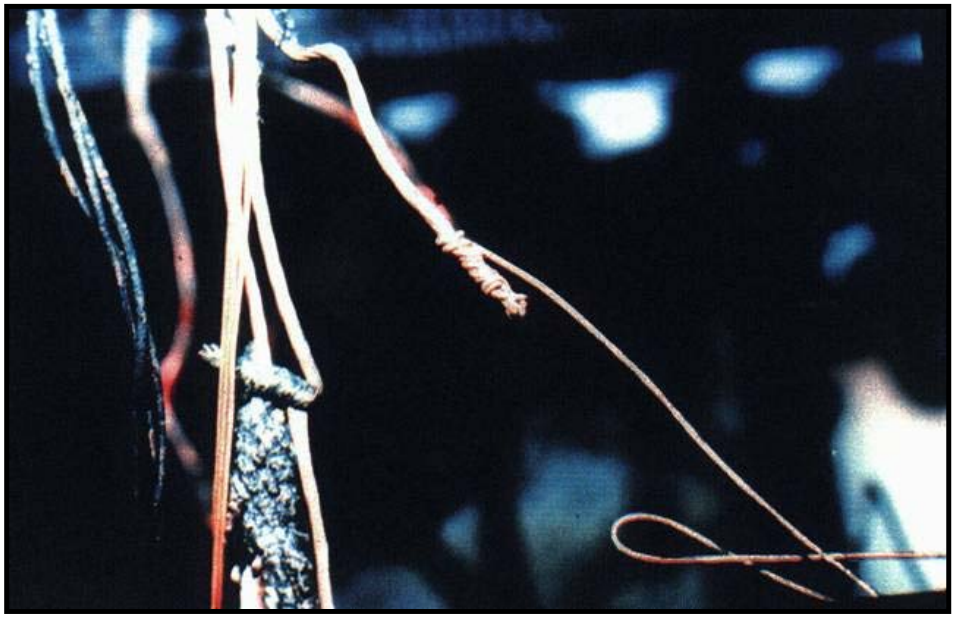
Fires Caused By Lamp Holders

- Typically result of poor connection to lamps
- Improper seating of the lamp
- Improper spacing of lamp holders
- Improper installation of lamp holders
- More common with higher current lamps
- Generally occurs with Instant Start circuits
- Ballast is designed to maintai an arc and it will!



Arcing Damage

LOOSE OR FAILED CONNECTIONS

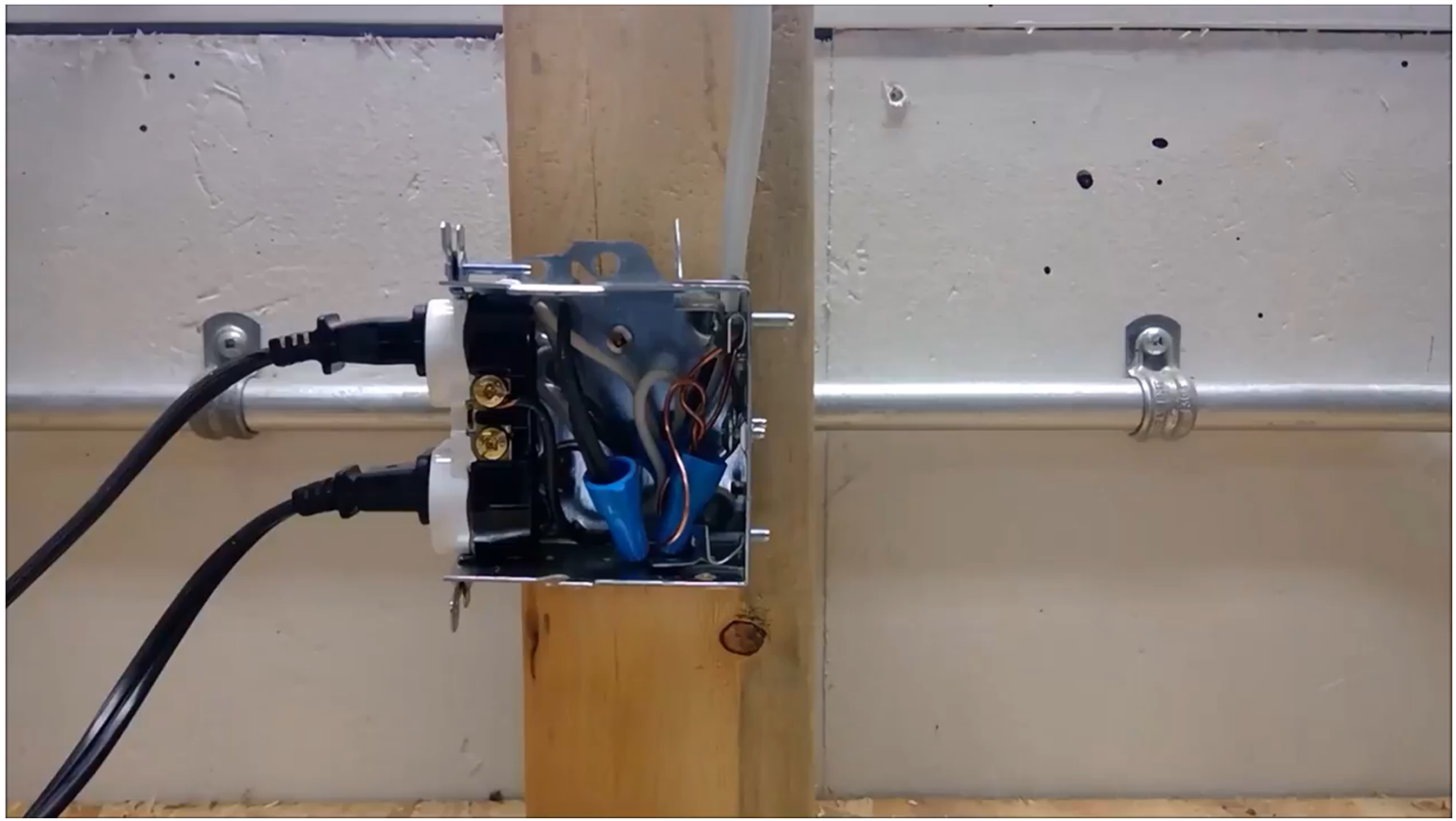


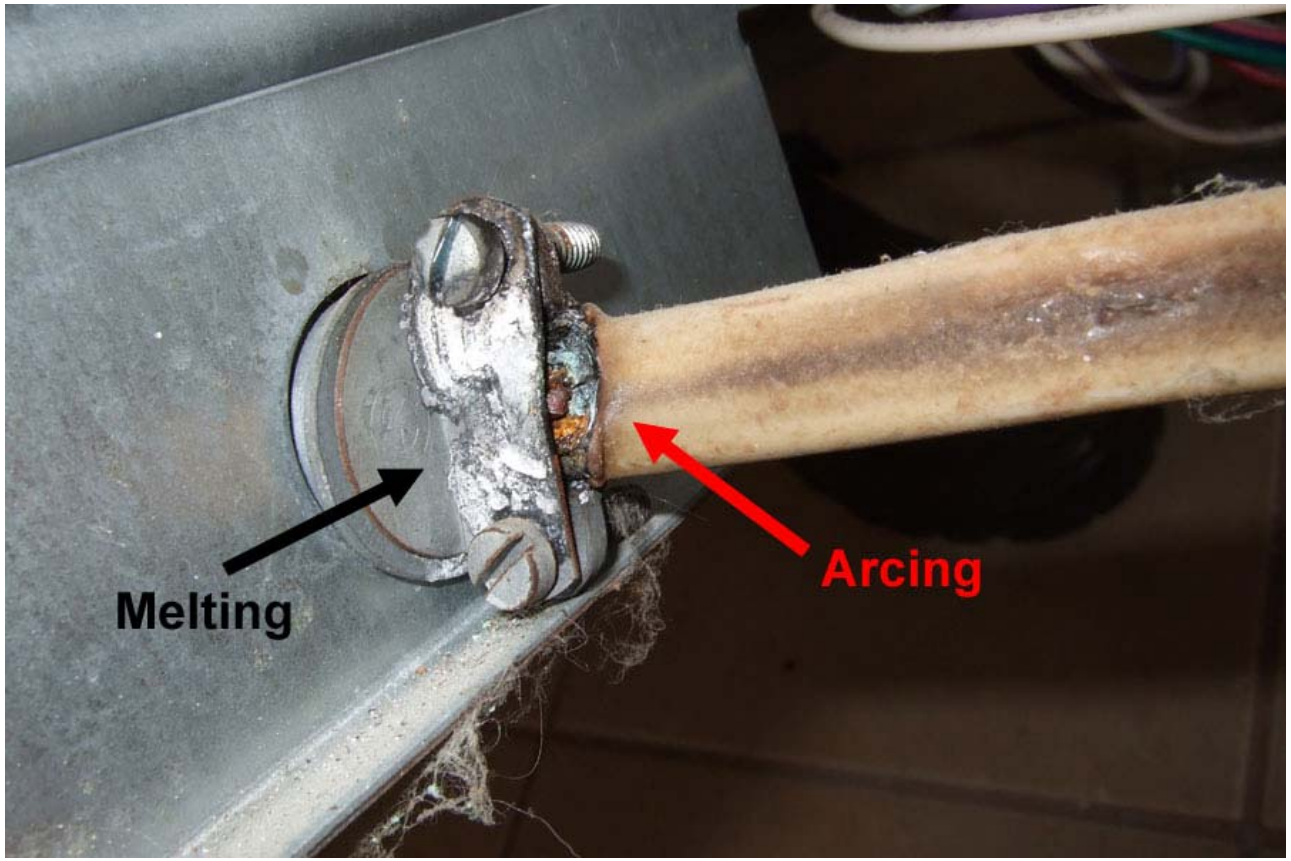
A splice requires electrical continuity. It also requires mechanical security. This requires the use of proper terminals or connectors. Wire nuts are one way to maintain electrical contact and mechanical integrity. Duct tape is NOT.

Wirenut Video

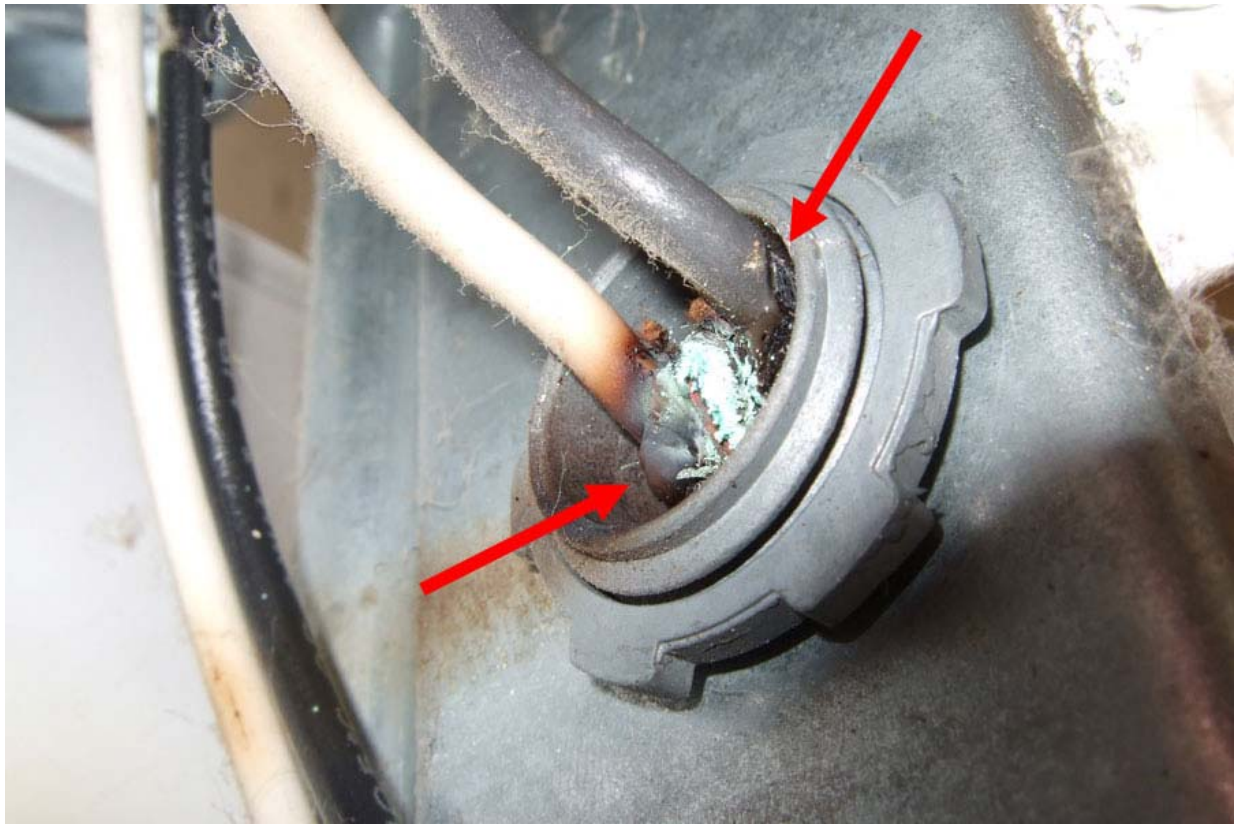
https://www.youtube.com/watch?v=nPhgQpRFe5A

Video - Loose Wirenut Connections

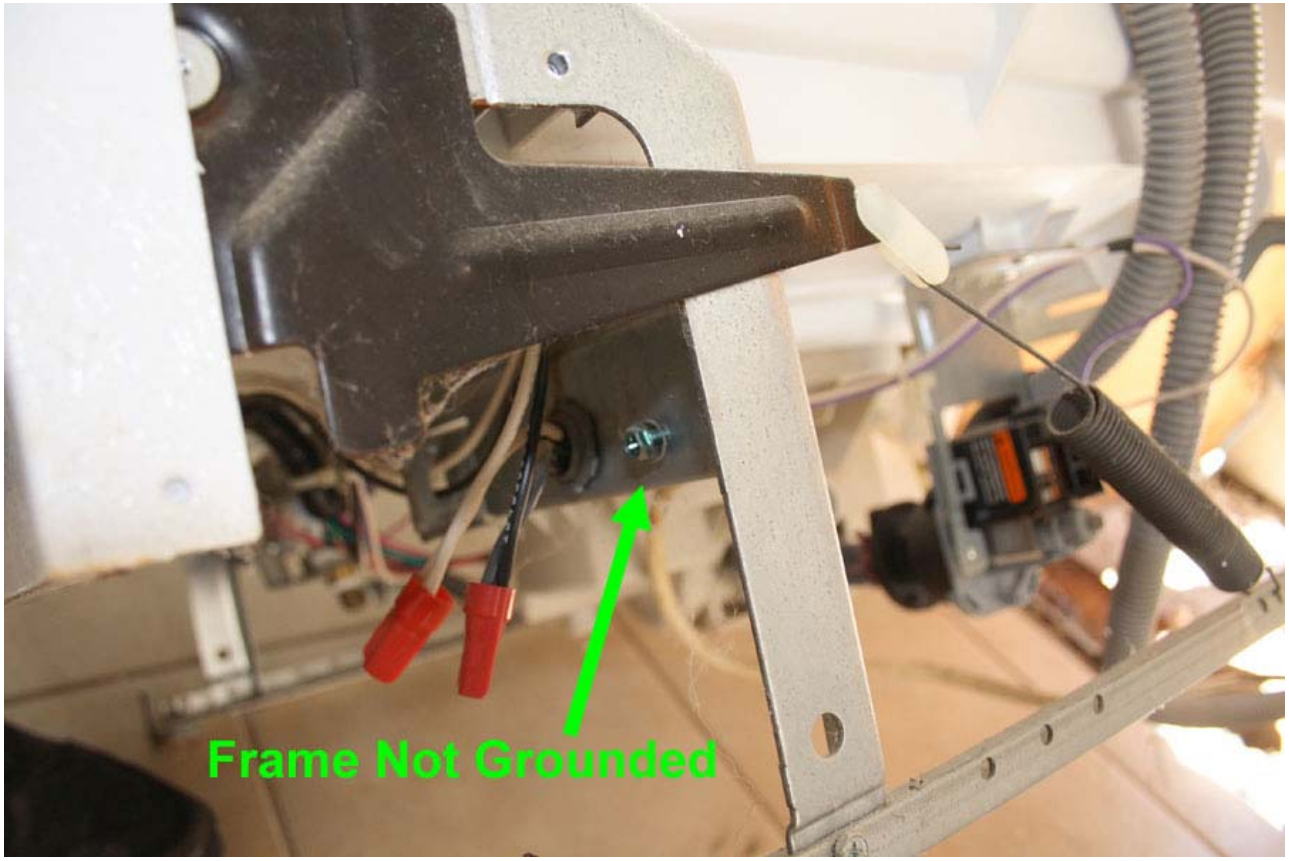




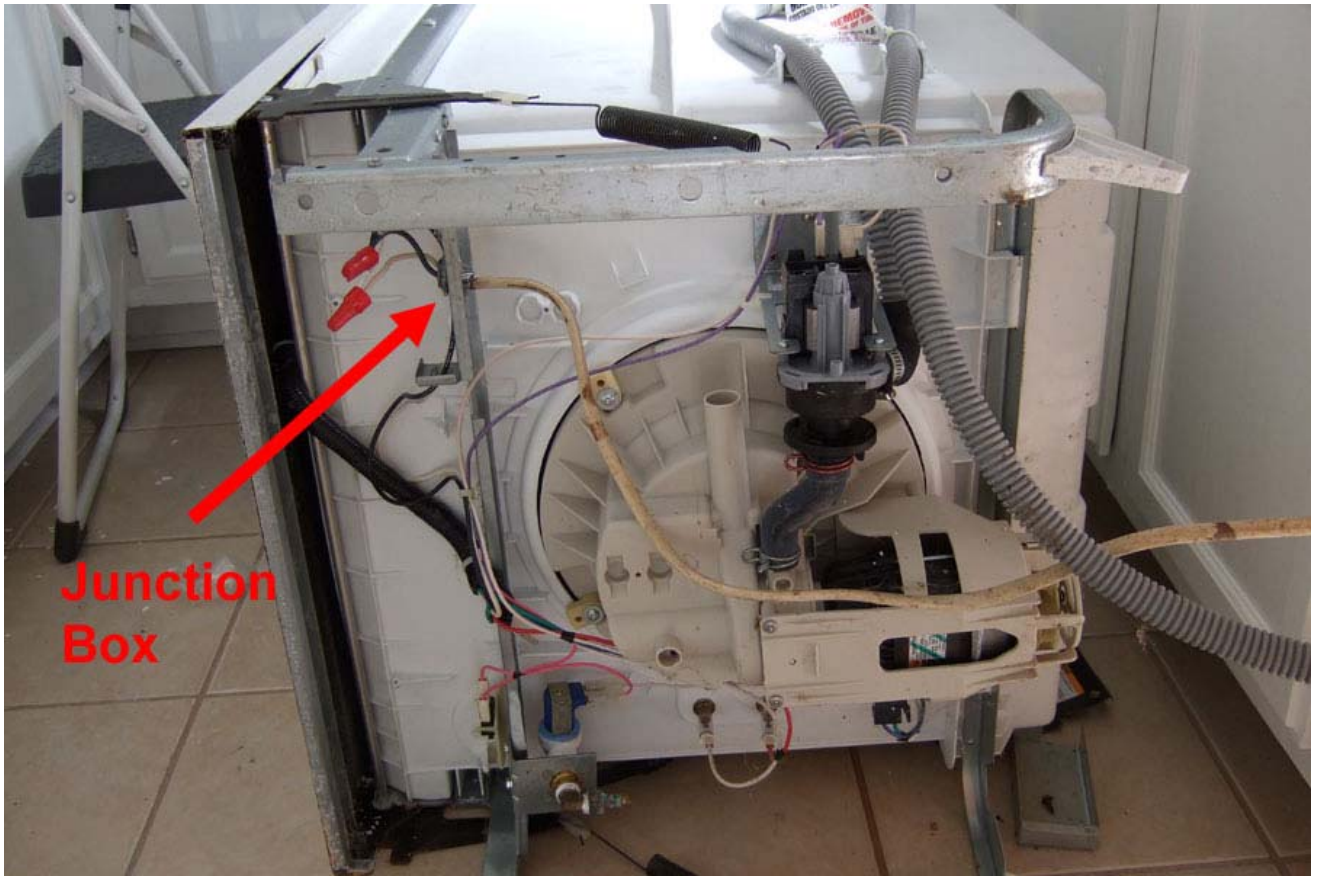
Over Tightened Romex Cable Clamp.

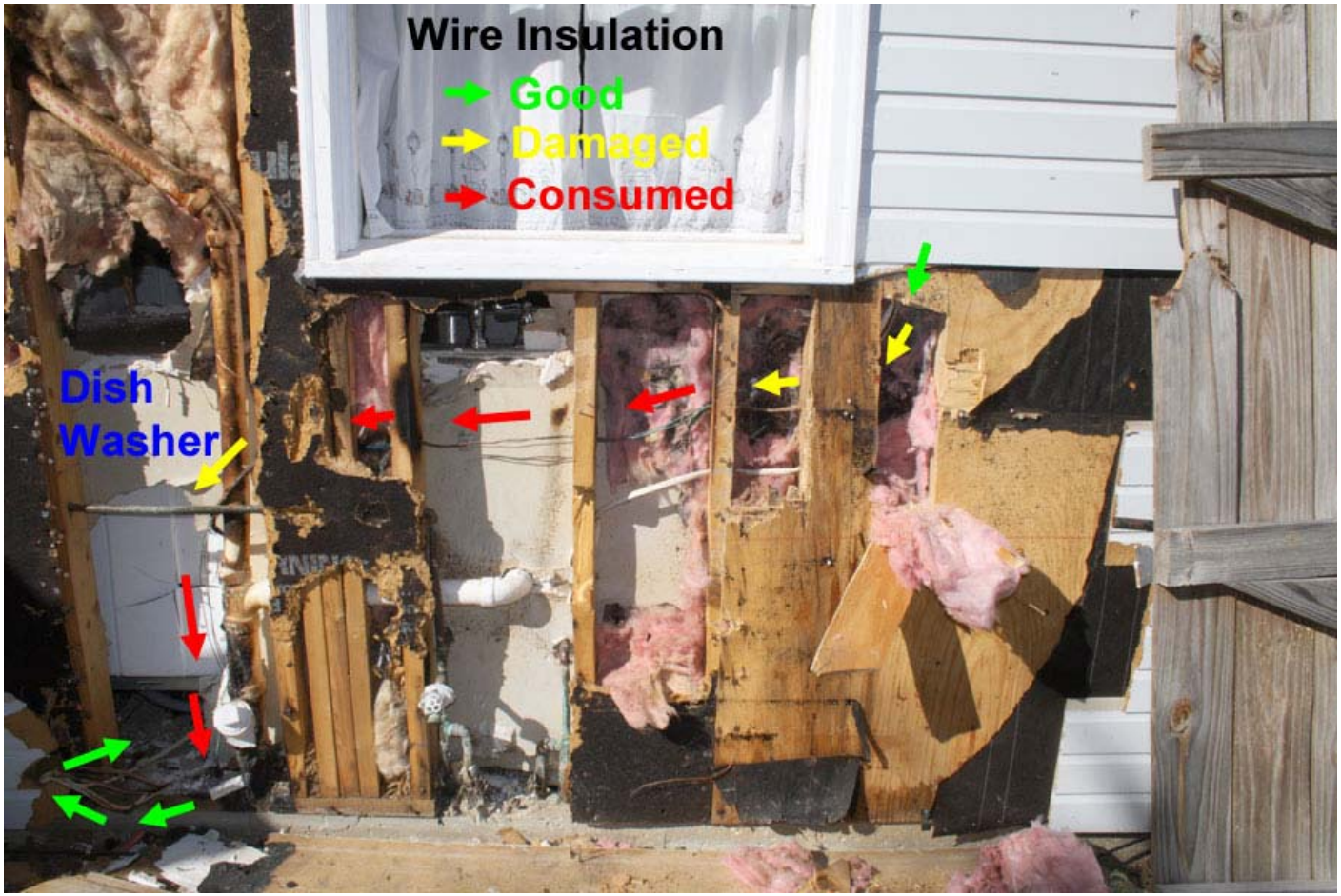


Damaged Wire Insulation at Front of Clamp.

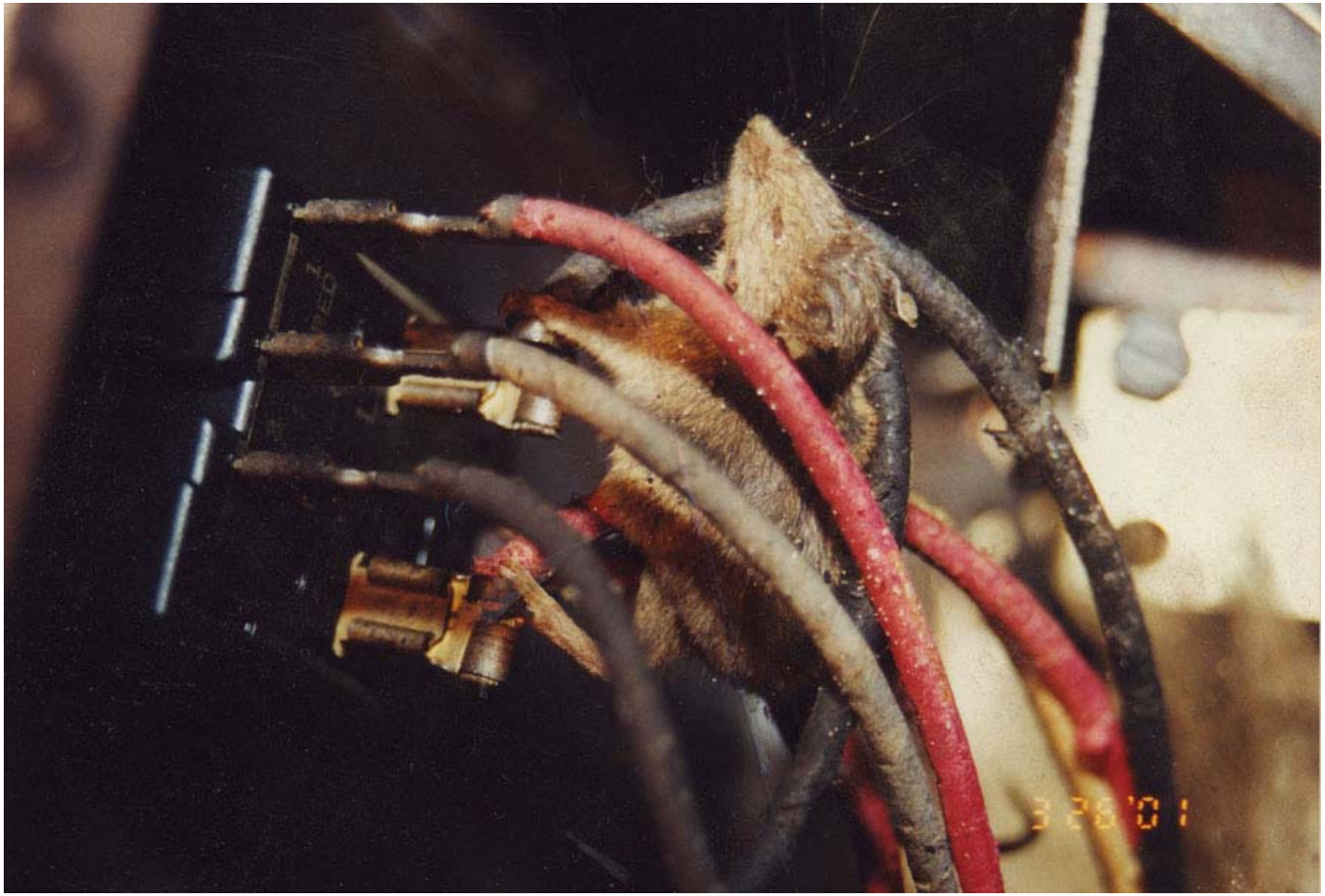


Safety Grounding Conductor Not Connected.

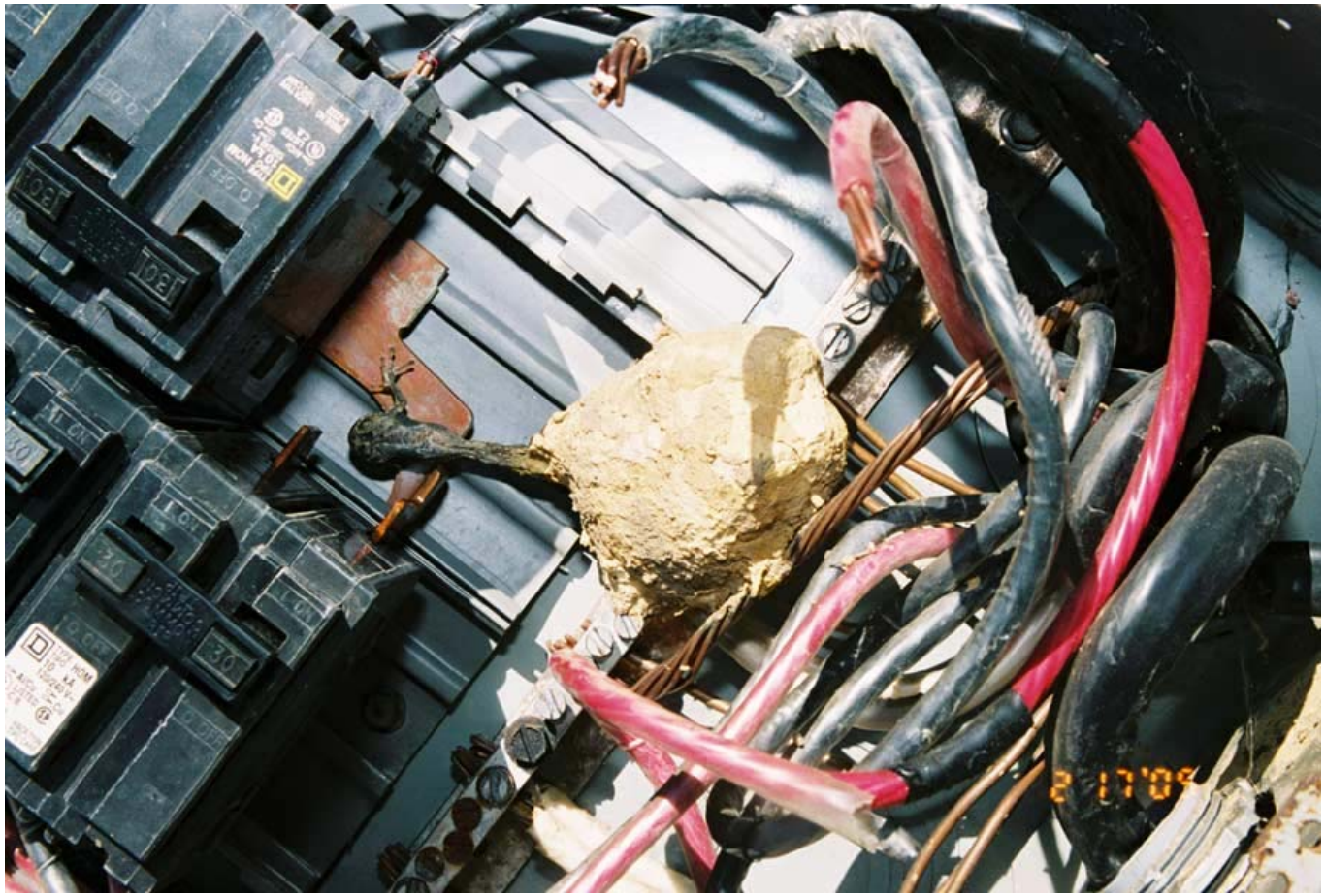

Junction
Box

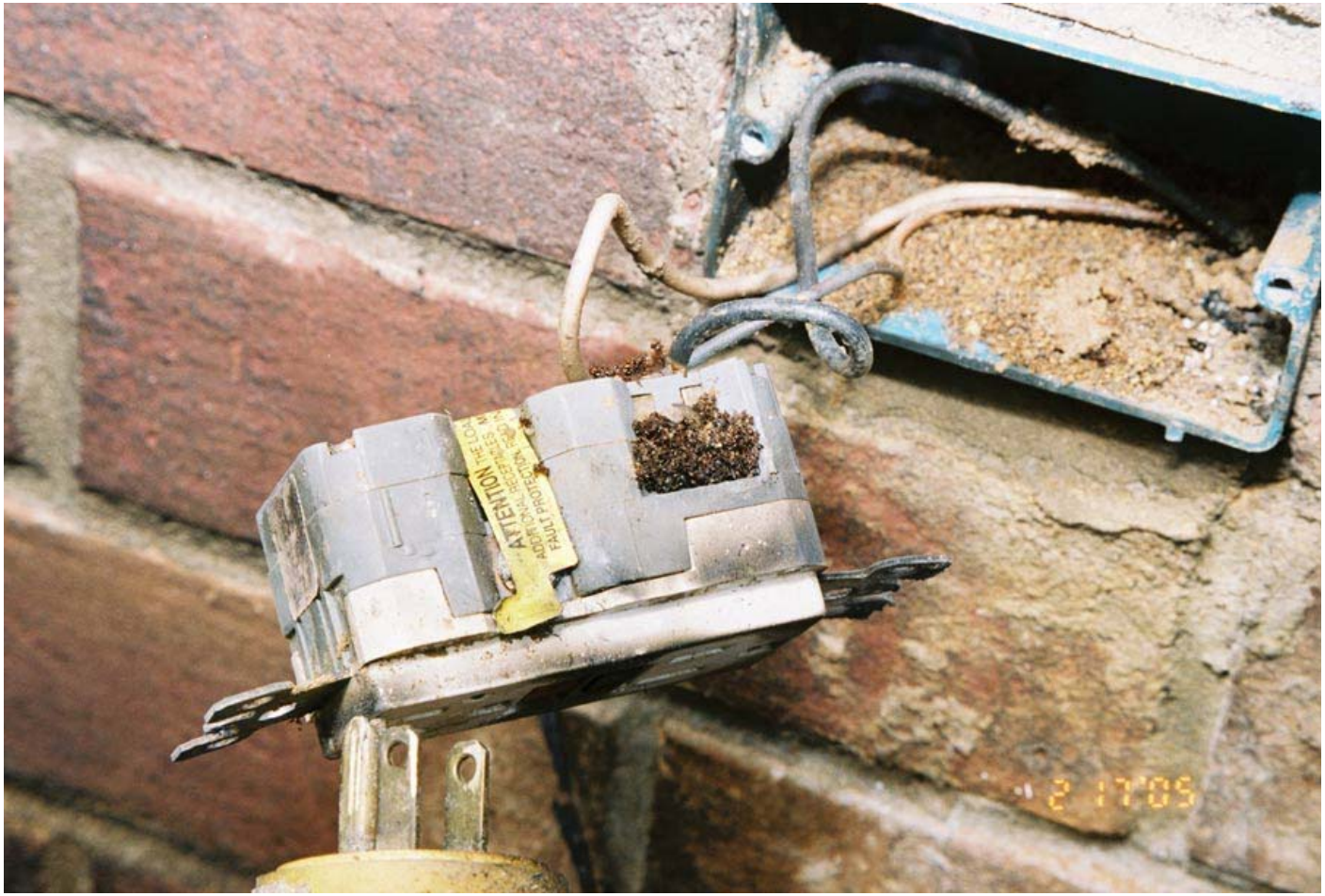

Wire Insulation
Good
Damaged
Consumed
Dish
Washer

Animal Problems



Animals



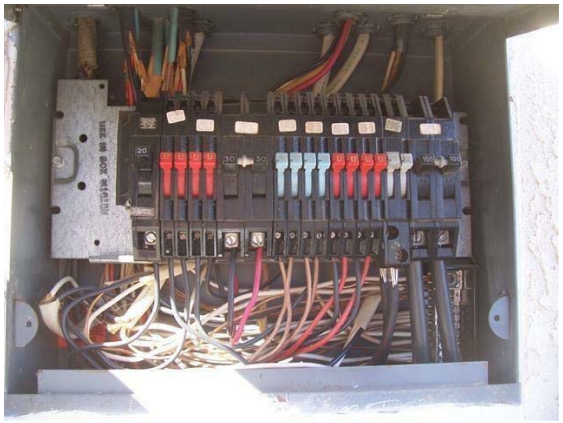

ATTENTION
2 17'05

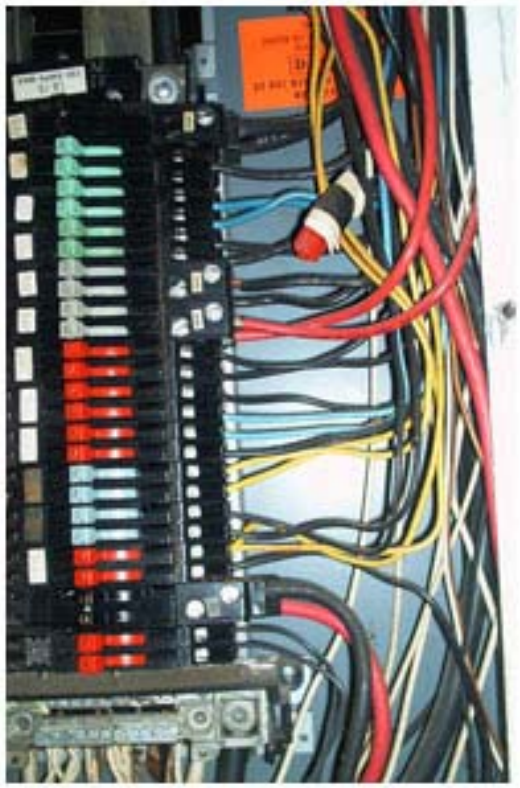
Product Failures


Hoverboard Fire Demonstration

CIRCUIT BREAKERS

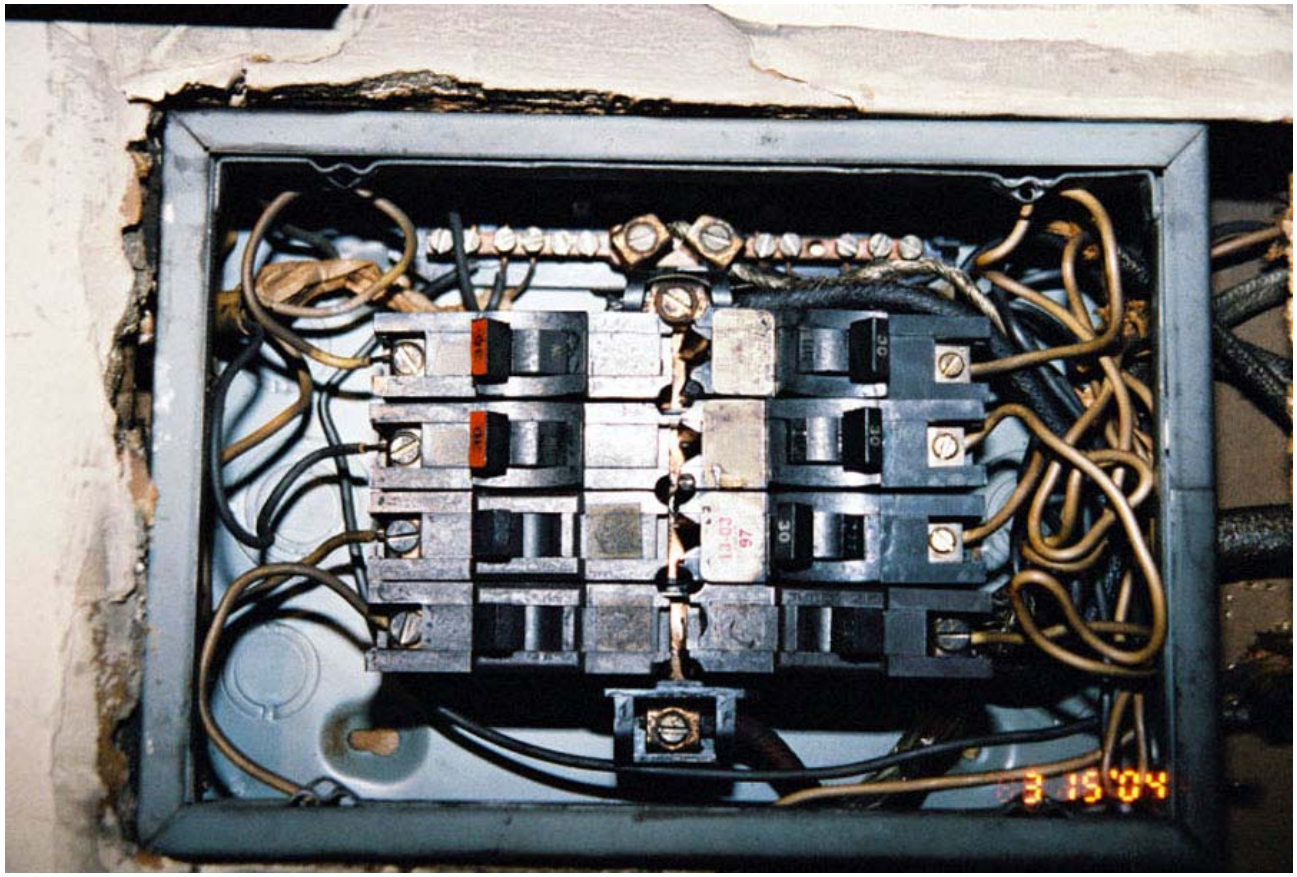
GTE/ SYLVANIA “ZINSCO” PANELS



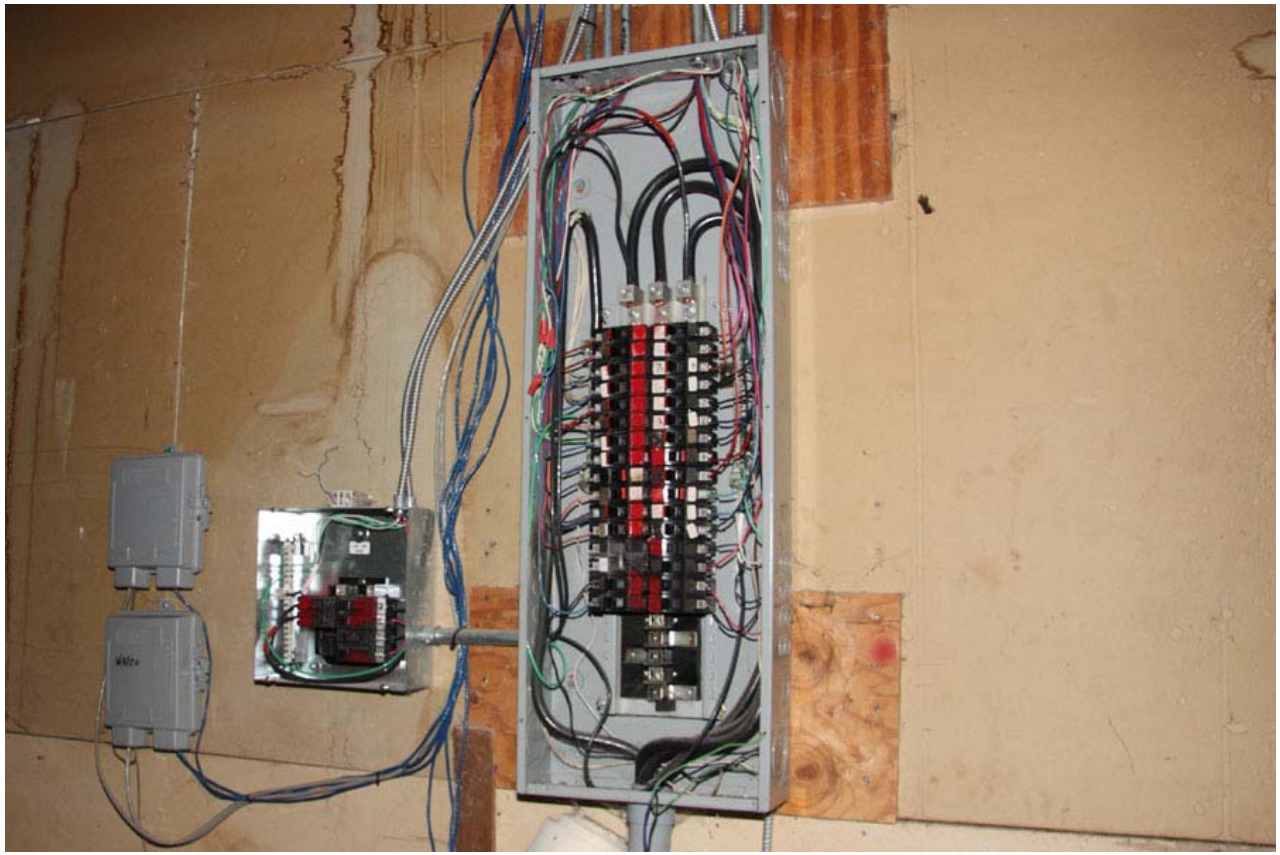


Federal Pacific Circuit Breakers

Federal Pacific – Red Handles



Federal Pacific – Red Handles



Re-locatable power tap

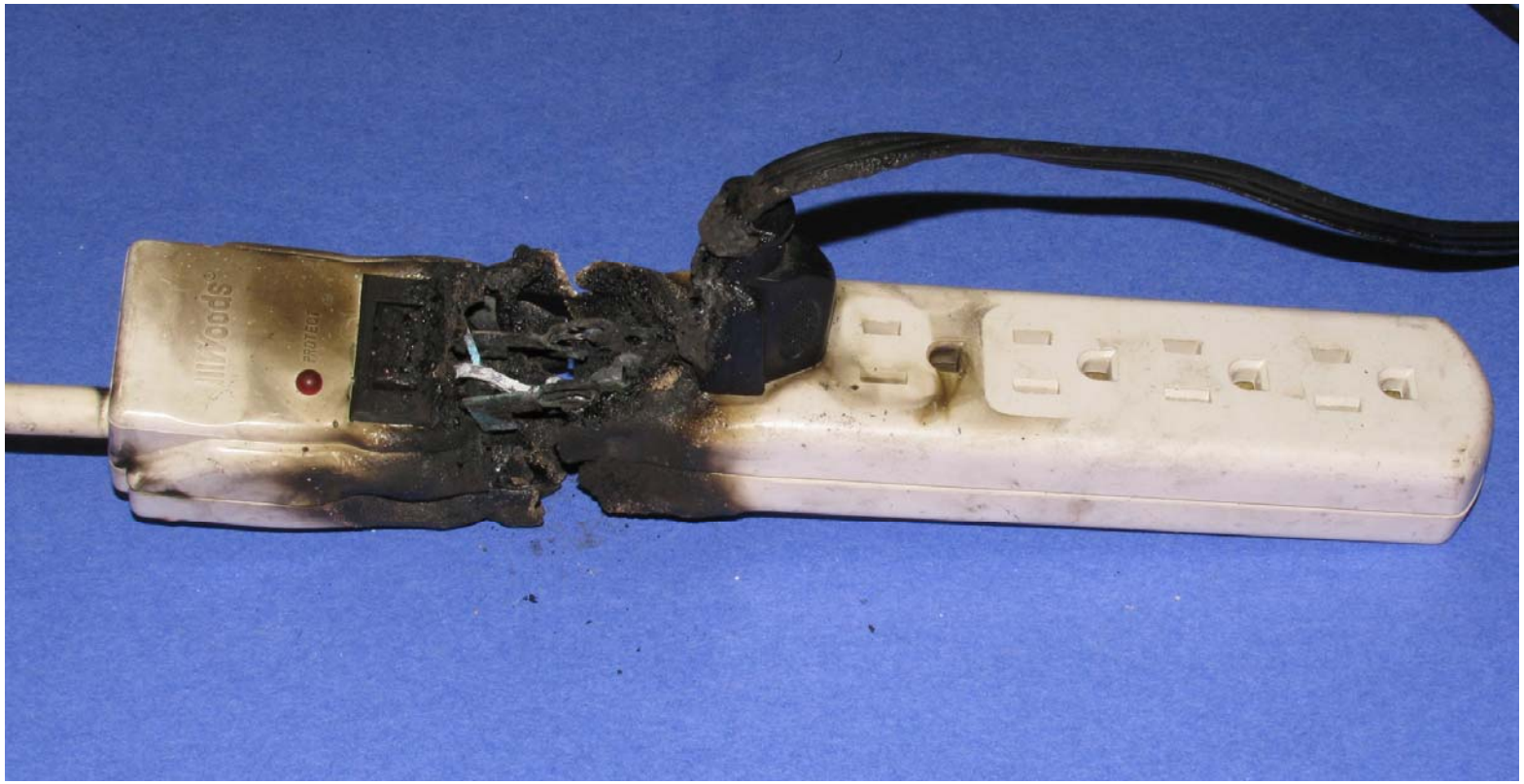
Short Circuits

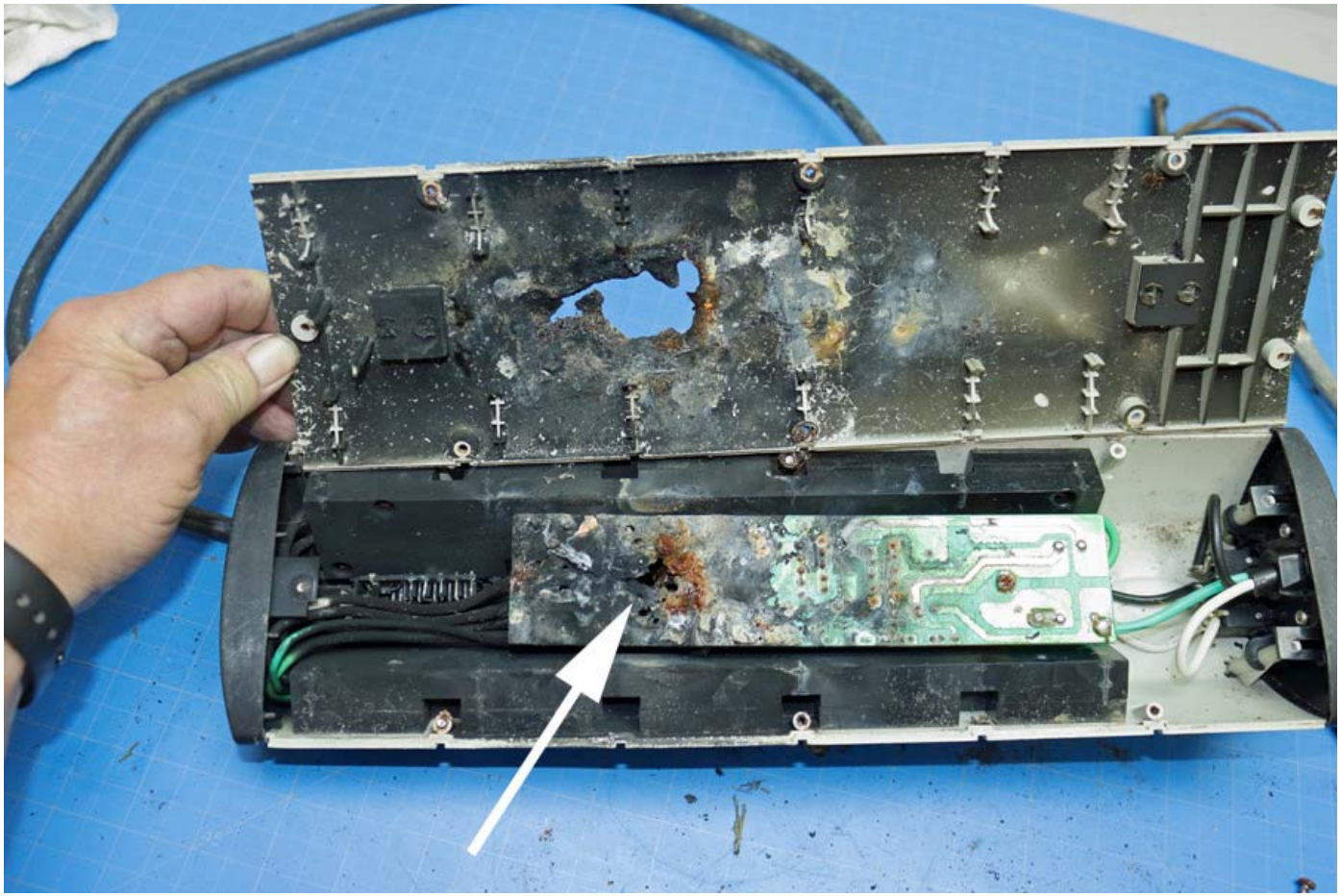
Surge Protection Failure

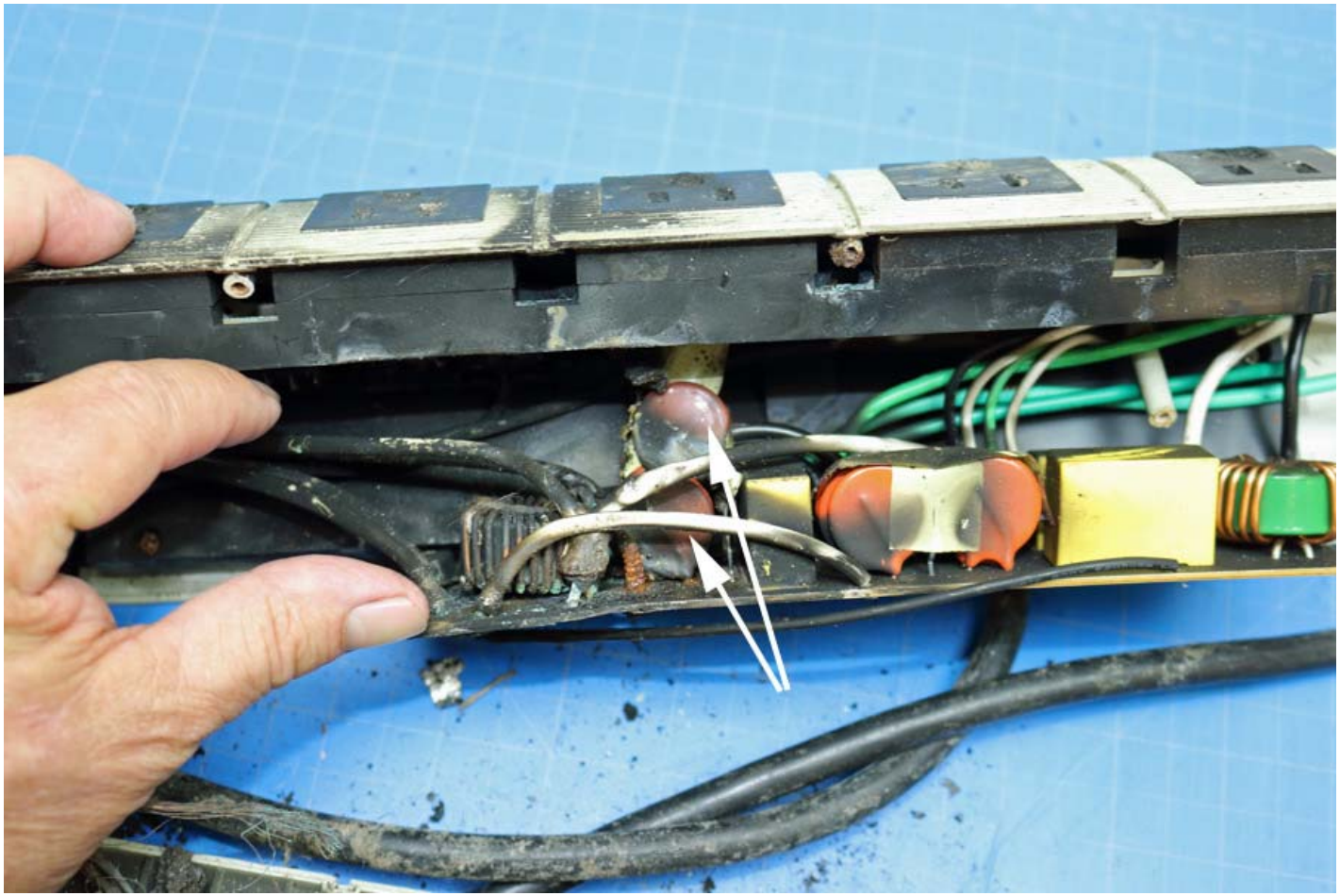
Damaged Wiring

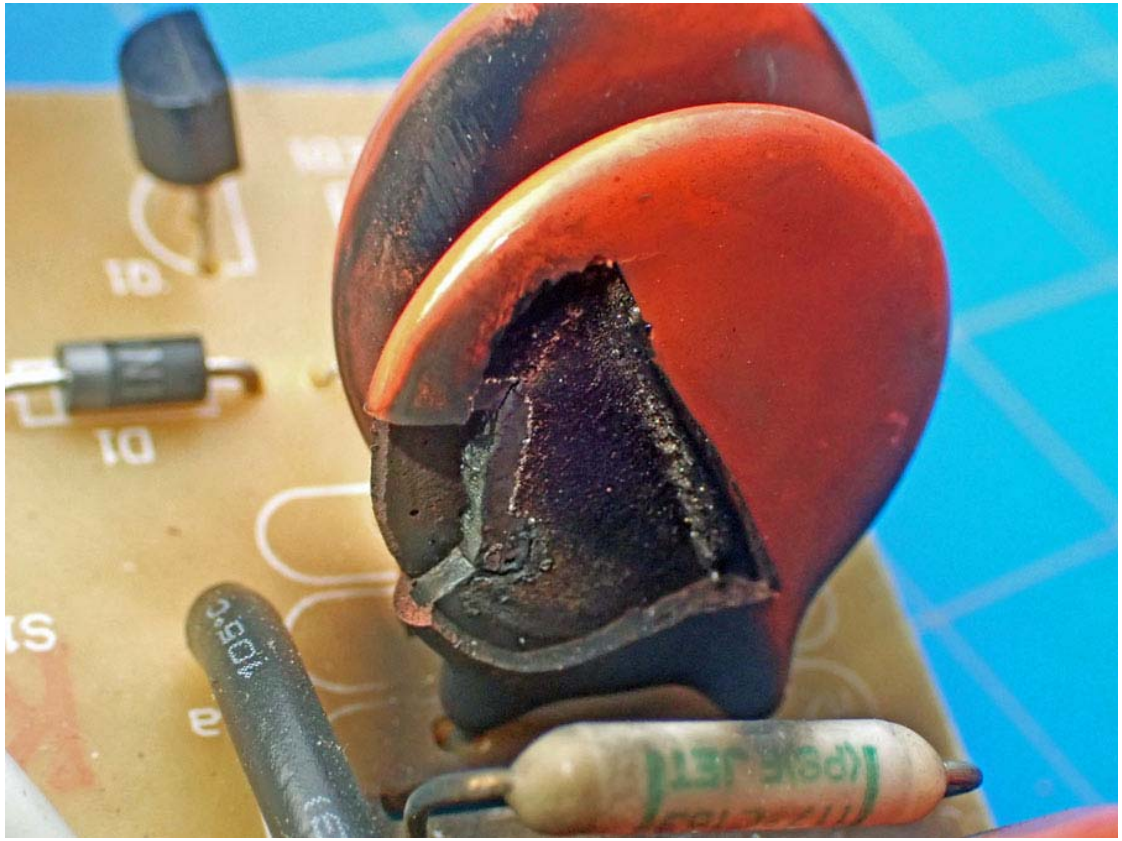
Overloaded / Abused

Re-locatable power tap


PROTECT






Q1
D1

QUESTIONS?

https://www.youtube.com/watch?v=oBJyyEAw-6g


MOJO HD