Fire Investigation: Electrical Systems

FI: ES-Student Manual

September 2016

FEMA

FEMA/USFA/NFA
FI: ES-SM
September 2016

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ELECTRICAL ASPECTS OF FIRE INVESTIGATION R255

National Fire Academy

Emmitsburg, MD

YOUR INSTRUCTORS

ATF STAFF
CPSC

ADMINISTRATIVE MATTERS

- Class roster
- Check your information - make any necessary changes
- Initial to the **RIGHT** of your name
- Voluntary class roster will be available on computer at back of classroom.

ADMINISTRATIVE MATTERS

- Dining hall and meal tickets
- Vehicle parking
- Breaks!
- Daily schedule 8 a.m. to 5 p.m.
- Homework assignments
- Phones
- Mail

ADMINISTRATIVE MATTERS

- Restrooms
- Fire exits and drills
- Computer room
- Superintendent's lunch
- No smoking
- Absence from class
- Class party
- Class shirts

THUMB DRIVES

MUST BE SCANNED BEFORE THEY CAN BE USED!

COURSE REQUIREMENTS

- Attendance required for all class sessions
- Active participation is expected in class
- Active participation is expected with the hands-on practical skill stations
- Required homework and classroom assignments must be completed
- Student Manual contains more material than is covered in the class
- Material may be covered in class that is not in Student Manual

STUDENT INTRODUCTIONS

NAME

DEPARTMENT

FIRE INVESTIGATION EXPERIENCE

ELECTRICAL EXPERIENCE

WHAT DO YOU EXPECT OUT OF THIS COURSE ?

WHAT IS YOUR WORST ELECTRICAL EXPERIENCE ?

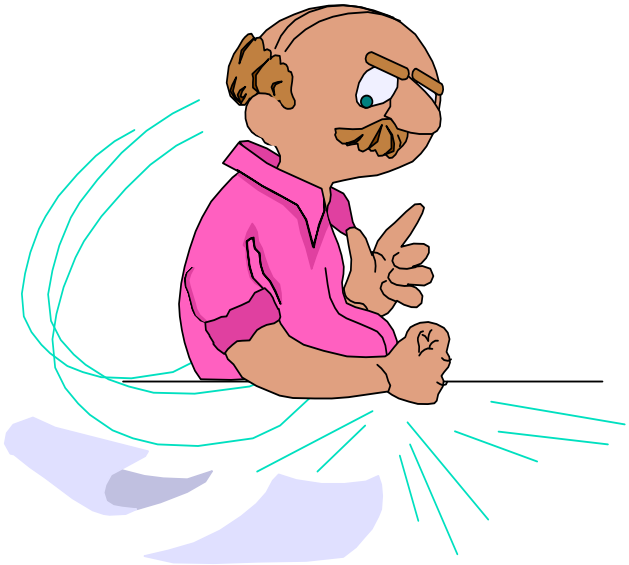
(Personal or Professional!)

COURSE GOAL

The goal of the *Electrical Aspects of Fire Investigation* course is to provide those critical skills in the technical, scientific and practical aspects required of all fire investigations, specifically the electrical system and associated components.

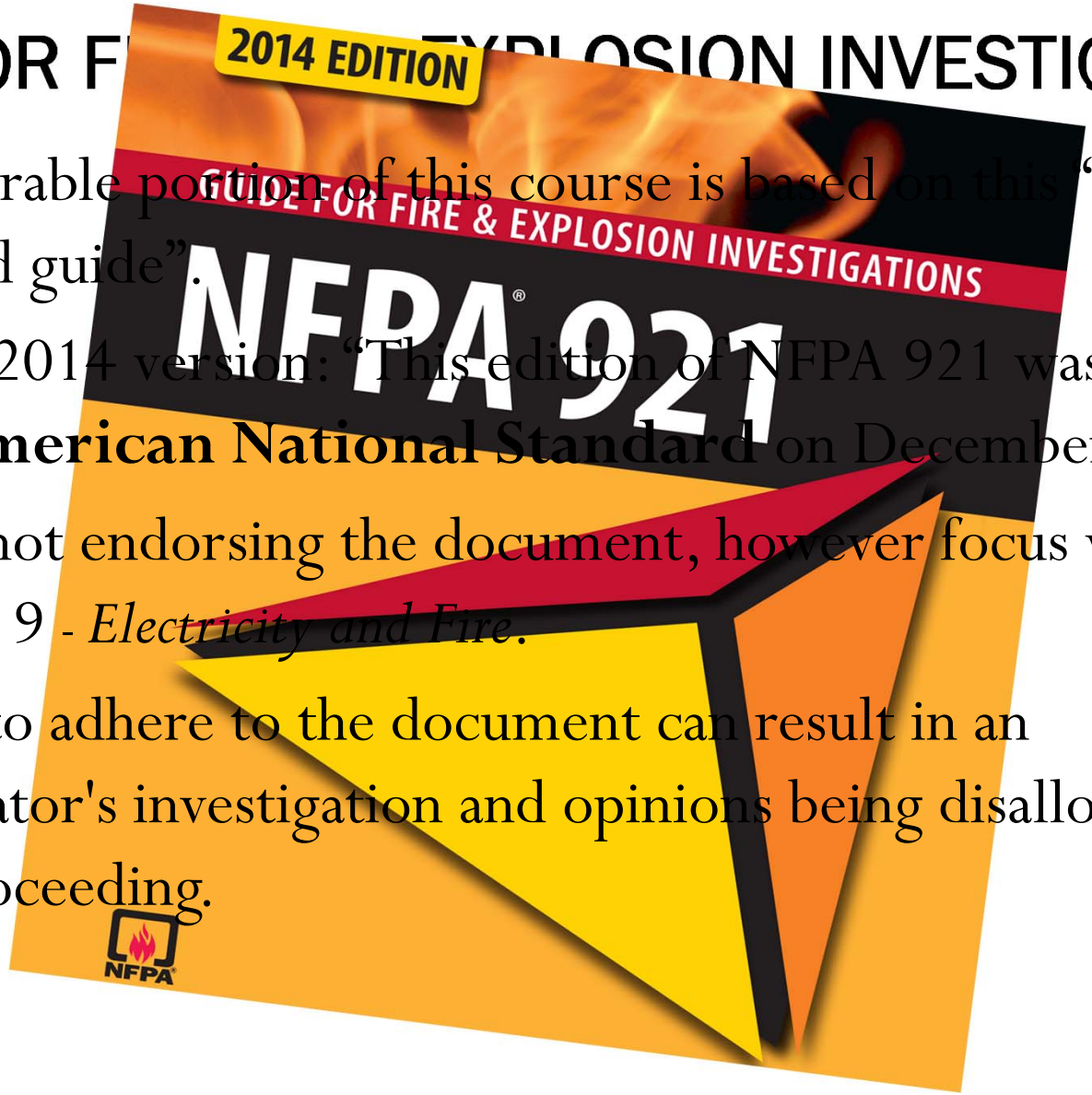
TESTING

- Grading will be based on practical skill stations and completion of either homework or classroom assignments



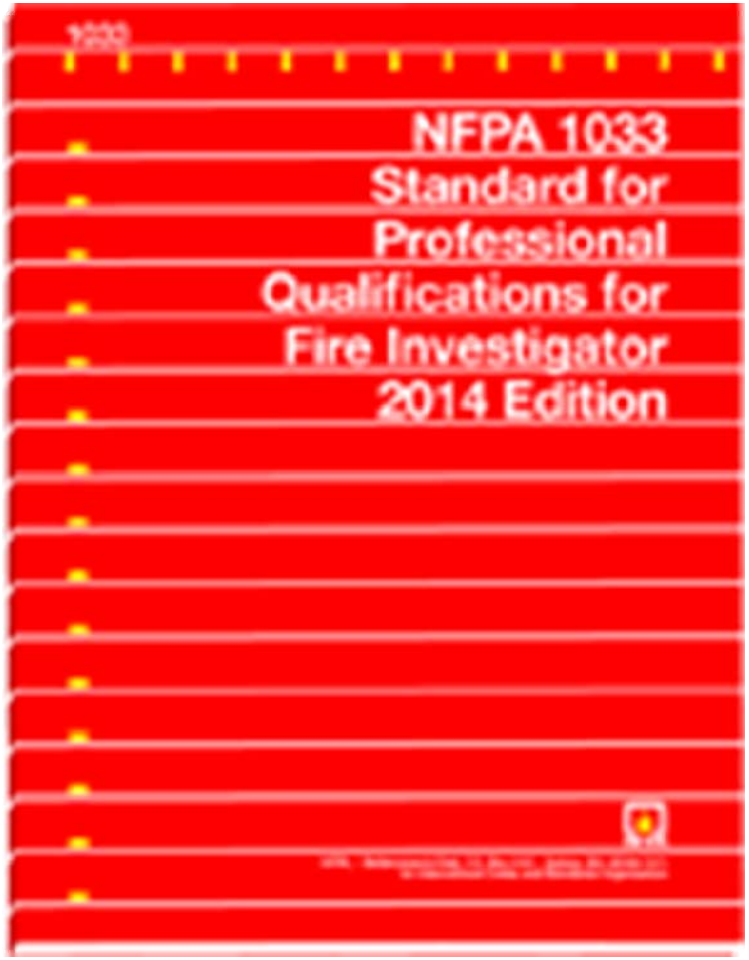
NFPA 921

GUIDE FOR F[illegible] EXPLOSION INVESTIGATIONS



- Considerable portion of this course is based on this "industry accepted guide".
- Page 1: 2014 version: "This edition of NFPA 921 was approved as an **American National Standard** on December 2, 2013"
- NFA is not endorsing the document, however focus will be on Chapter 9 - *Electricity and Fire*.
- Failure to adhere to the document can result in an investigator's investigation and opinions being disallowed in a legal proceeding.

Protocols: NFPA 1033



1.2* Purpose. The purpose of this **standard** shall be to specify the minimum job performance requirements for serving as a fire investigator in both the private and public sectors.

3.3.10 Requisite Knowledge. Fundamental knowledge one must have in order to perform a specific task.

3.3.11 Requisite Skills. The essential skills one must have in order to perform a specific task.

NFPA 1033 2014 Ed.

1.3.7* The investigator shall have and maintain at a minimum an up-to-date basic knowledge of the following topics beyond the high school level:

(1) Fire science

(2) Fire chemistry

(3) Thermodynamics

(4) Thermometry

(5) Fire dynamics

(6) Explosion dynamics

(7) Computer fire modeling

(8) Fire investigation

(9) Fire analysis

(10) Fire investigation methodology

(11) Fire investigation technology

(12) Hazardous materials

(13) Failure analysis and analytical tools

(14) Fire protection systems

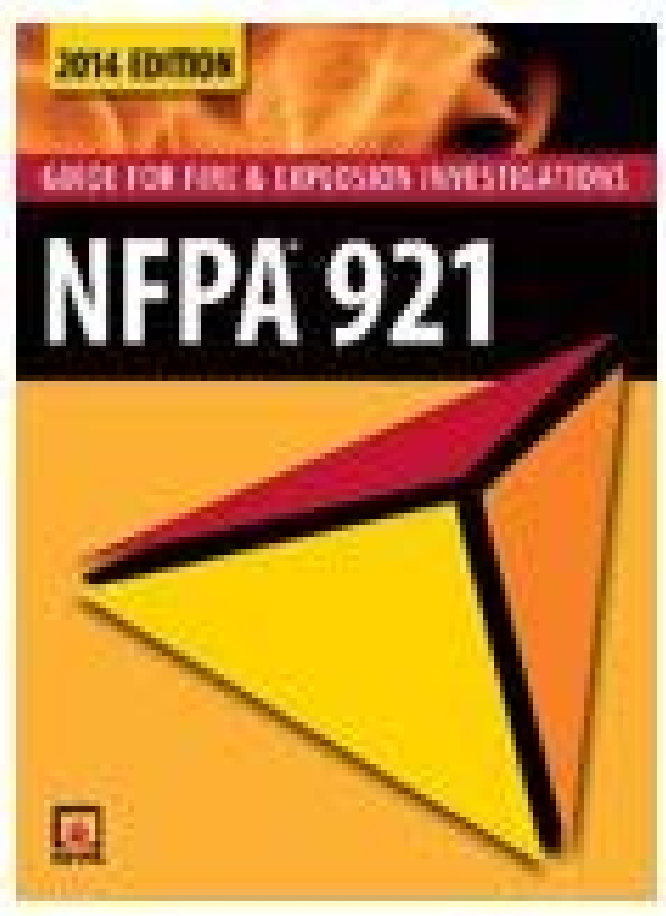
(15) Evidence documentation, collection, and preservation

(16) Electricity and Electrical Systems

NFPA 1033

4.1.2* The fire investigator **<u>shall</u>** employ **<u>all</u>** elements of *the scientific method* as the operating analytical process throughout the investigation and for the drawing of conclusions.

Protocols: NFPA 921

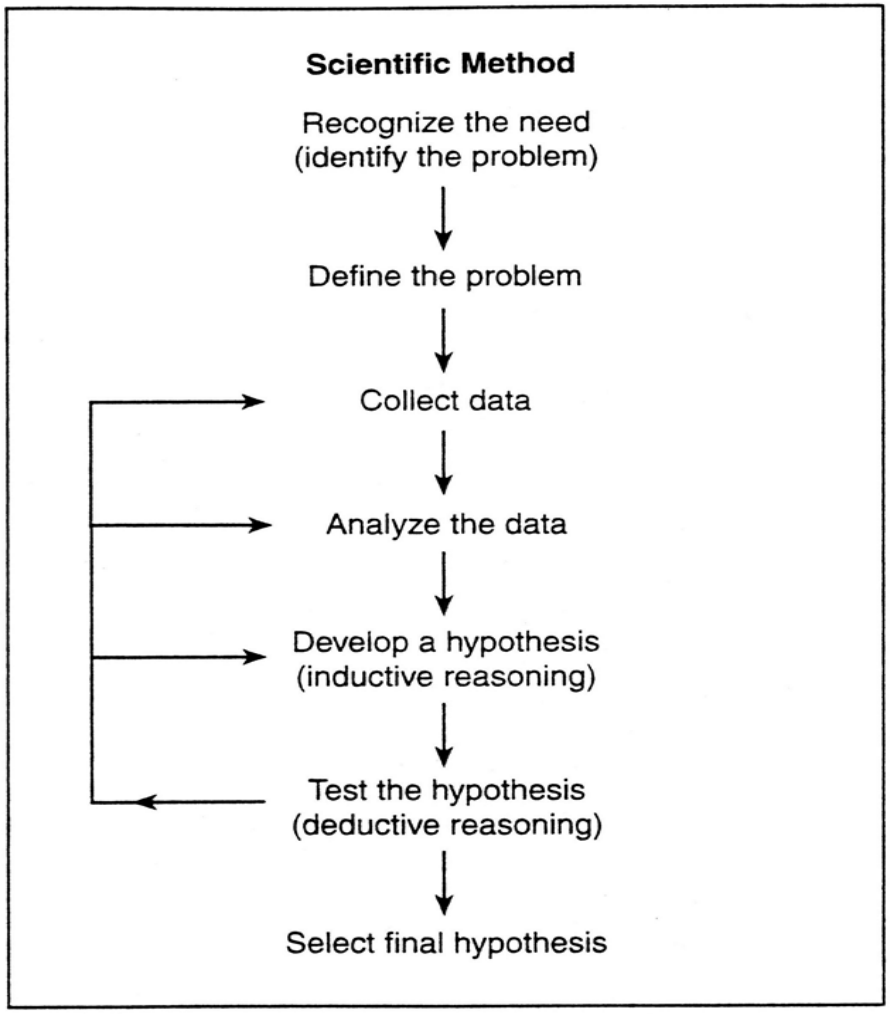


1.2.1 **Purpose**: ***"The purpose of this document is to establish guidelines and recommendations for the safe and systematic investigation or analysis of fire and explosion incidents…*** This document has been developed as a model for the advancement and practice of fire and explosion investigation, fire science, technology, and methodology."

1.3 **Application**: ***This document is designed to produce a systematic, working framework*** or outline by which effective fire and explosion investigation and origin and cause analysis can be accomplished. It contains specific procedures to assist in the investigation of fires and explosions. These procedures represent the judgment developed from the NFPA consensus process system that if followed can improve the probability of reaching sound conclusions. Deviations from these procedures, however, are not necessarily wrong or inferior but need to be justified.

4.2 **Systematic Approach**: ***The systematic approach recommended is based on the scientific method***, which is used in the physical sciences. This method provides an organizational and analytical process that is desirable and necessary in a successful fire investigation.

Scientific Method



Origin first … then Cause

- Most important task of a fire investigator is to first identify the origin – Sometimes this may also be most difficult!
- In short, after the investigator identifies origin, only then can we begin the task of cause determination.
- Investigators are much more likely to determine cause only when they have correctly identified the origin first!!

How do Fire Investigators arrive at the Origin?

NFPA 921 Guide for Fire & Explosion Investigations (2014 Ed./Chapter 18)

Section 18.1.2
Determination of the origin of the fire involves the coordination of information derived from one or more of the following:

- **Witness Information.** The analysis of observations reported by persons who witnessed the fire or were aware of conditions present at the time of the fire

- **Fire Patterns.** The analysis of effects and patterns left by the Fire.

- **Arc Mapping**. The analysis of the locations where electrical arcing has caused damage and the documentation of the involved electrical circuits .

- **Fire Dynamics.** The analysis of the fire dynamics, that is, the physics and chemistry of fire initiation and growth, and the interaction between the fire and the building's systems .

ENABLING OBJECTIVES

- Provide a basic knowledge of electricity, electrical circuits, and distribution systems.
- Understand the National Electrical Code and how it is applicable to fire investigators.
- Use of "Arc Fault Mapping" and how it can be used during fire scene examinations.
- Evaluating and recognizing common electrical faults and failures of electrical components, and circuits.
- Understanding that Electricity is only <u>one</u> side of the fire triangle: **HEAT**.

ELECTRICITY…?????

As an investigator you must have knowledge in various fields to successfully determine fire causes.

This is one of those fields…..

INDUSTRY "EXPERTS"

Electrical Experts → Cannot start fires

Fire experts → Causes all fires

<u>"Catch-all" cause !!</u>

ELECTRICAL EXPERT

- FIRE CAUSED BY ELECTRICITY
- 80 amps through a piece of 14/2 NMC
- Improper installation, code violation - YES

BASIC TERMS

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

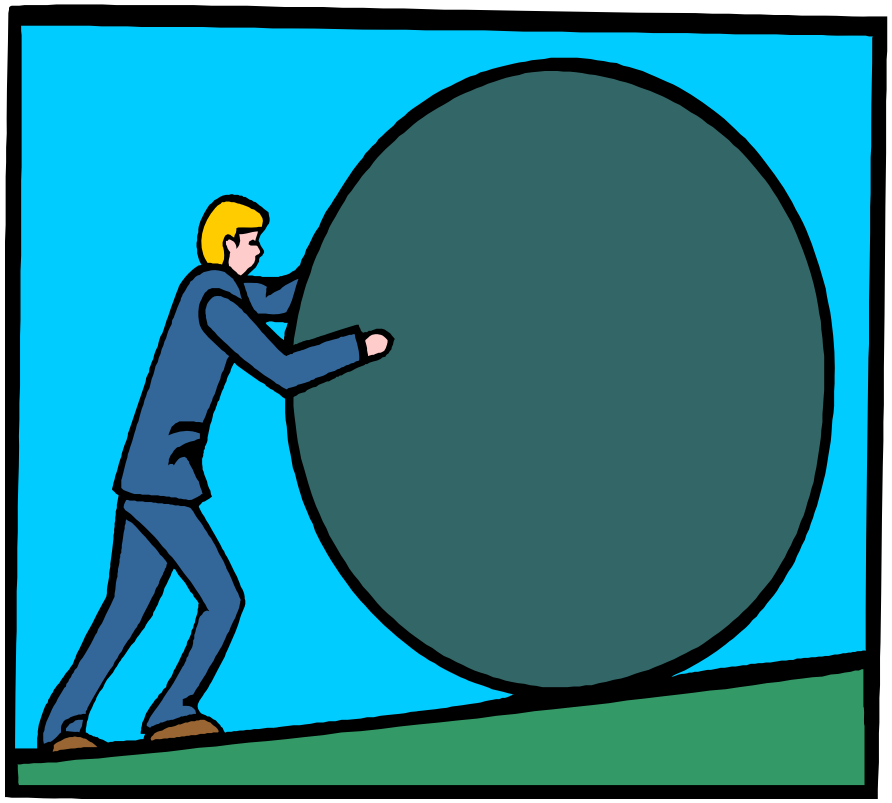
For some these will be new, and others this will be a refresher.

COMMON ELECTRICAL TERMS

- Voltage (V) or Electromotive force (E or EMF)
- Current (I) or amperes/amps (A)
- Power (P) or watts (W)
- Resistance (R)

- Conductance (1/R)
- Capacitance (C)
- Inductance (L)

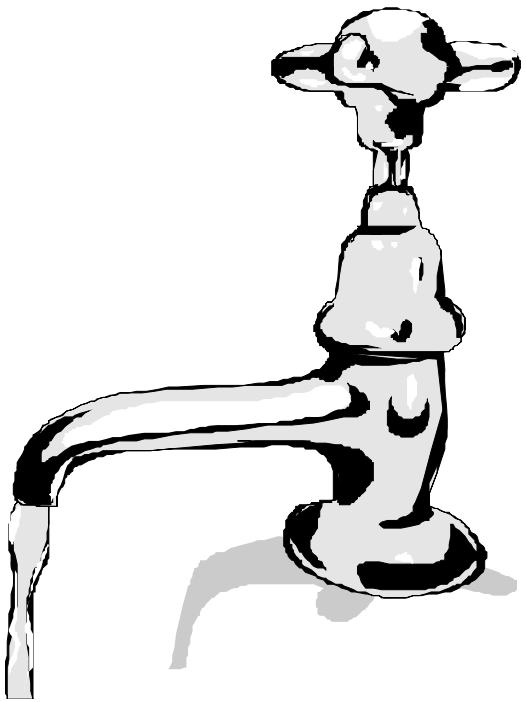
VOLTAGE (VOLTS)



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

$$\mathbf{E} = \text{Volts}$$

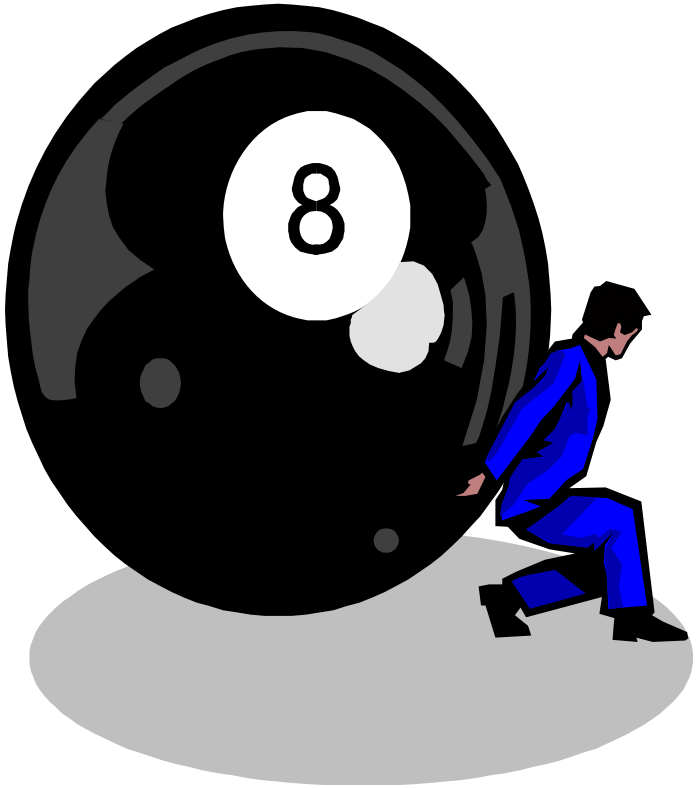
CURRENT (AMPERE)



Is the <u>rate</u> 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

RESISTANCE (OHMS)



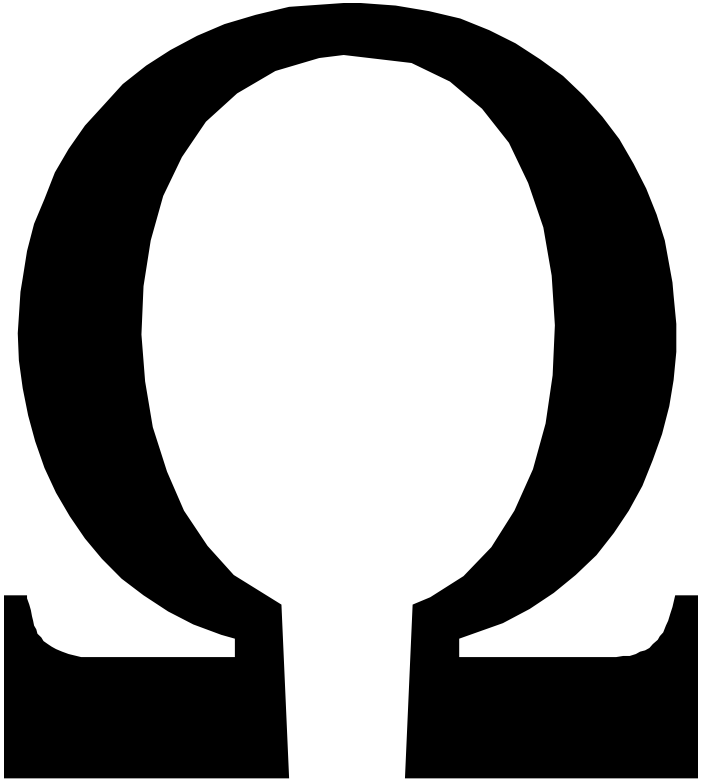
This is the opposition to current flow.

Measured in Ohms

Greek Symbol Omega

R or **Ω**

RESISTANCE (OHMS)



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

POWER

Power is the measure of the rate at which work is done. Electrical power is measured according to voltage and current values.

Electrical power is measured in watts (**W**)

For the purposes of this class,

Watts (W) = Volts (V) x Amps (A)

HORSEPOWER CALCULATIONS

$$\text{Efficiency} = \frac{\text{Power Output}}{\text{Power Input}}$$

$$\text{Horsepower} = \frac{\text{Volts x Amps x Efficiency x PF}}{746}$$

$$\text{Amperes} = \frac{746 \text{ x HP}}{\text{Volts x Efficiency x PF}}$$

PF = Power Factor

746 Watts = 1 Horsepower

$$\text{Horsepower} = \frac{\text{Watts}}{746}$$

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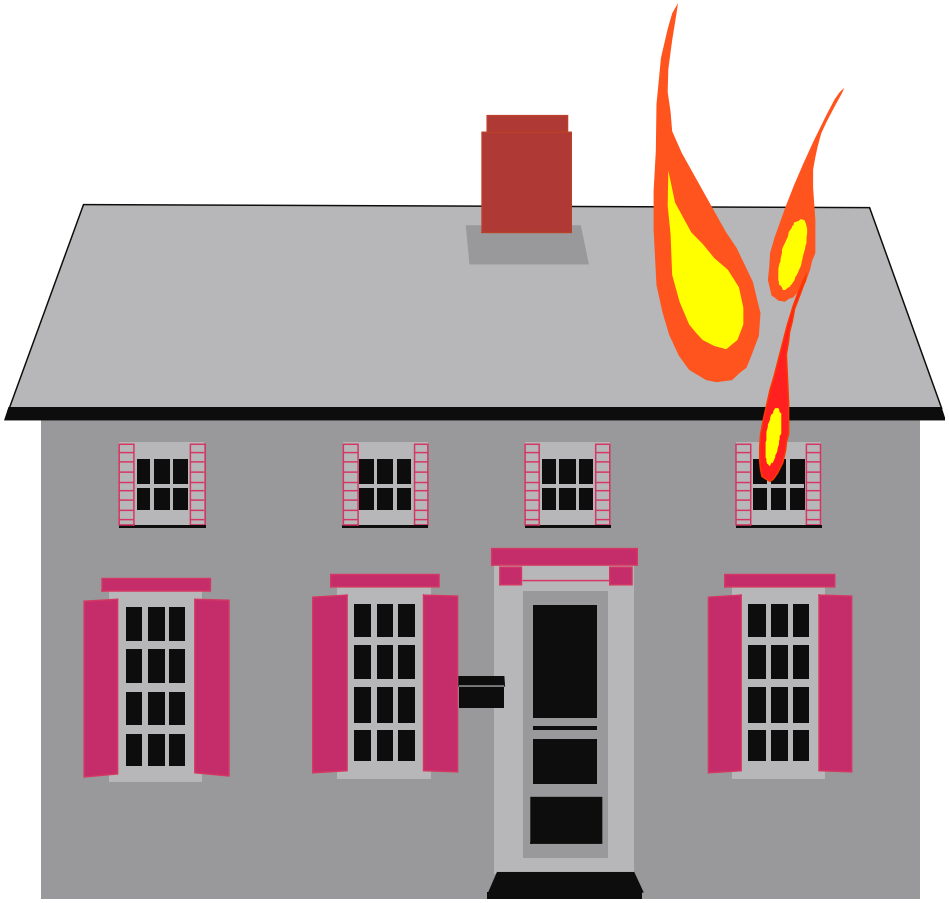
WHAT IS ELECTRICITY?

e·lec·tric·i·ty (ĭlĕc-trĭ'cĭtē ēlĕ-) *noun*
Abbr. **elec.**

1. **a.** The physical phenomena arising from the behavior of electrons and protons that is caused by the attraction of particles with opposite charges and the repulsion of particles with the same charge. **b.** The physical science of such phenomena.
2. Electric current used or regarded as a source of power.
3. Intense, contagious emotional excitement.

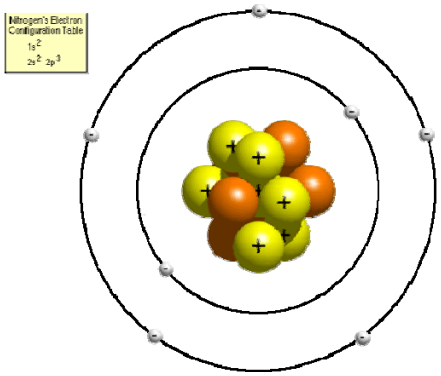
Excerpted from The American Heritage Dictionary of the English Language, Third Edition Copyright © 1992 by Houghton Mifflin Company.

ELECTRICITY



- Is the flow of electrons due to a difference in energy potential between two points on a conductor.
- You cannot see electrons, only their effects.

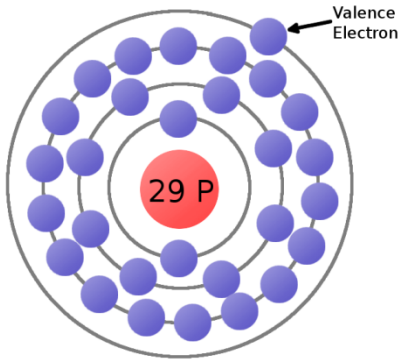
ATOMIC THEORY



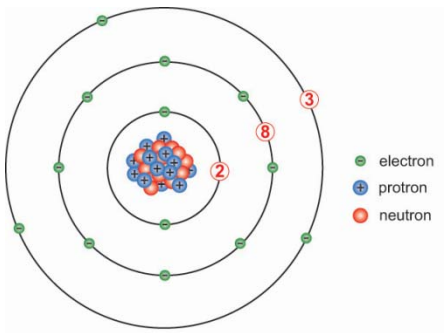
- All matter is made of atoms.
- Protons + neutrons = nucleus.
- Electrons forms valance rings.
- # of electrons = # of protons.
- Outer valence ring has 1 to 8 electrons.
- 1-2 electrons in outer ring = unstable ring (conductor).

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

ATOMIC THEORY



Copper Atom

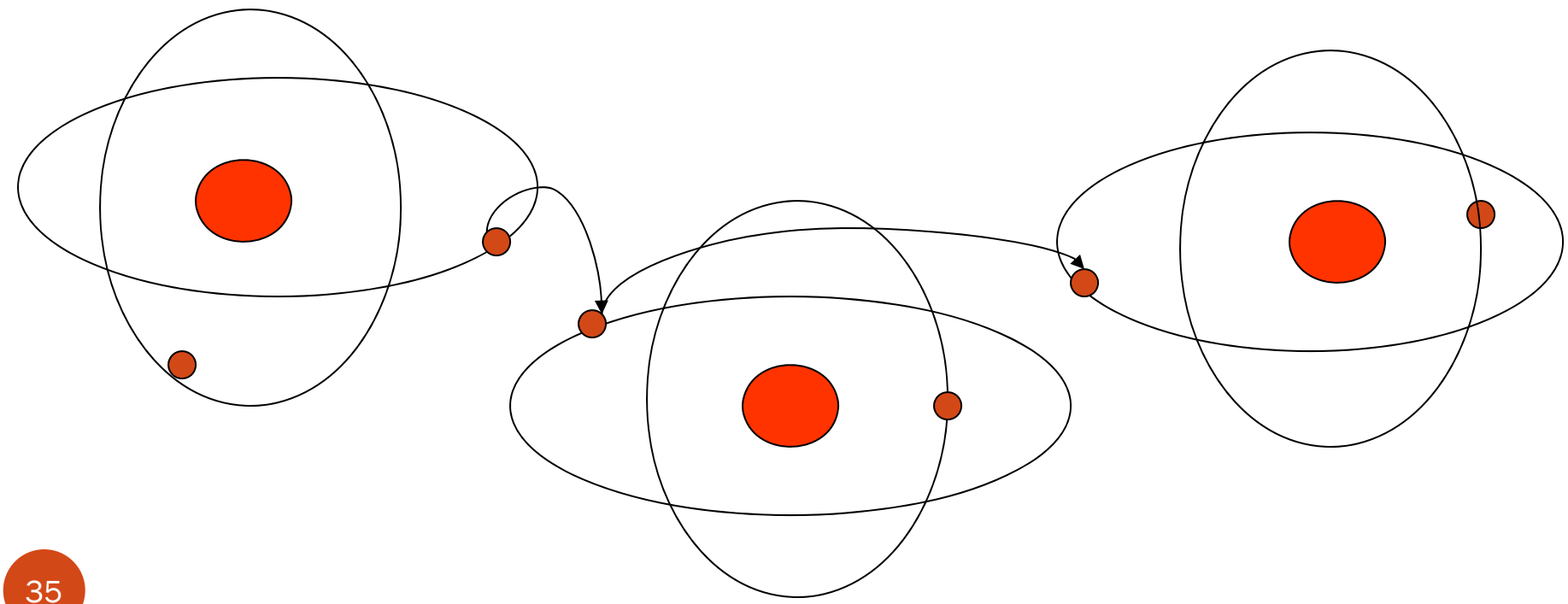


Aluminum Atom

- More valence electrons in the outer ring = more stability
- More stability = Less conductive
- Copper atom has **1** valence electron
- 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.

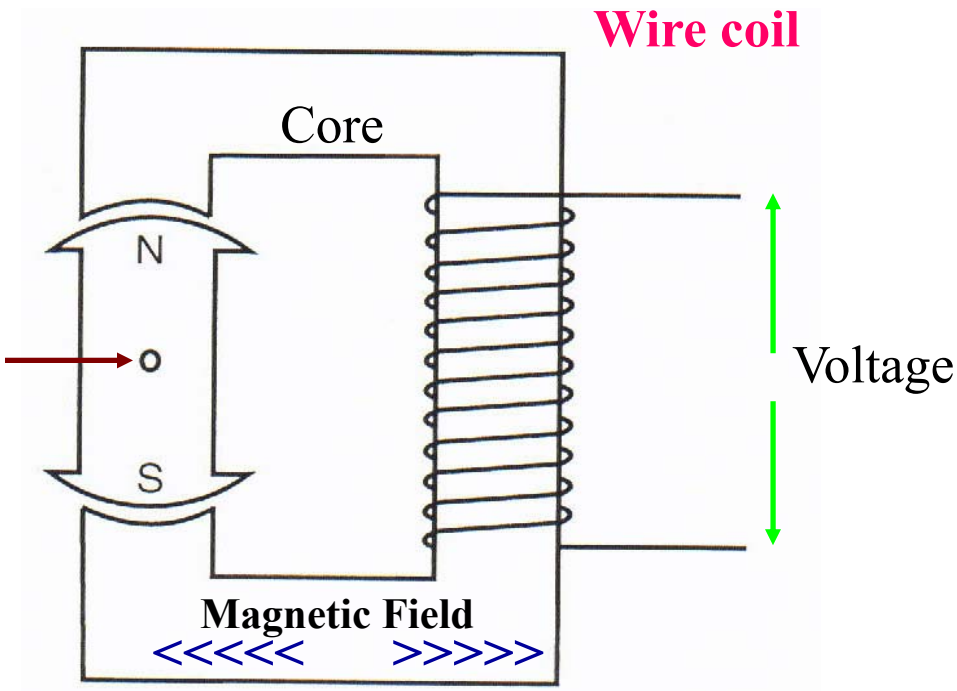
ATOMIC THEORY

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



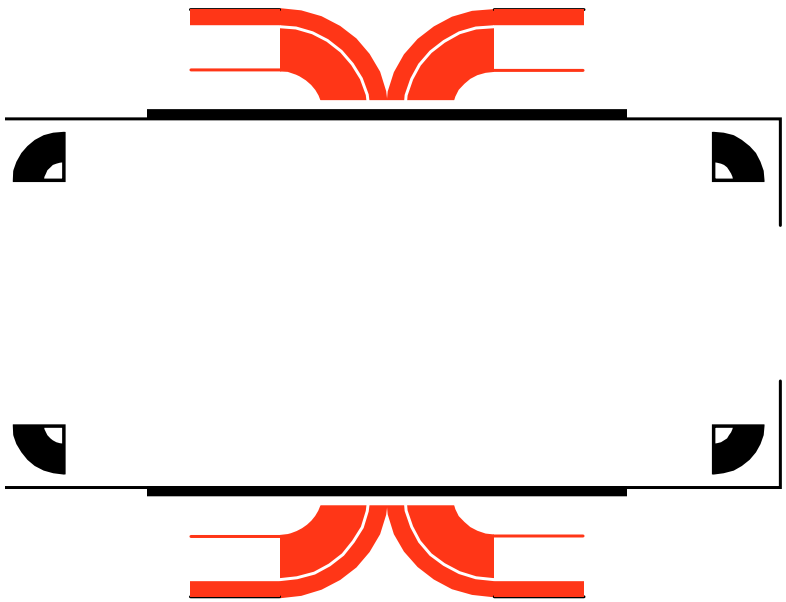
WHAT CAUSES THE ELECTRONS TO MOVE: MAGNETISM

A magnet is rotated in a core



As the magnet is rotated it creates a field in the core.
This field is strongest as 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.

MAGNETIC FIELD



When current flows a magnetic field is generated; this is the principal of a motor

Conversely when a conductor is put into a magnetic field, current will flow, that's the principal of a generator.

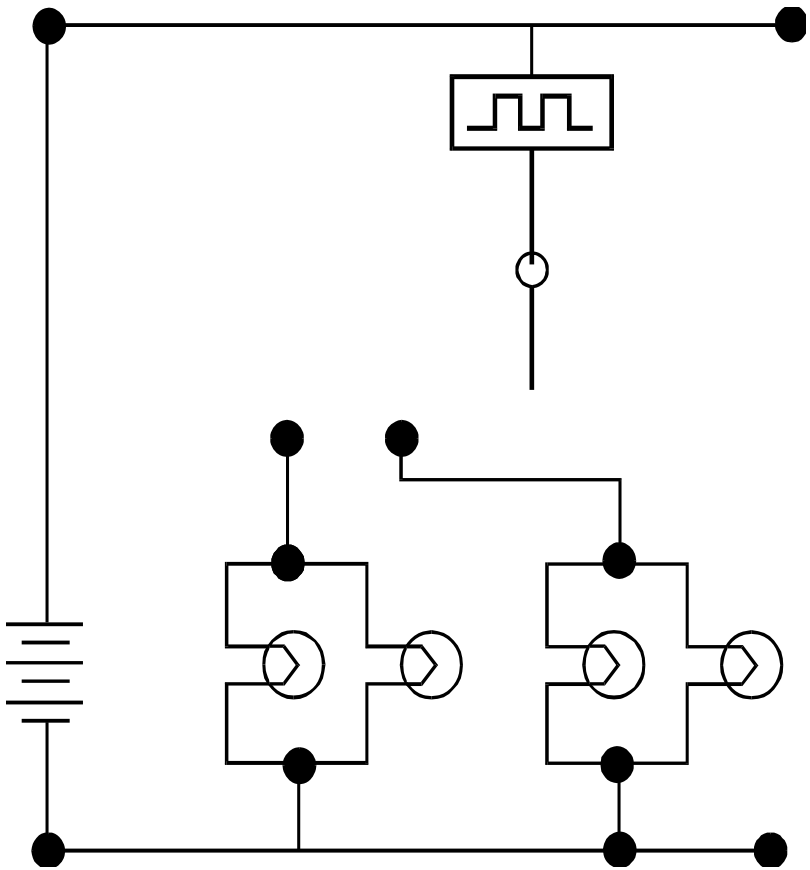
OHM'S LAW

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

Ohm's Law is stated as:

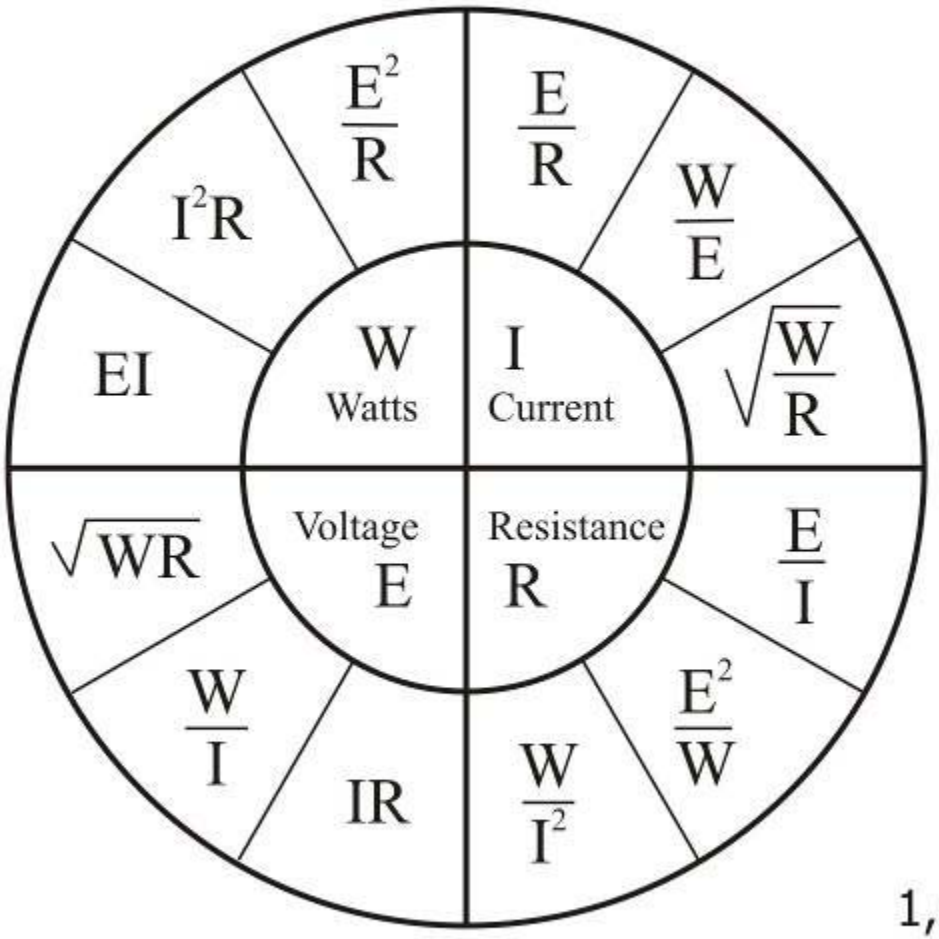
"The amount of current flowing in a circuit made up of pure resistance is directly proportional to the electromotive forces impressed on the circuit and inversely proportional to the total resistance of the circuit."

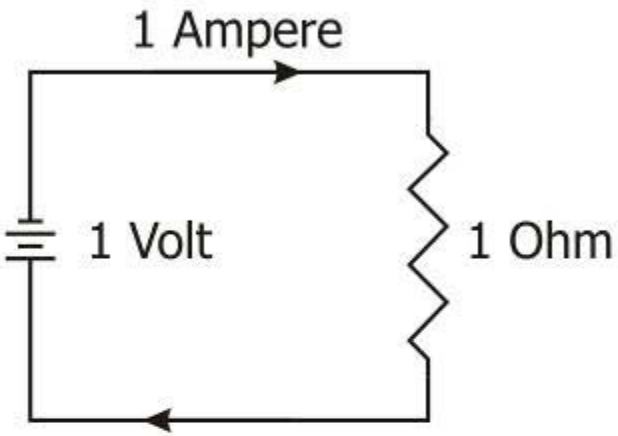
OHMS LAW & JOULE'S LAW



- Mathematical equations that calculate Voltage, Wattage, Current and Resistance in electrical circuits.
- Basically a model of what is happening in the circuit

WATT'S WHEEL





W = Ohm
1,000 Ohms = 1 Kilohm (K)
1,000,000 Ohms = 1 Megohm (Meg)
1,000 Kilohms (K) = 1 Megohm (Meg)

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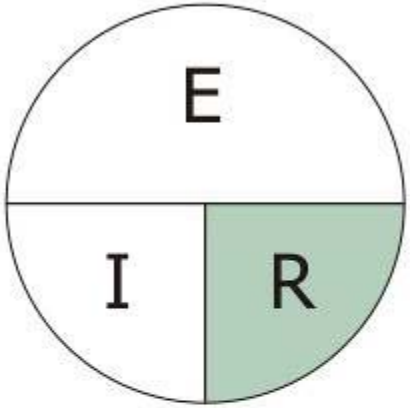
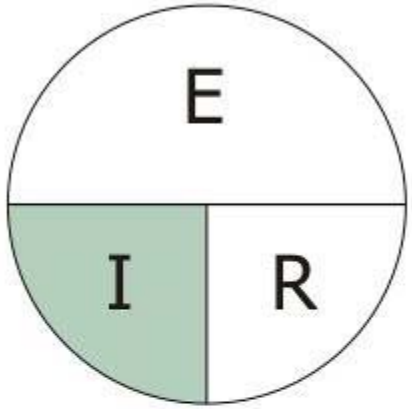
BASIC OHM'S LAW



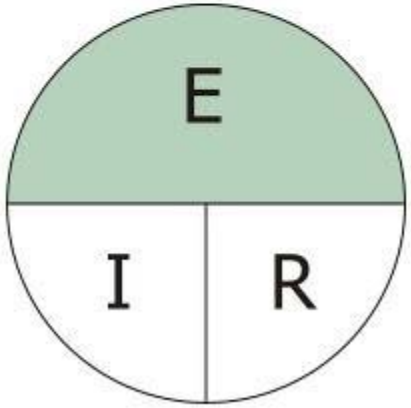
$$R = \frac{E}{I}$$

Resistance = Voltage ÷ Current



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

Current = Voltage ÷ Resistance



$$E = I \times R$$

Voltage = Current x Resistance

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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.

JOULE'S LAW

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

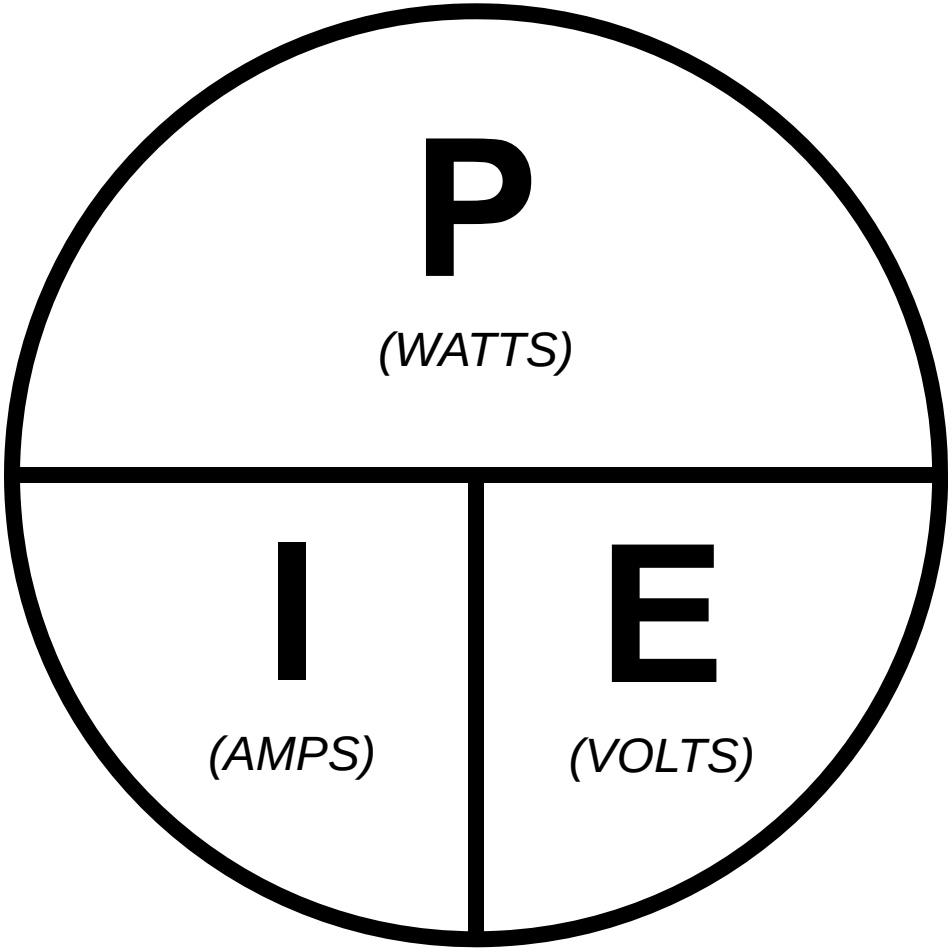
I (current) = P (watts) / E (volts)

E (volts) = P (watts) / I (current)

15 amps = 1800 watts / 120 volts

750 watts / 120 volts = 6.25 amps

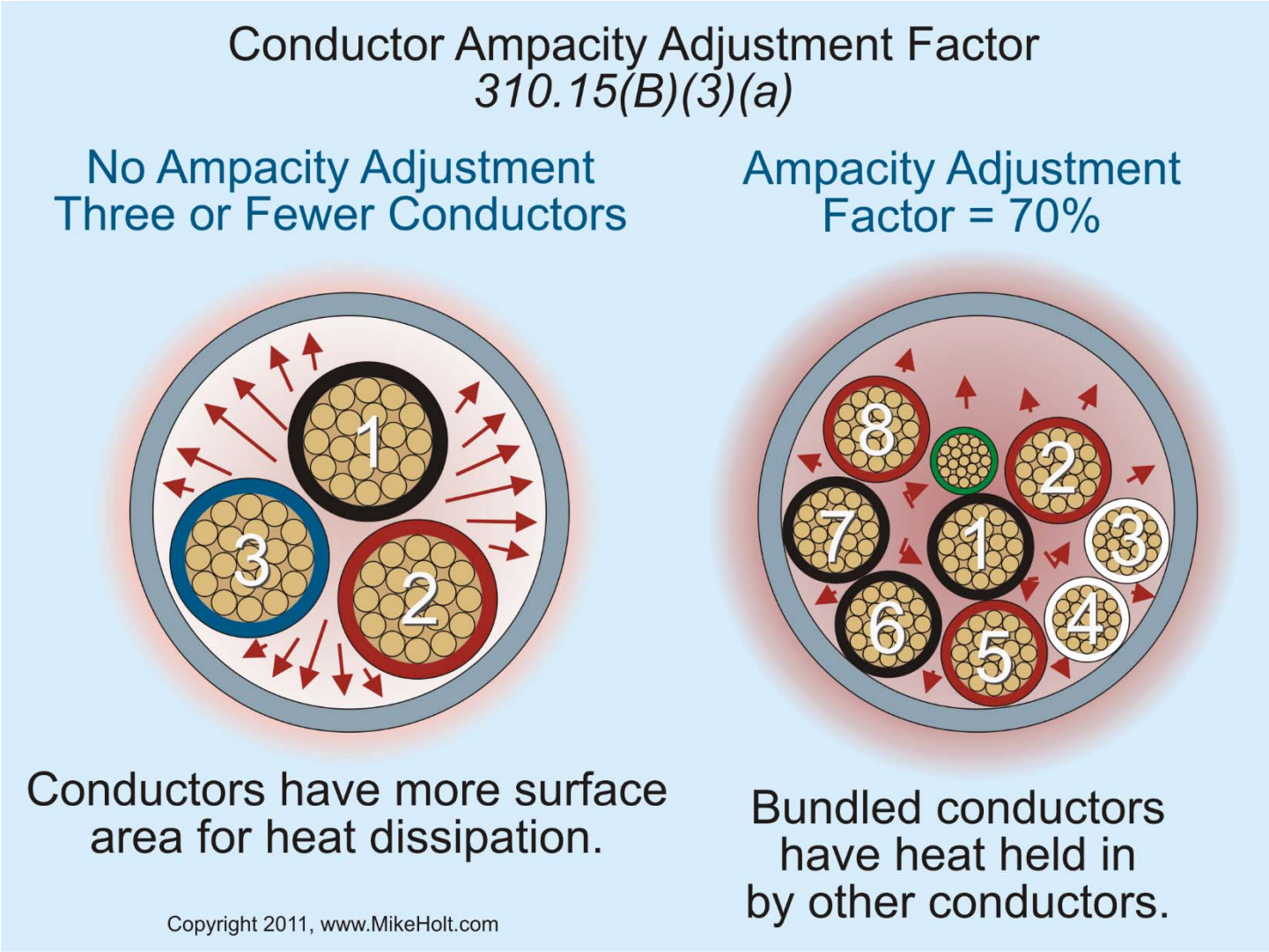
JOULE'S LAW



AMPACITY

- The current, in amperes, that a conductor can carry <u>continuously</u> under the conditions of use without exceeding its temperature rating.
- The definition of the term **ampacity** states that the maximum current a conductor carries continuously will vary with the conditions of use, as well as with the temperature rating of the conductor insulation. For example, ambient temperature is a condition of capacity rating and use. The ampacity of a conductor must be "de-rated" (reduced) under conditions of use such as when combined with other conductors in conduit, or due to high ambient temperature conditions, such as when installed in conduit on a rooftop.

AMPACITY


Conductor Ampacity Adjustment Factor
310.15(B)(3)(a)
No Ampacity Adjustment
Three or Fewer Conductors
Ampacity Adjustment
Factor = 70%
1
3
2
8
2
7
1
3
6
5
4
Conductors have more surface area for heat dissipation.
Bundled conductors have heat held in by other conductors.
Copyright 2011, www.MikeHolt.com

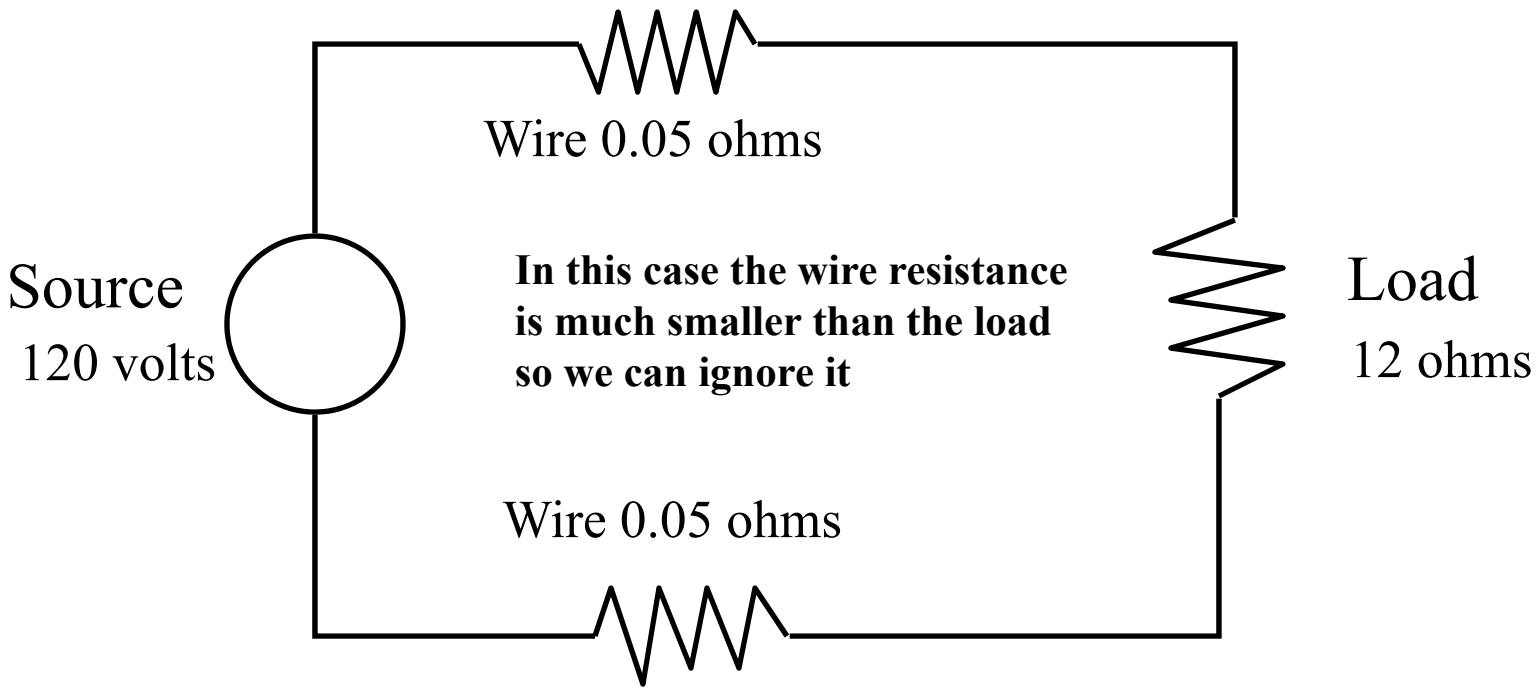
OHM'S LAW CALCULATIONS

- Used to determine load on the circuit
- Can prove if overload condition existed on circuit or circuit components
- Basically "model" what was occurring in the circuit provided you have proper input data, i.e. resistance, voltage, wattage, etc…

NAME PLATE CURRENT RATINGS

XR 12
MFR
DATE 03/2003
MOD. NO. 2TTR2024A1000AA VOLTS 200/230
SERIAL NO. 3105R3D4F PH 1 HZ 60
MINIMUM CIRCUIT AMPACITY 11.0 AMPS
OVERCURRENT PROTECTIVE DEVICE USA CANADA
MIN FUSE / BREAKER (HACR) 15 15
MAX FUSE / BREAKER (HACR) 15 15
HCFC – 22 5 LBS. 00 OZ. OR 2.27 Kg(si)
BAYFCCV 057A REQUIRED INDOORS FOR RATED PERFORMANCE
THE TRANE COMPANY
OUTDOOR USE
TYLER, TX 75711–9010 ASSEMBLED IN USA
COMPR. MOT. 8.4 RLA 200/230 V 62 LRA
O.D. MOT. .90 FLA 200/230 V 1/8 HP
M.E.A. NO. 208 – 02 – E
F. ID. A01
DESIGN PSI – HIGH 300 LOW 300

OHM'S LAW

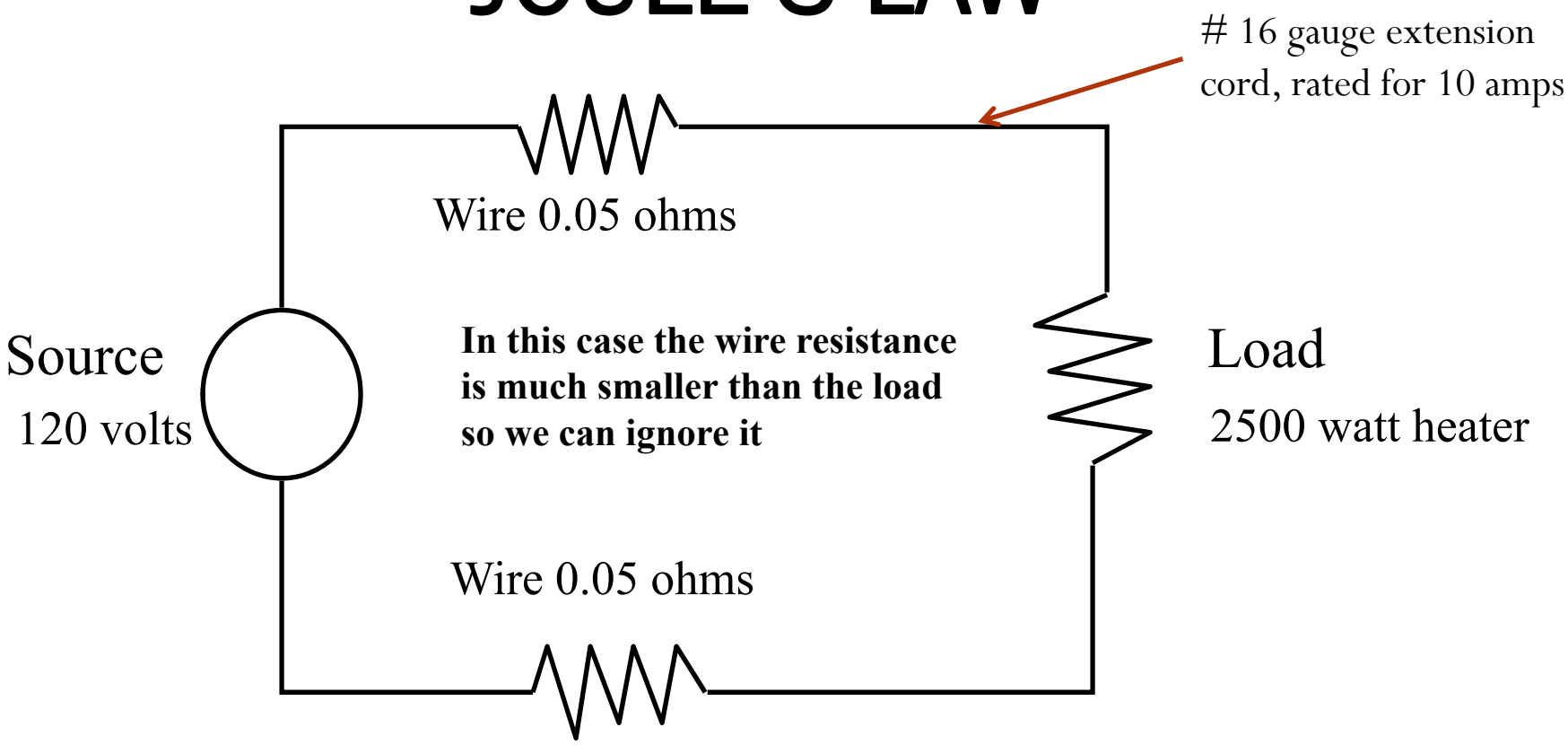


For this simple circuit, calculate the current I

Using Ohm's Law I=E/R

$120V/12\Omega = 10A$

JOULE'S LAW

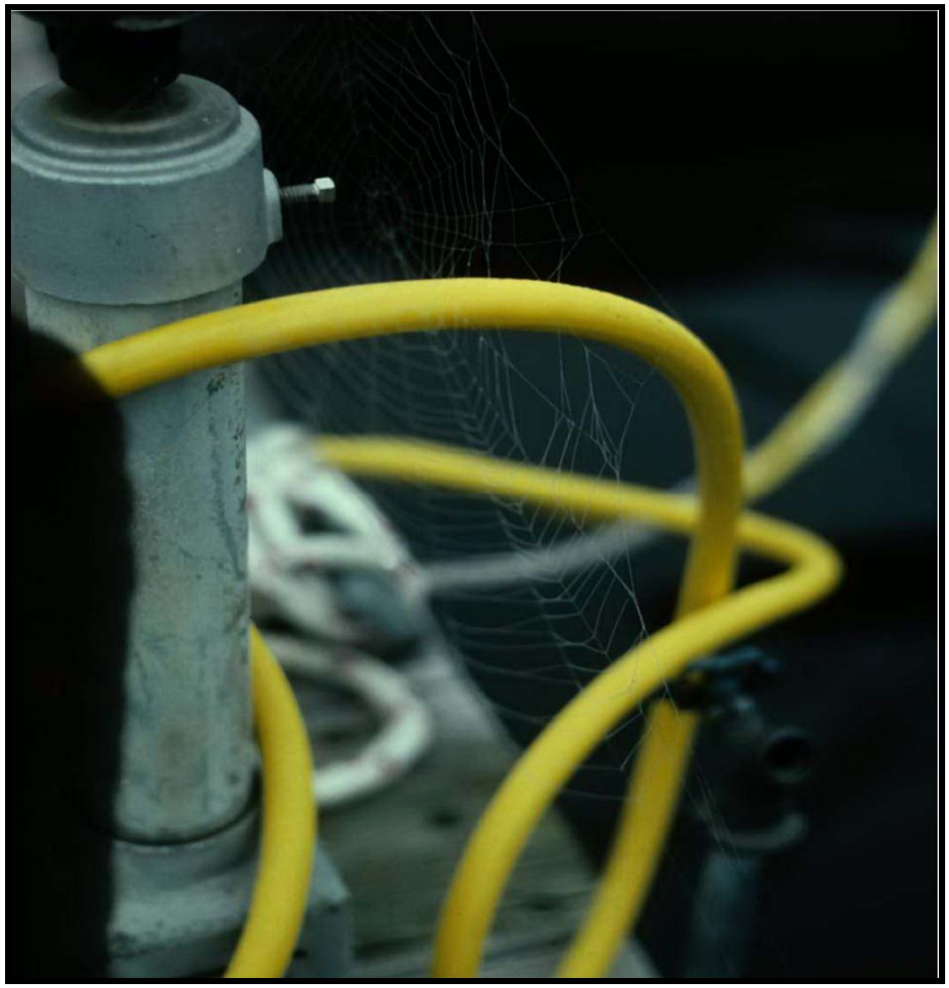


For this simple circuit, calculate the current ***I***

Using Joule's Law ***I***=P/E

2500 W/120 V = **20.8 amps**

CONDUCTORS



- Materials that allow current to flow freely with minimal resistance.
- Copper and aluminum are two of the most recognized
- Both used in electrical systems.
- Gold and silver are also used, but usually at points of contact.

INSULATORS

- They work the opposite of conductors, they oppose or stop the flow of current. Some insulators are glass, porcelain, air, and pure water.
- HOWEVER, a high enough voltage may defeat an insulator.

INSULATORS

- Air: look at the distance lightning travels to reach the earth.
- Dirty insulators on pole tops can create a path for current flow.

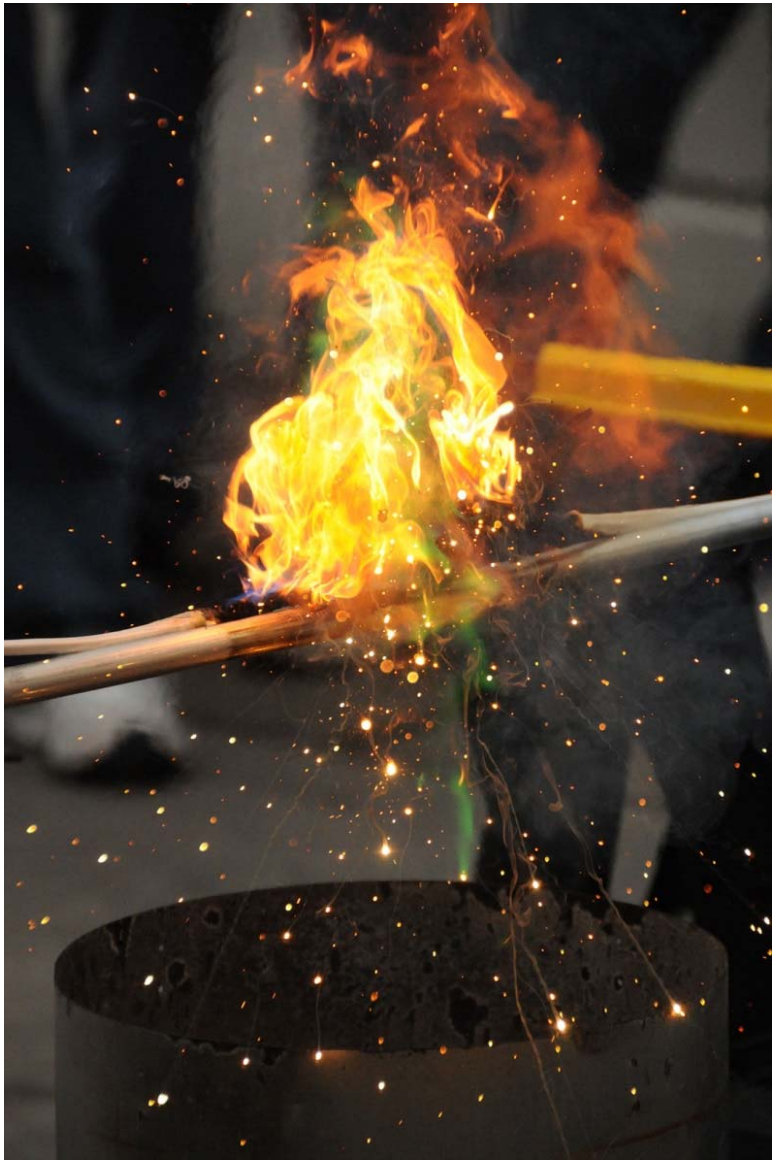
ARCS & SPARKS

- An **arc** is the flow of current through air, temperatures of 5000°-7000°F. Static electricity and lightning are natural arcs.
- It takes at least 350 volts to bridge a small (0.01mm /width of human hair) air gap.
- 4500 volts to bridge 1mm gap.

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.

SPARKS



- Sparks are much different, a **spark** is an incandescent particle, not an electrical discharge.
- Much better ignition source than an arc

ELECTRICAL THEORY

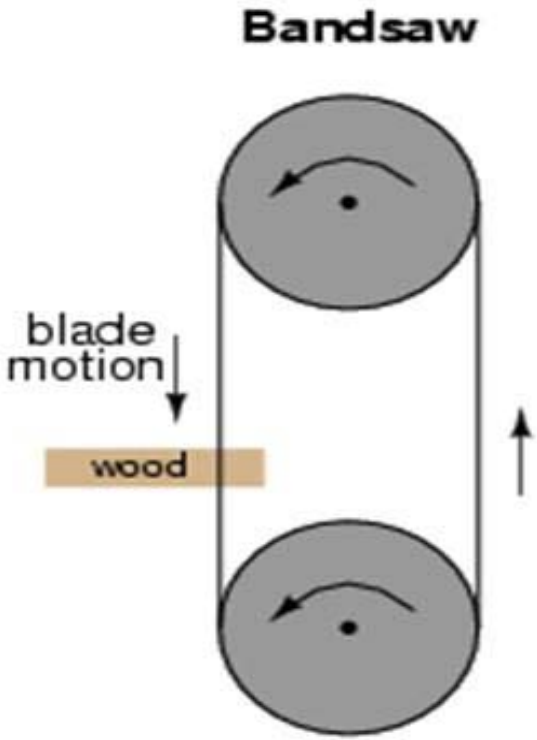
- Two types of electrical current:
  - Direct Current (DC)
  - Alternating Current (AC)

DIRECT CURRENT

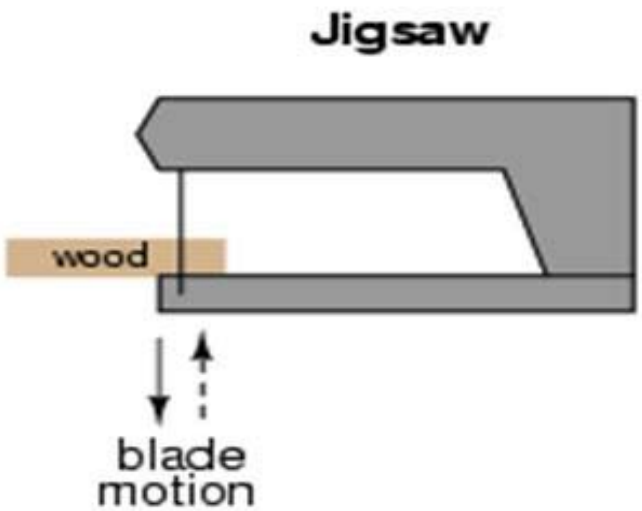
- Mechanically or chemically generated
- Chemical = batteries or photovoltaic.
- Mechanical = generator.
- Electrons flow in one direction only; from negative to positive
- Positive and negative terminals on equipment.

ELECTRICAL THEORY

DC vs. AC Current



(analogous to DC)



(analogous to AC)

DC CURRENT

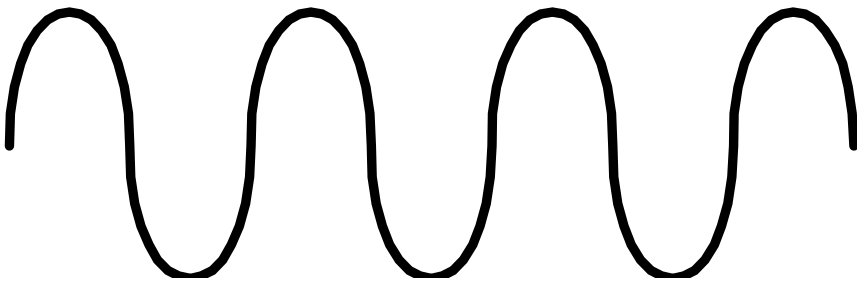
- Most recognized form is as a battery, found in power supplies, DC generators.
- In some industrial applications DC is used for numerous operations.

ELECTRICAL THEORY

ALTERNATING CURRENT

- Mechanically generated.
- Electrons reverse direction many times per second (frequency/Hertz/Hz).
- Ungrounded (hot) and grounded (neutral) terminals on equipment.
- Voltages can be changed with transformers.

AC CURRENT

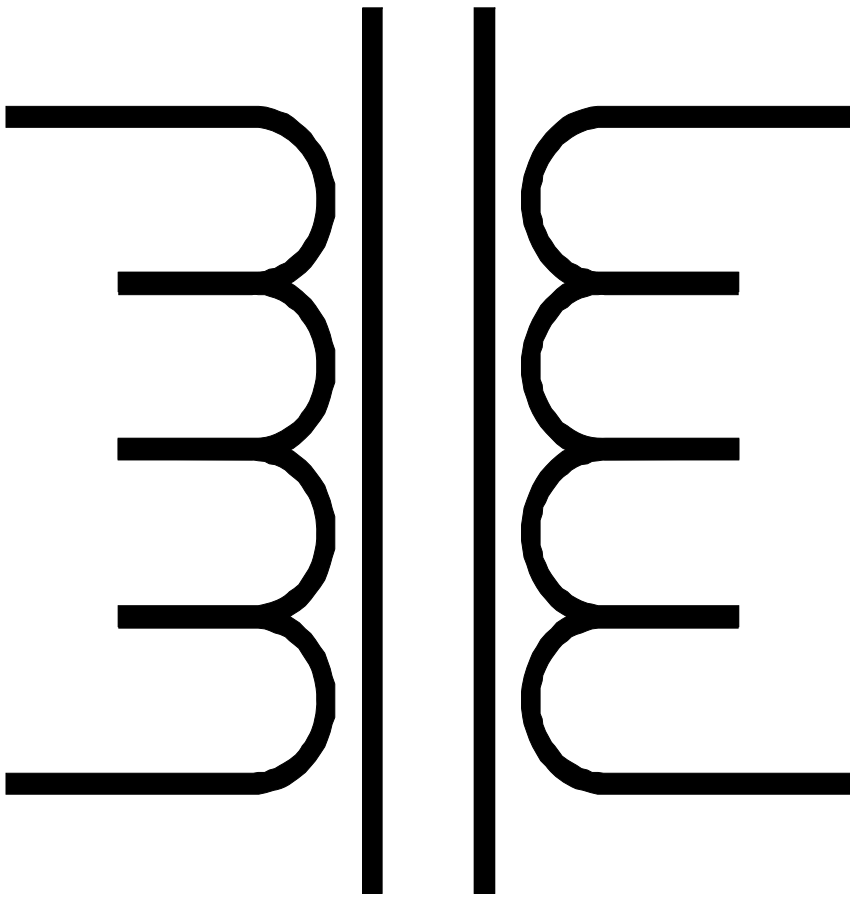


- Found predominantly in structures.
- Voltages of 120, 240, 208, 277 ,480 volts

FREQUENCY

- The number of times the direction of AC electricity reverses itself in the span of one second.
- FREQUENCY is measured in Hertz (Hz).
- In the US, the frequency is 60 Hz.
- Foreign countries use 50 Hz systems.

TRANSFORMERS



- Used to step AC voltage up or down. DC can be increased or decreased but not with a transformer.
- AC can be rectified to act like DC and supply one way current.
- DC can not be transformed.

WATER ANALOGY

Pump = Source Generator

Pressure = Voltage (EMF)

PSI = Volts

Pressure gauge = Voltmeter

Booster pump = Transformer

Water or Fluid = Electrons

Flow = Current

WATER ANALOGY

GPM = Amperes

Flow Meter = Ammeter

Empty space within pipe = Conductor

Valve = Switch

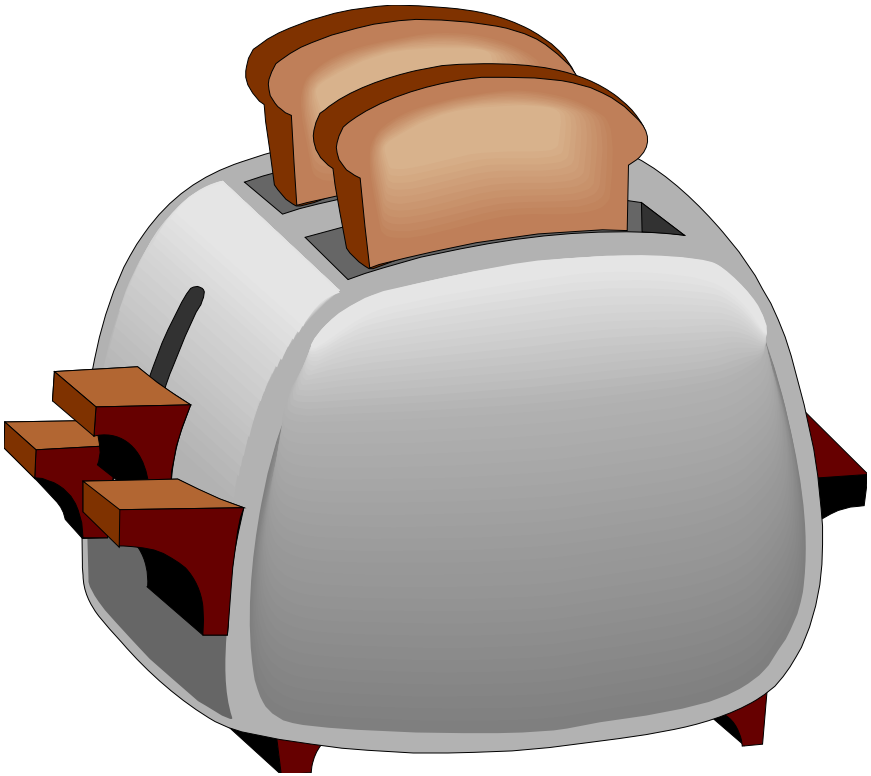
Friction loss = Resistance

Pipe size = Wire Size

SOME EFFECTS OF ELECTRICITY

- Thermal Action
- Magnetism
- Chemical Reaction
- Illumination

THERMAL ACTION



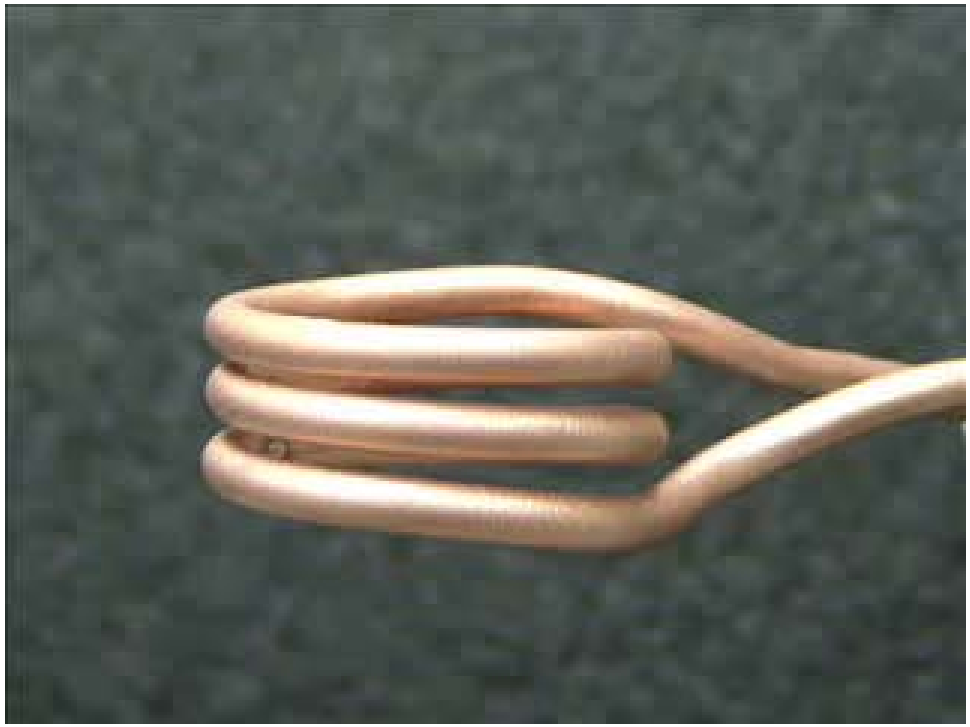
- Heat caused by flowing current through a conductor.
- Stoves, toaster, Baseboard Heat, etc.

MAGNETISM

- Current flow produces a magnetic field.
- Large enough field will produce heat
- Electric Motors

MAGNETISM

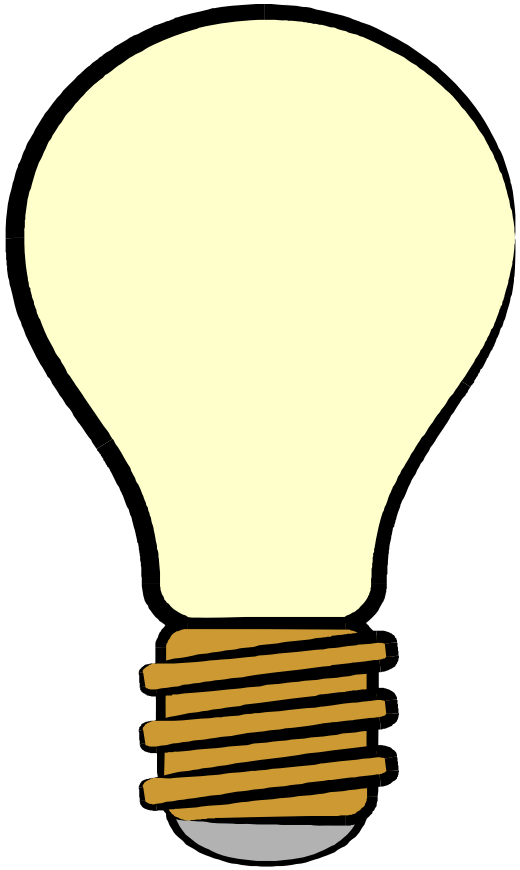
- Magnetism can create electron flow, and also create heat.



CHEMICAL REACTION

- Oxidation can occur at loose or improperly made connections.
- Oxidation will increase resistance, in turn produces higher currents
- Higher currents = higher heat
- Higher heat = more oxidation

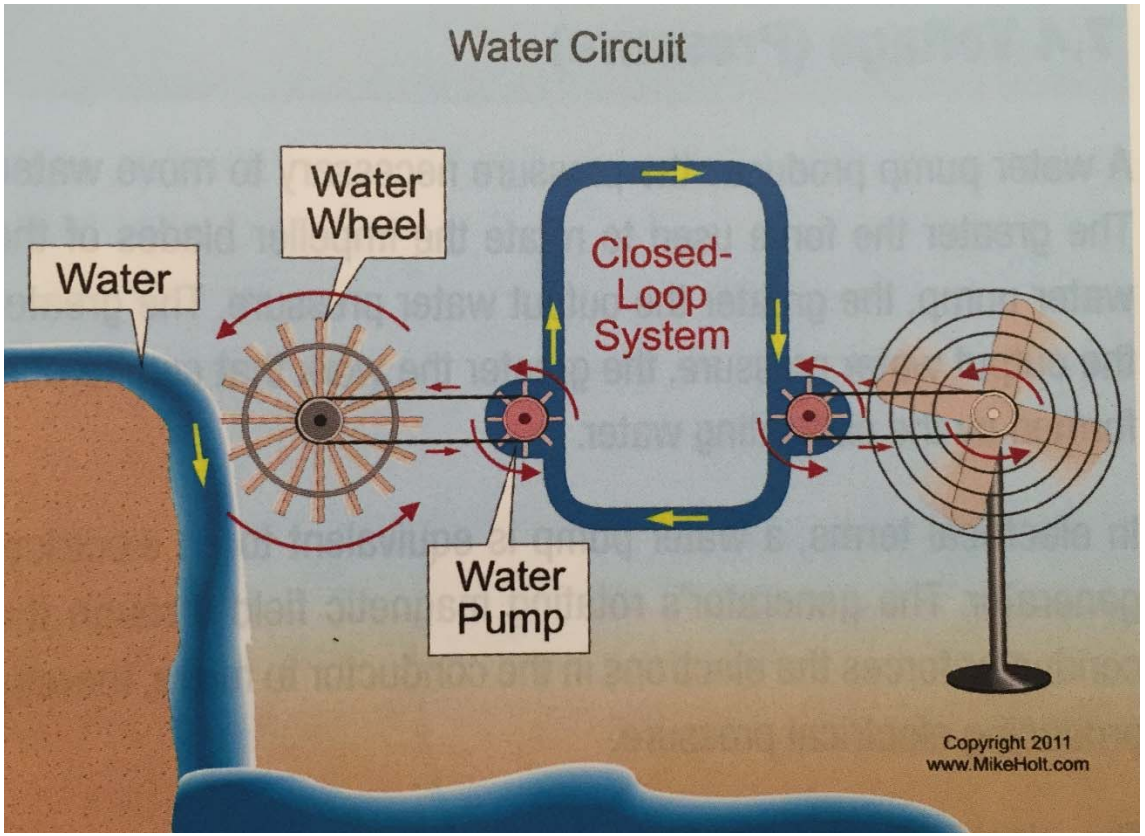
ILLUMINATION



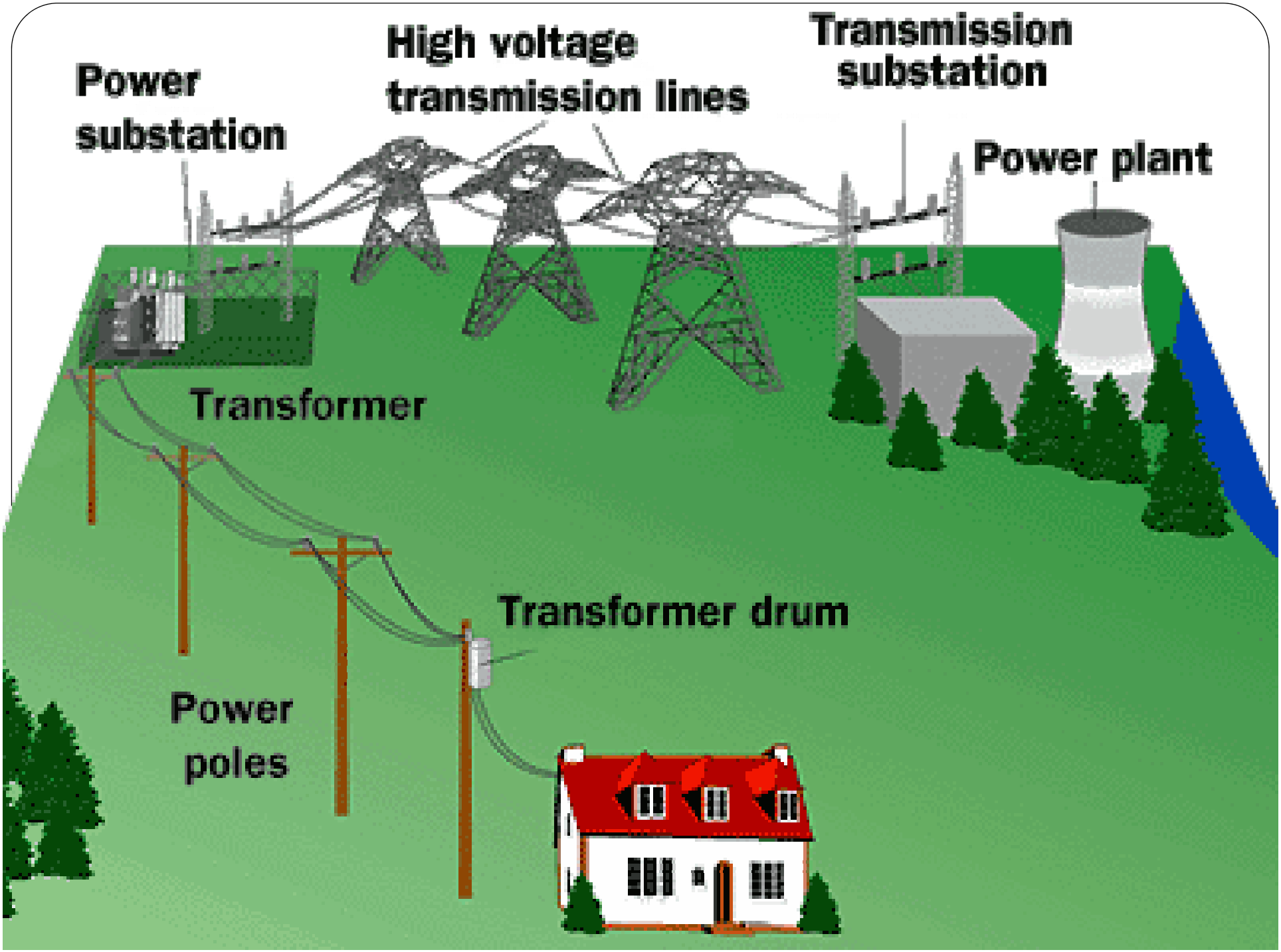
- It's the light that can be seen from a glowing conductor.

GENERATION TO DISTRIBUTION

AC POWER DISTRIBUTION

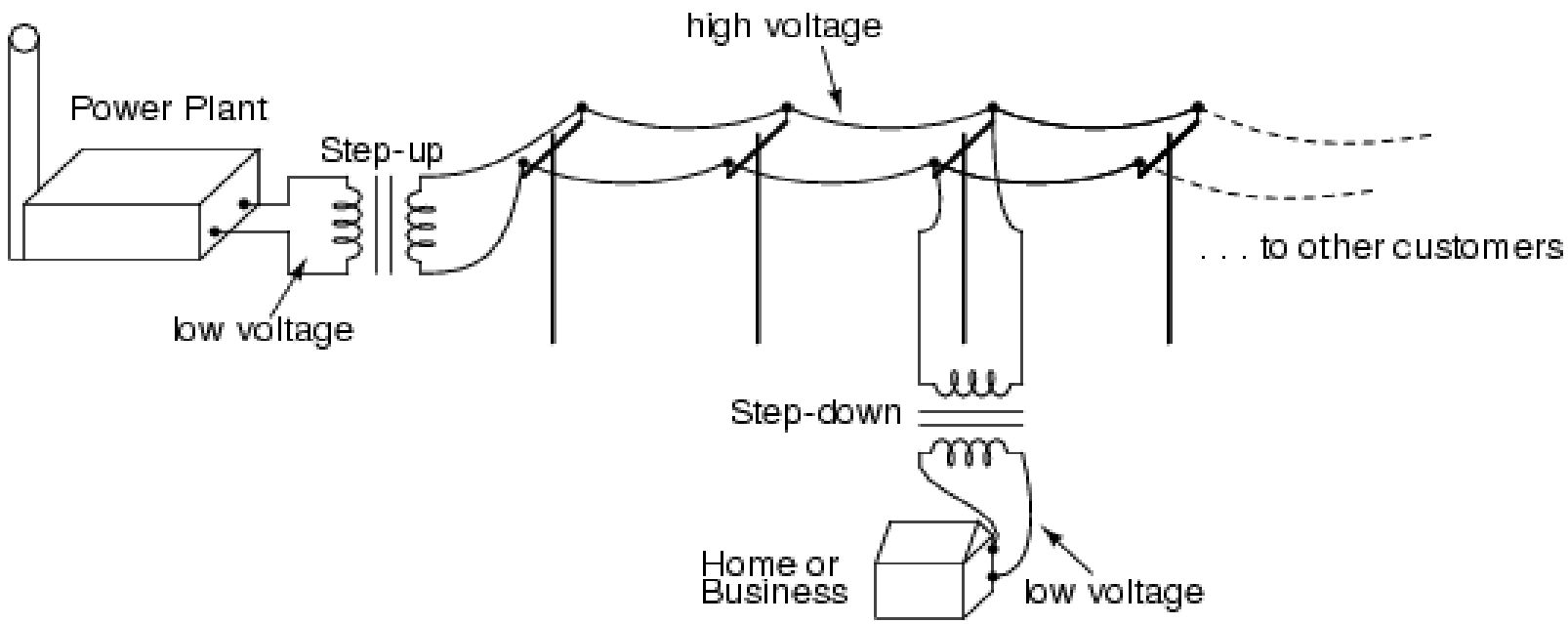


Electricity is created and used in a “closed loop” system – it returns back to the source from which it was generated – and will use every path possible to do that.


Power substation
High voltage transmission lines
Transmission substation
Power plant
Transformer
Transformer drum
Power poles

AC POWER DISTRIBUTION

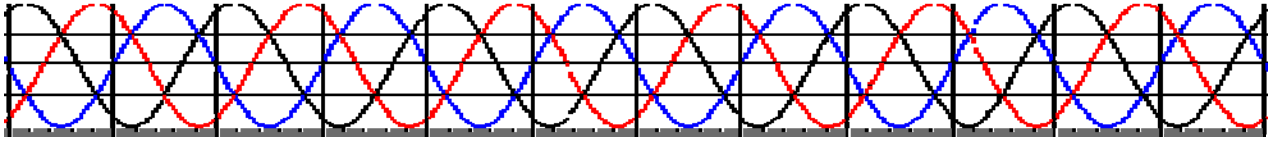
Typical Distribution Model for Alternating Current Systems



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



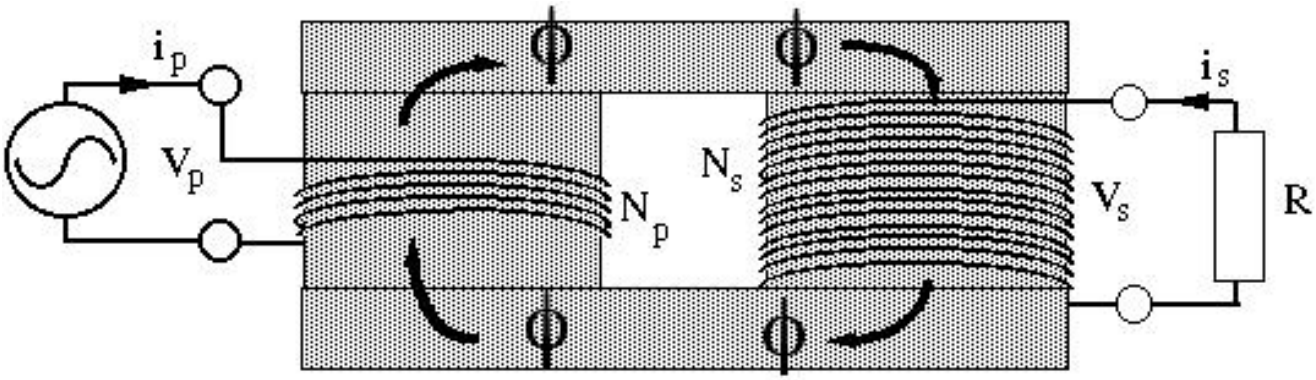
Notice the towers have three wires. This is a three phase, A/C system. Each wire carries a sinusoidal voltage wave 120°out of phase from the others. The color graph above shows three sinusoidal waveforms over time.

TRANSMISSION LINES

SUBSTATIONS

TRANSFORMERS

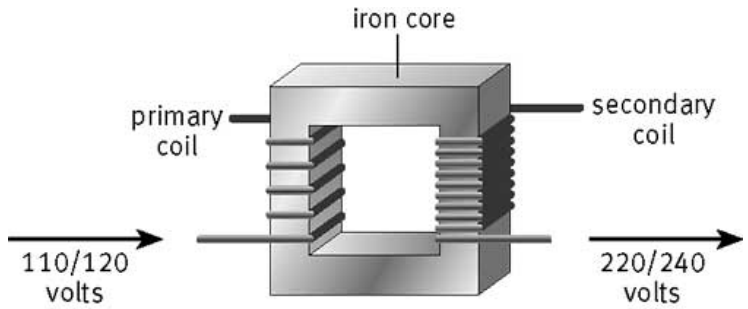
- Used to increase or decrease voltage.
- Consists of two isolated coils of wire around an iron core.
- **Primary coil** is the input voltage coil.
- **Secondary coil** is the output voltage coil.



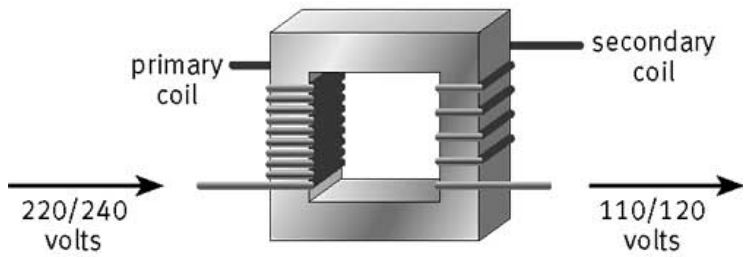
TRANSFORMERS

- Ratio of coil turns determines voltage change

1:2 Ratio



2:1 Ratio



Typical three
phase assembly

THREE PHASE POWER

- Used in larger occupancies where lighting and motor 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:

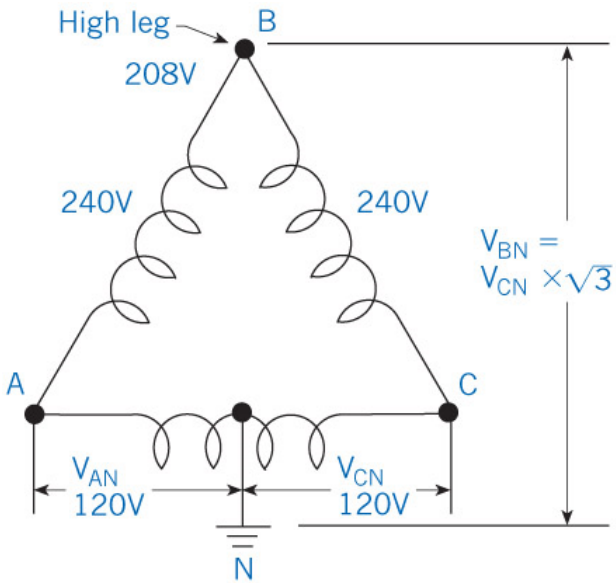
120/240 with a 208 "High Leg"- Orange in Color / B Phase

120/208

277/480

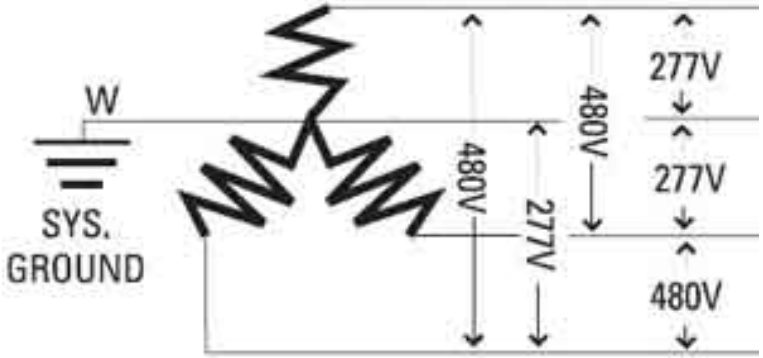
ELECTRICITY DISTRIBUTION

- Three phase 120/240 volt system with a 208 volts to ground “high leg.”
- Two transformers are indicative of this "delta" transformer configuration.



ELECTRICITY DISTRIBUTION

- Three phase 120/208 or 277/480 volt service.
- Three transformers are indicative of this "wye" transformer configuration.



THREE PHASE SERVICE

Parallel Service Drop

Note: Two conductors per phase

ELECTRICITY DISTRIBUTION

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

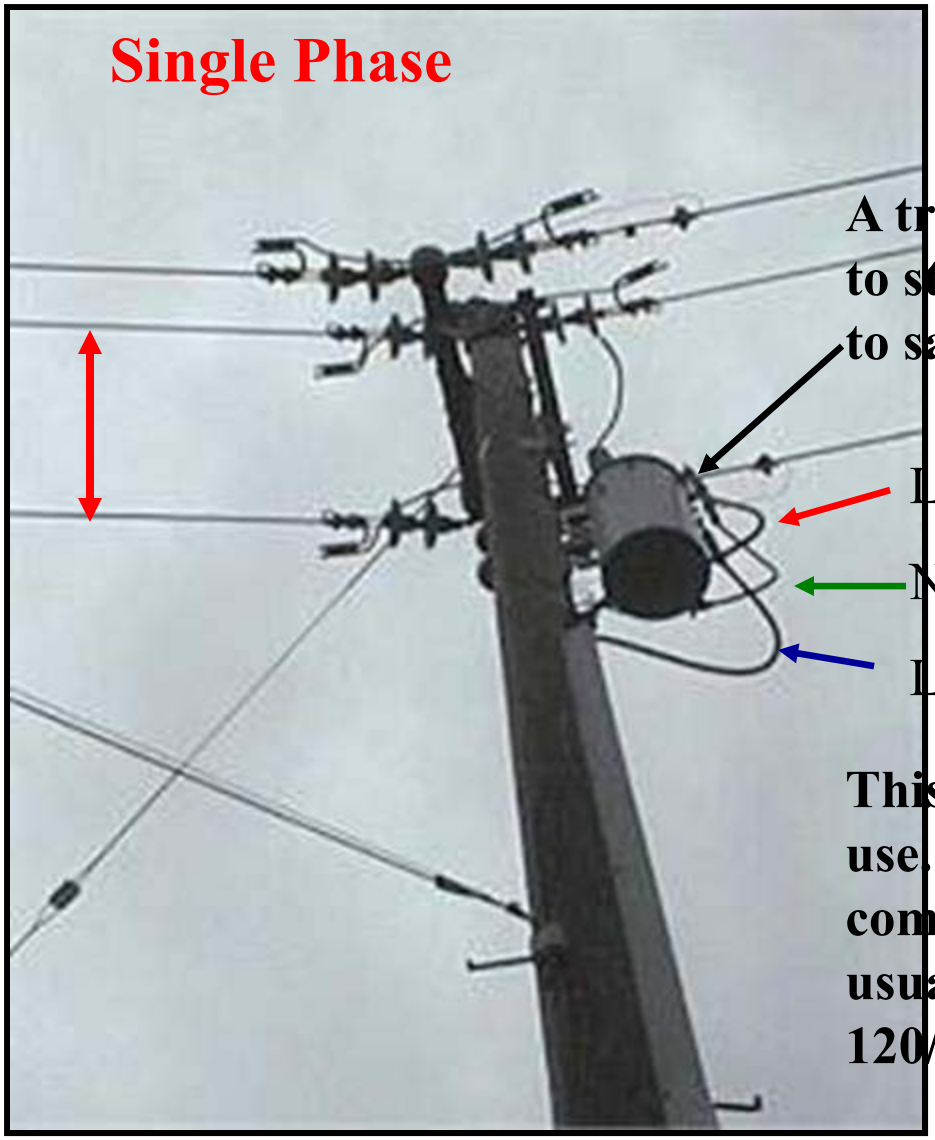
ELECTRICITY DISTRIBUTION

"Step Down" or "Step Up" Transformers

- Can be located almost anywhere
- Transform voltages for use by building electrical components

DISTRIBUTION LINES

Distribution voltages are usually 7200V or 4800V

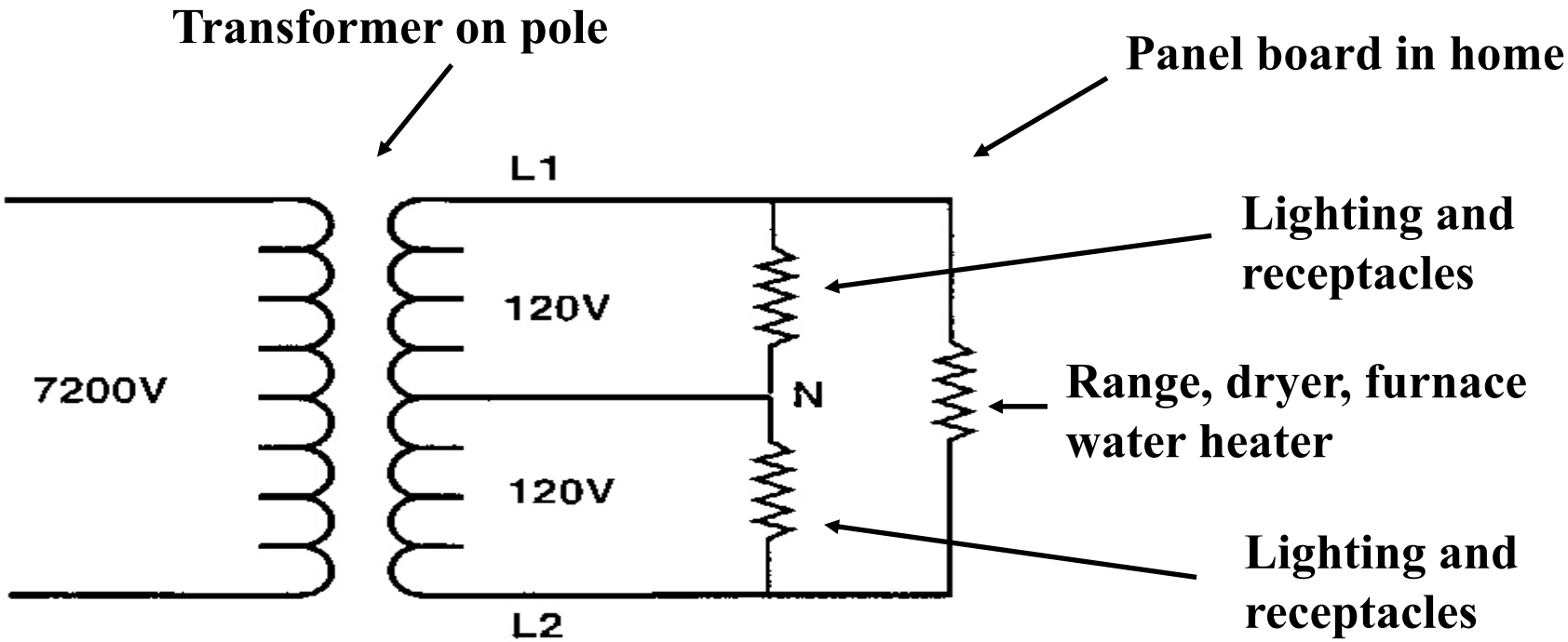


A transformer is provided to step the voltage down to safer voltages

This is for household use. Industrial and commercial use is usually three phase 120/208V or 277/480V

THREE-WIRE EDISON SYSTEM

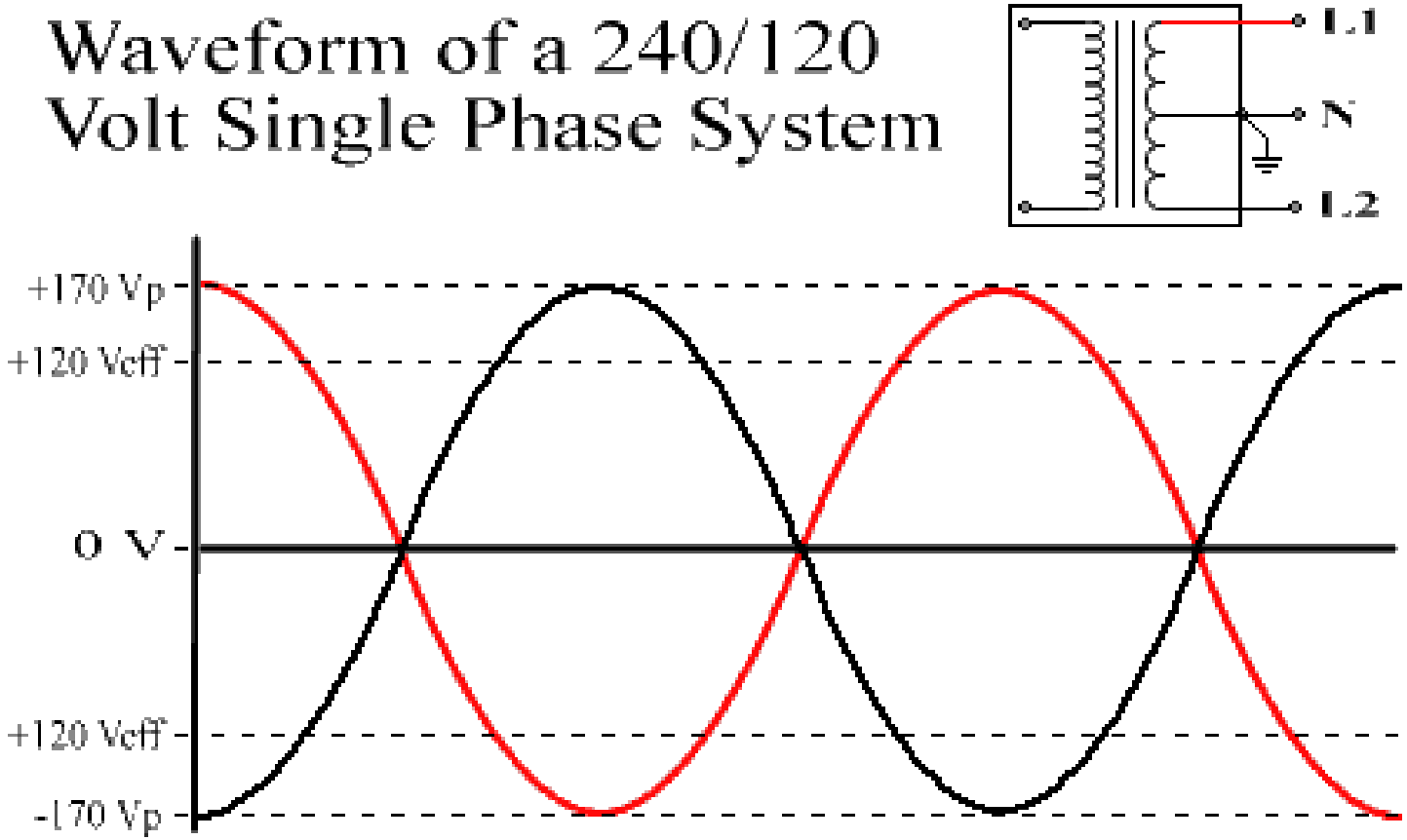
Single Phase



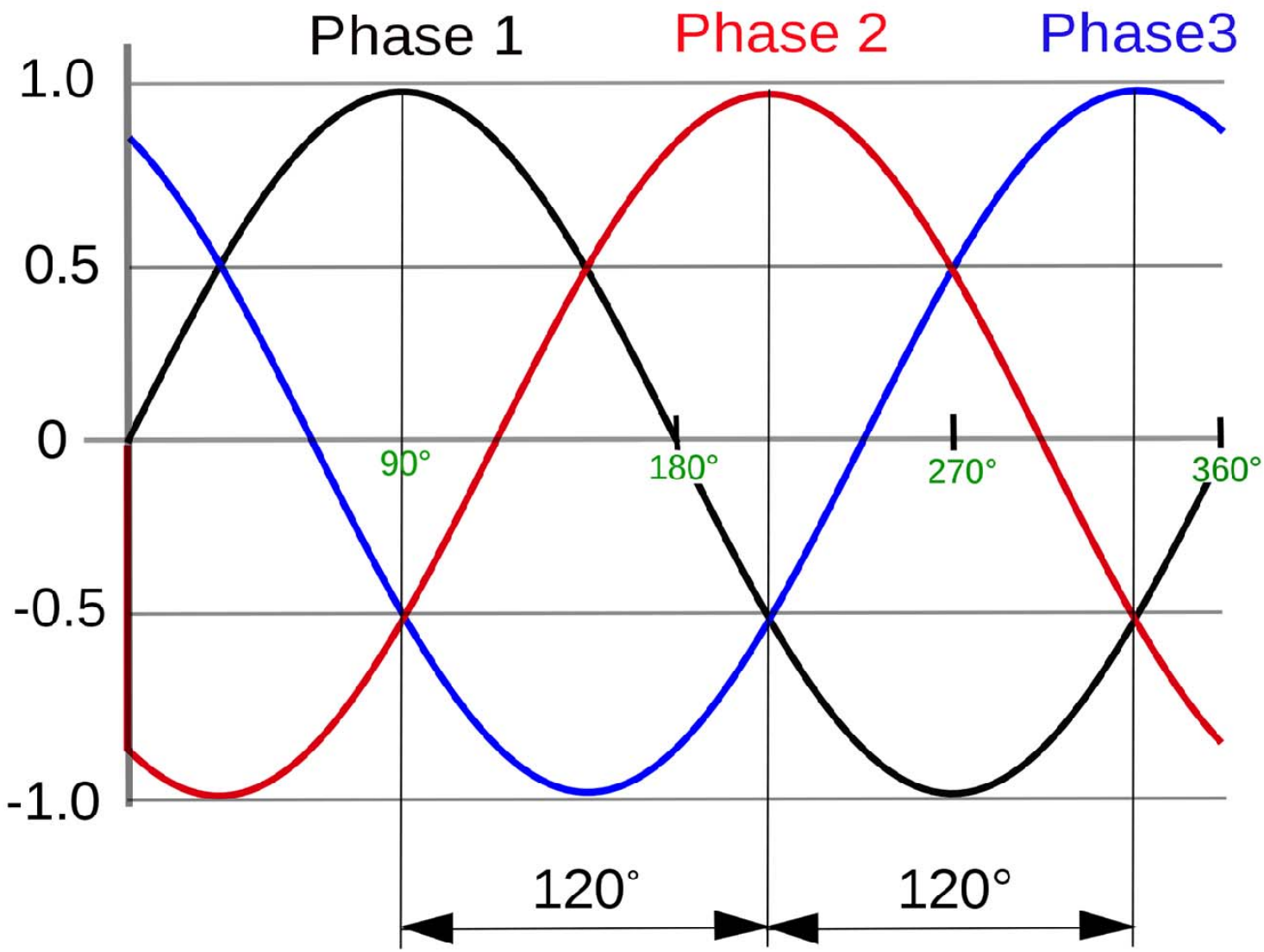
Lighting and receptacles are on 120 volt circuits. Because of the greater current requirements, dryers and furnaces are on 240 volt circuits.

Notice: No ground (earth) connection is shown. Ground is not required for operation. Ground is for lightning and fault protection. The neutral wire maintains 120 volts between the two 120 volt legs.

RESIDENTIAL vs. 3-PHASE DIFFERENCES



THREE PHASE

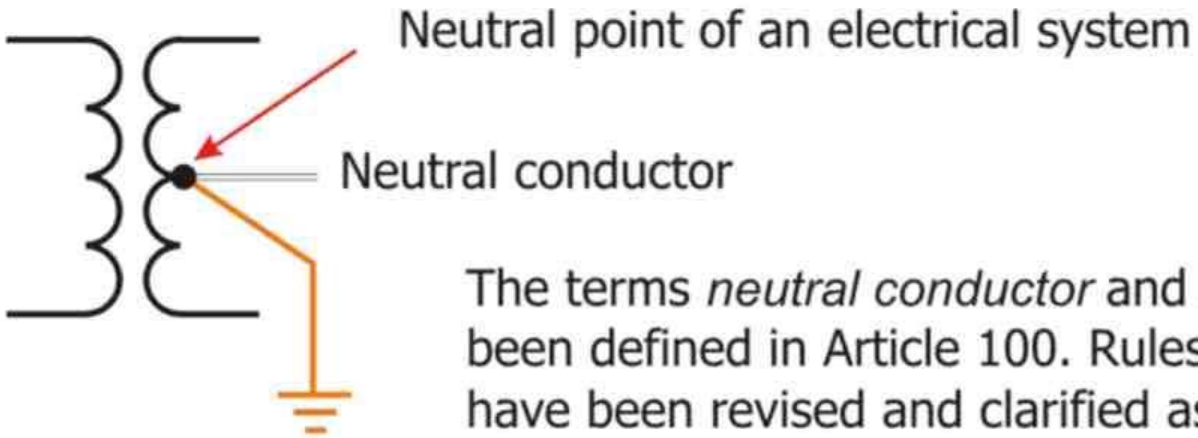


NEUTRAL CONDUCTOR

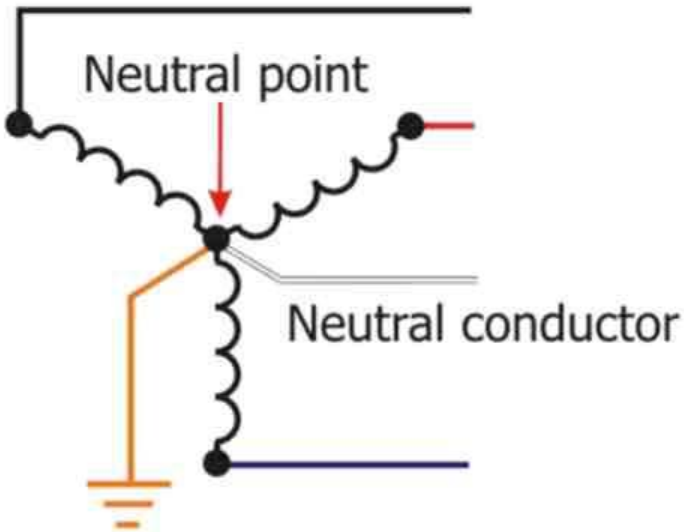
- The conductor connected to the neutral point of a system that is intended to carry current under normal conditions.

- It is important to remember that the neutral conductor is a current-carrying conductor. Many believe that because the neutral conductor is a grounded conductor, it is safe to work on it while it is energized. This is a very dangerous practice that has led to many serious electric shocks. When current is flowing through it, it can be just as dangerous as an ungrounded conductor.

Neutral Conductor and Neutral Point



The terms *neutral conductor* and *neutral point* have been defined in Article 100. Rules throughout the *NEC* have been revised and clarified as to when the word "neutral" refers to the neutral conductor of a system or circuit or when the term refers to the neutral point of system.



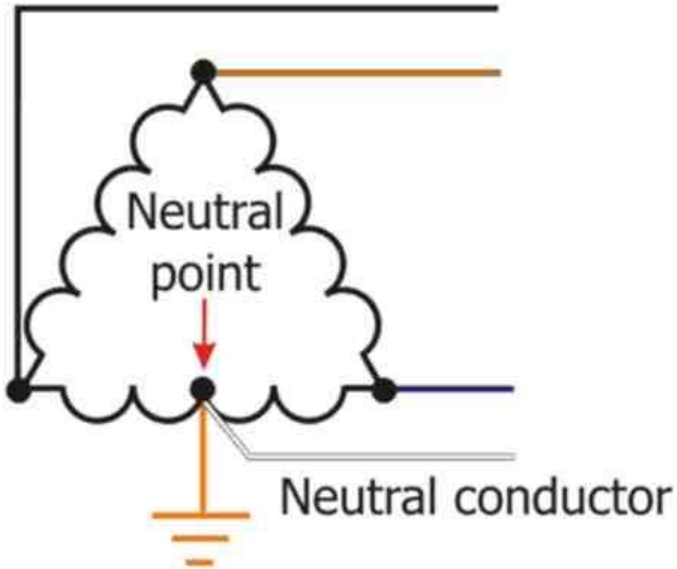


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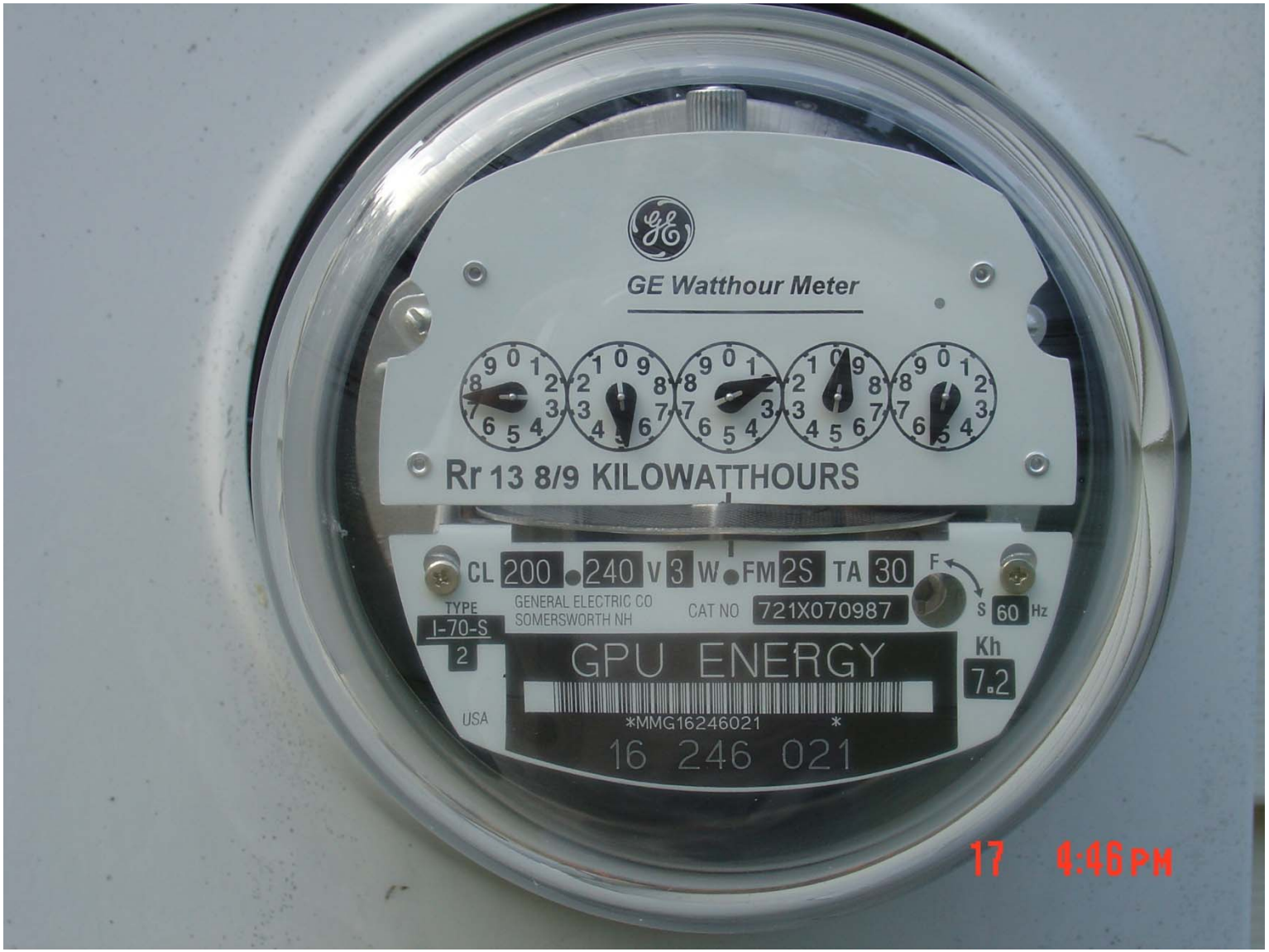
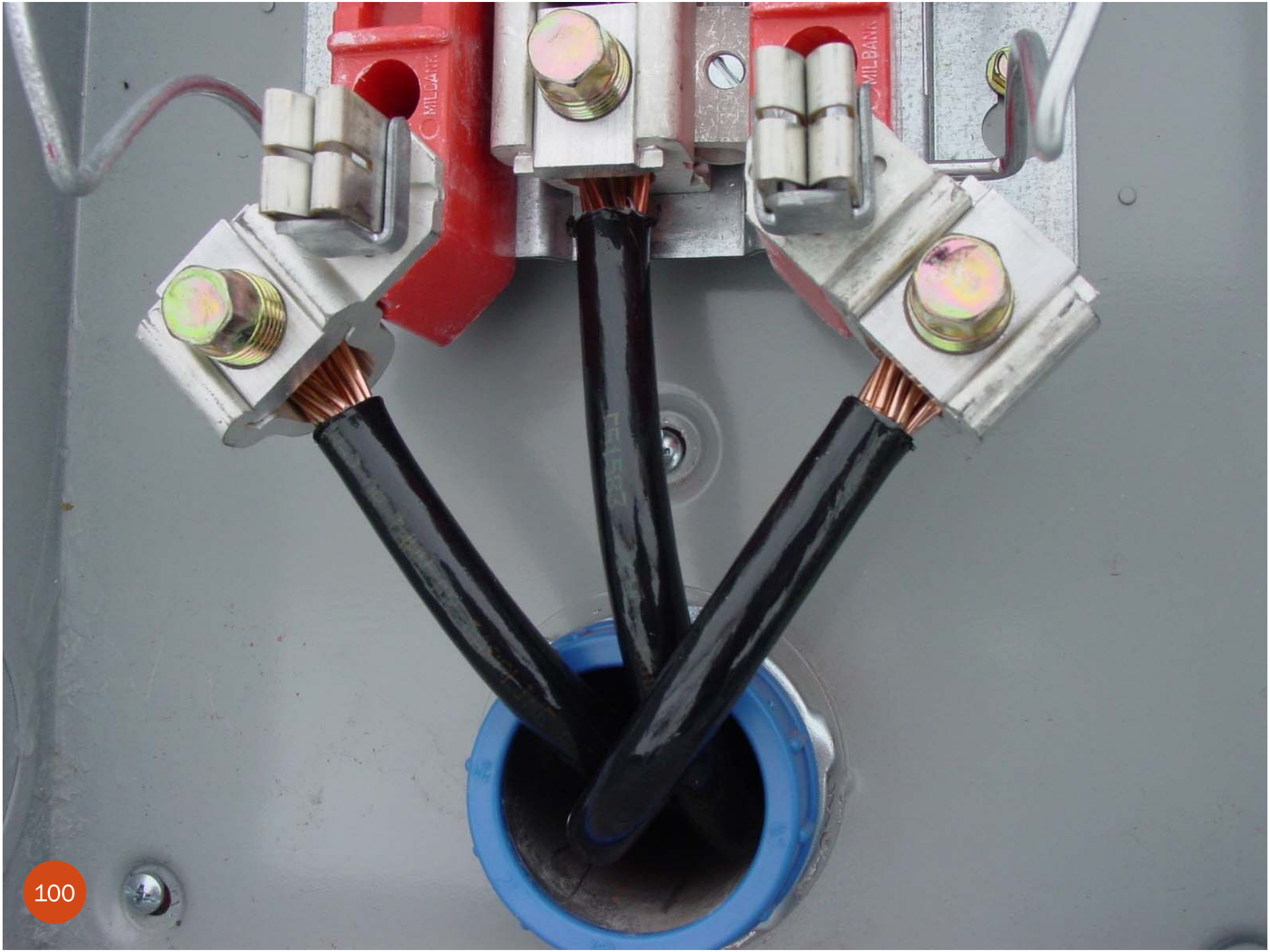
Photo: IAEI Archives

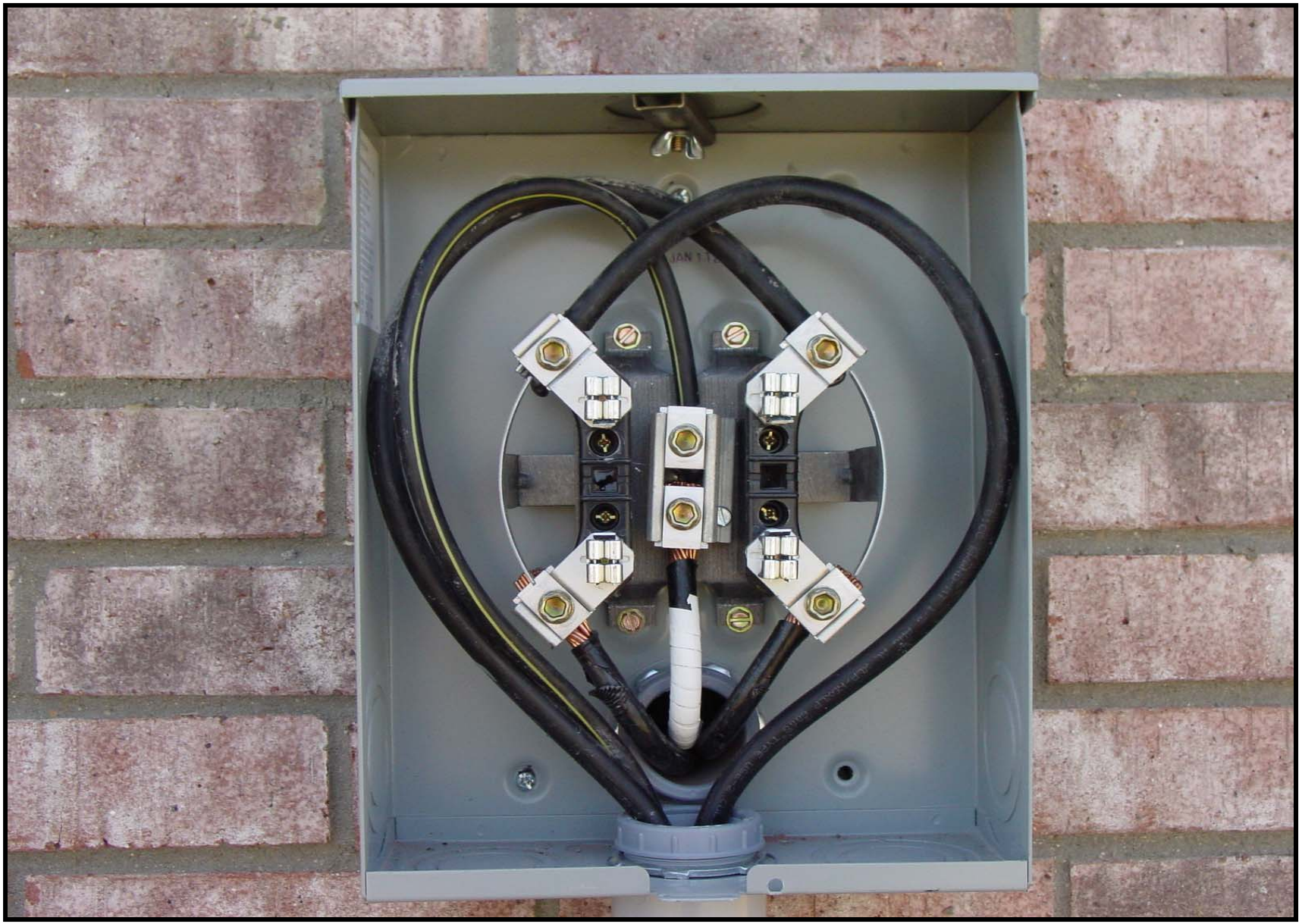
SECONDARY VOLTAGE

Photo: IAEI Archives

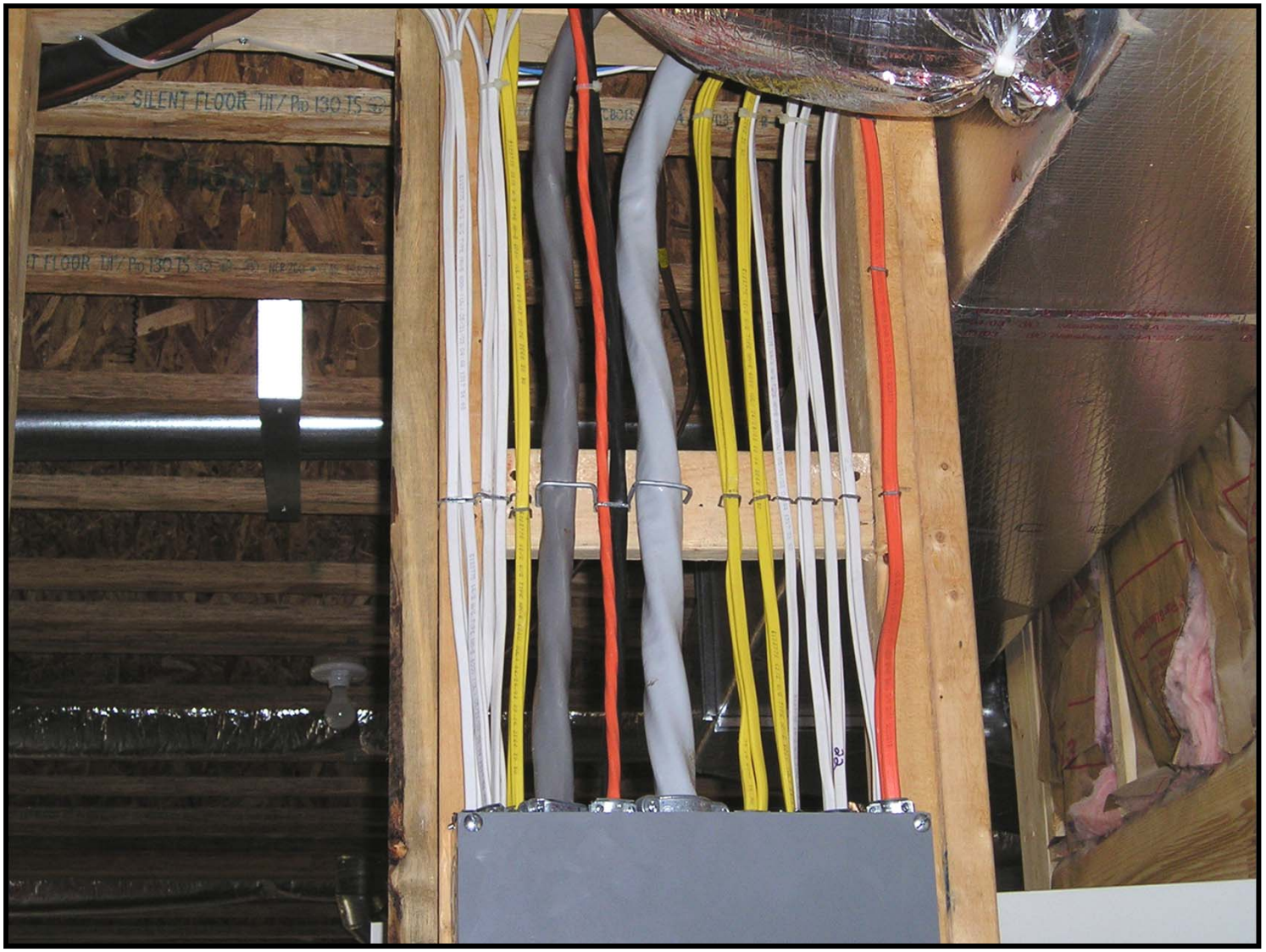

GE Watthour Meter
Rr 13 8/9 KILOWATTHOURS
CL 200 240 V 3 W FM 2S TA 30
F
S 60 Hz
TYPE
I-70-S
2
GENERAL ELECTRIC CO
SOMERSWORTH NH
CAT NO 721X070987
Kh
7.2
GPU ENERGY
*MMG16246021 *
16 246 021
USA
17 4:46 PM


MILBANK
MILBANK

METER BASE



SERVICES



Feeders and Feeder Overcurrent Protection

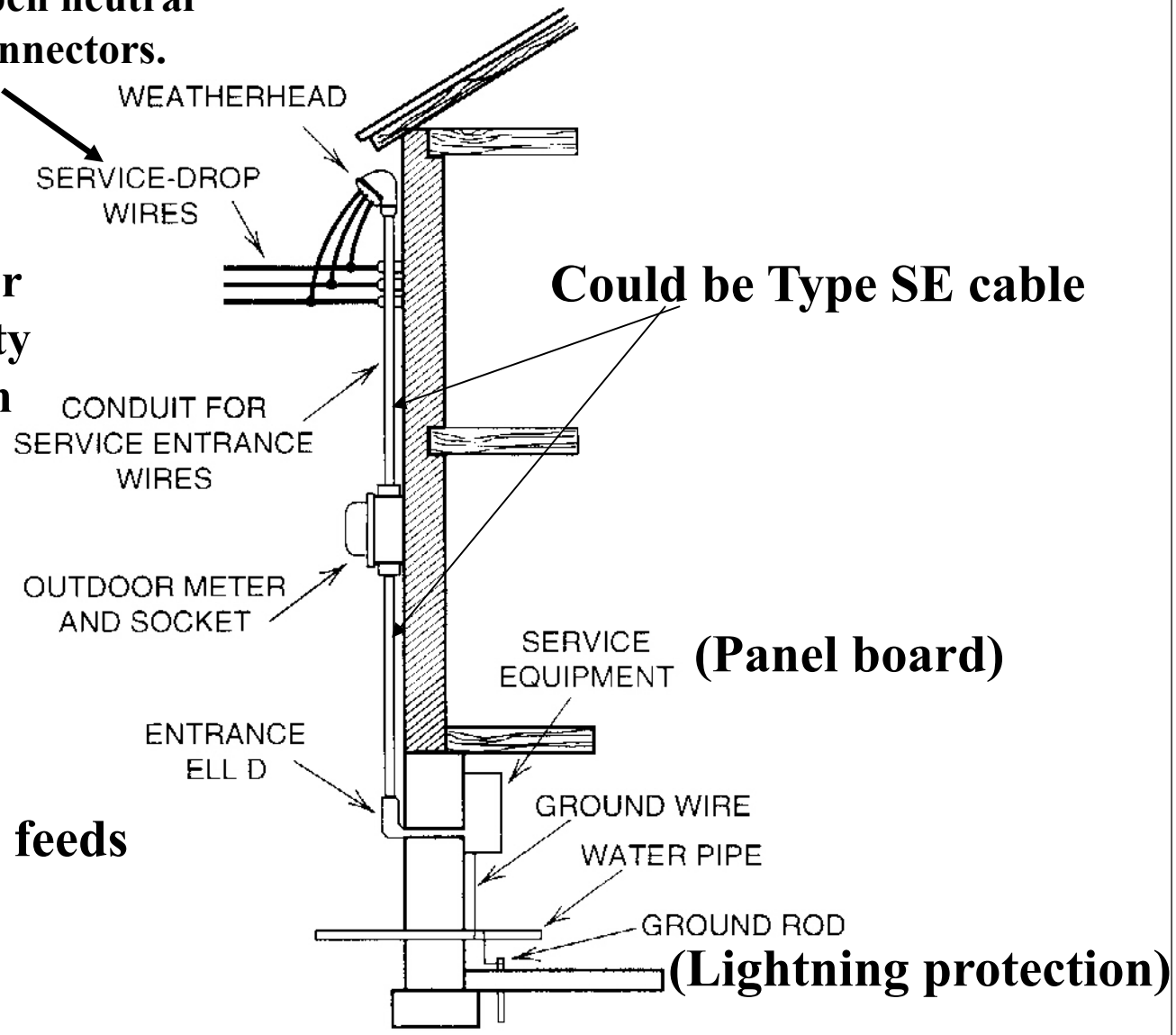
ELECTRICAL SERVICES

- Starts at utilities demarcation point
- Includes metering equipment
- Includes a main disconnect and overcurrent protection for the premises
- May include a load center with individual branch circuit protection
- Includes premises grounding systems
- Two classifications or types: overhead and underground

SERVICE EQUIPMENT TERMINOLOGY

Most likely place for an open neutral to occur from trees and connectors.

Note: No overcurrent protection is provided between the transformer and the home. The utility only provides protection on the primary side of the transformer. This protection is for the transformer only. Not the home.



Could be Type SE cable

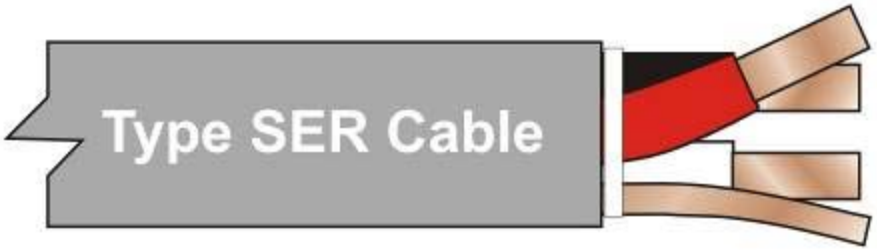
(Panel board)

(Lightning protection)

Underground utility feeds are called service laterals.

SERVICE-ENTRANCE CABLE

Type SEU cable (CU)



Type SER cable (CU)

Type SEU cable (AL)

Type SER cable (AL)

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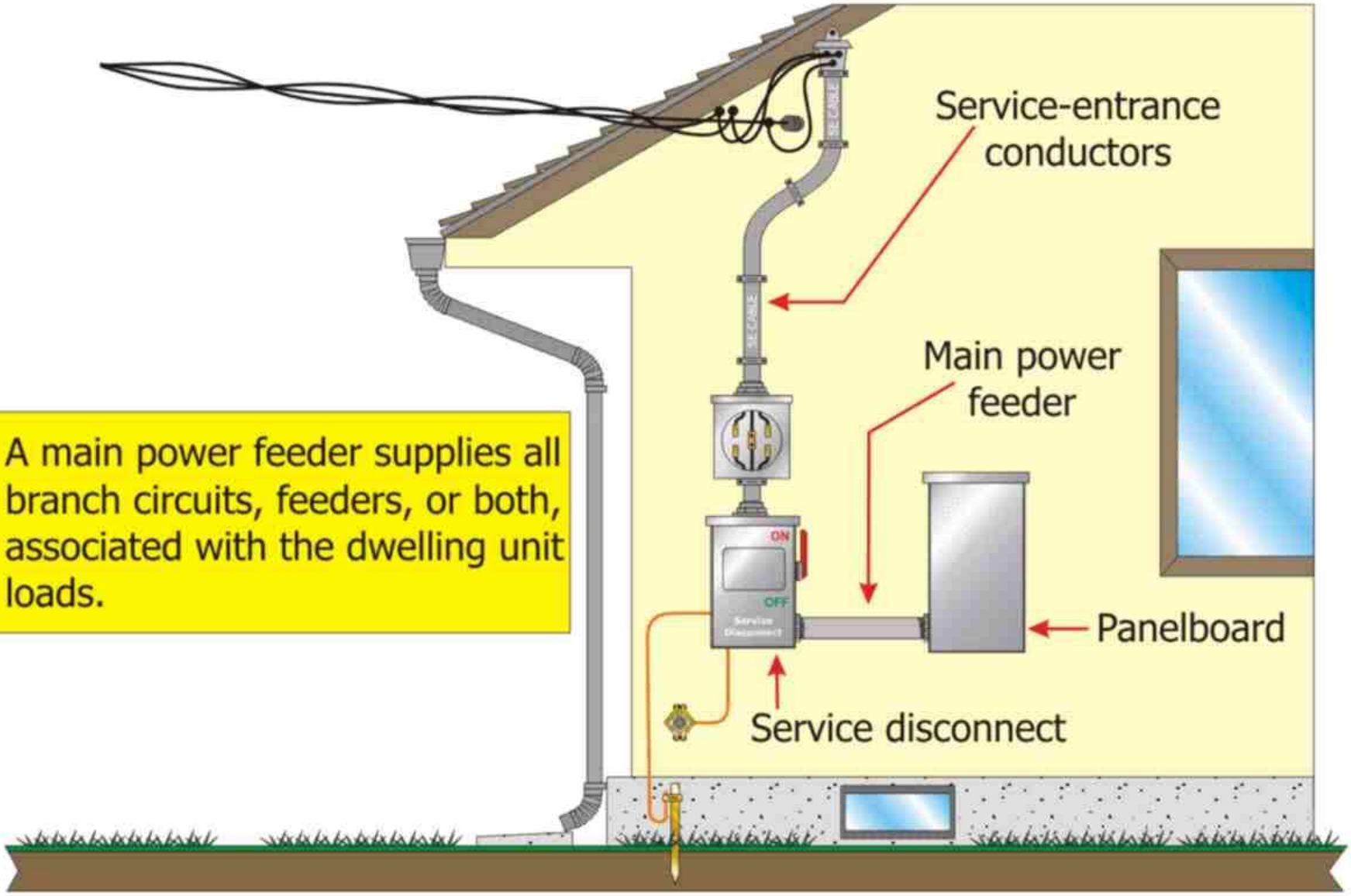
310.15(B)(6) 120/240-Volt, 3-Wire, Single-Phase Dwelling Services and Feeders



A main power feeder supplies all branch circuits, feeders, or both, associated with the dwelling unit loads.

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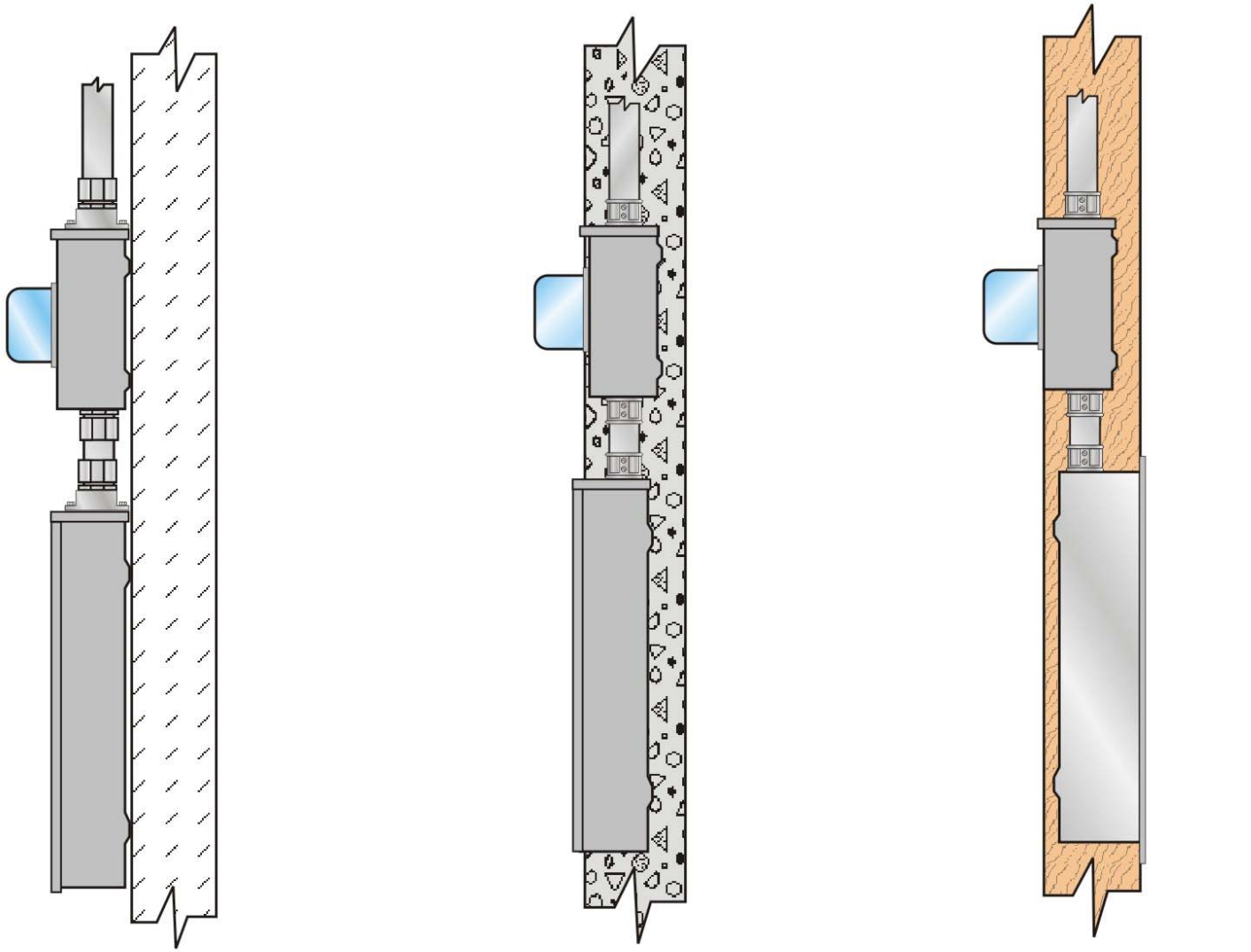
CABINET AND CUTOUT BOX INSTALLATION



Wet locations, 6 mm (¼ in.)

Noncombustible, recessed not more than 6 mm (¼ in.)

Combustible, flush or project

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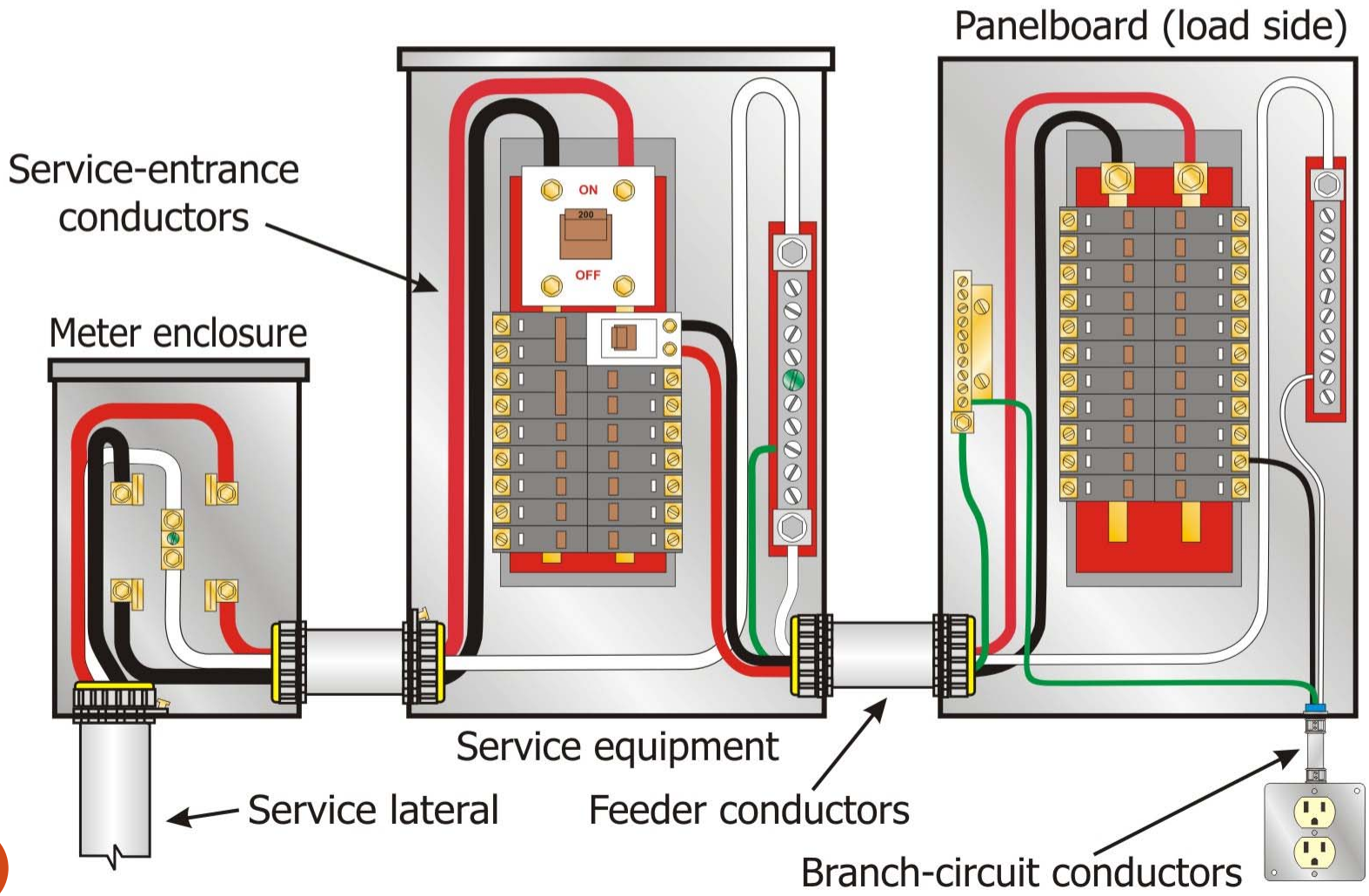
DEFINITION OF A FEEDER

Feeder is defined as "the conductors between the service equipment, the source of a separately derived system, or other power supply source and the final branch-circuit overcurrent device."



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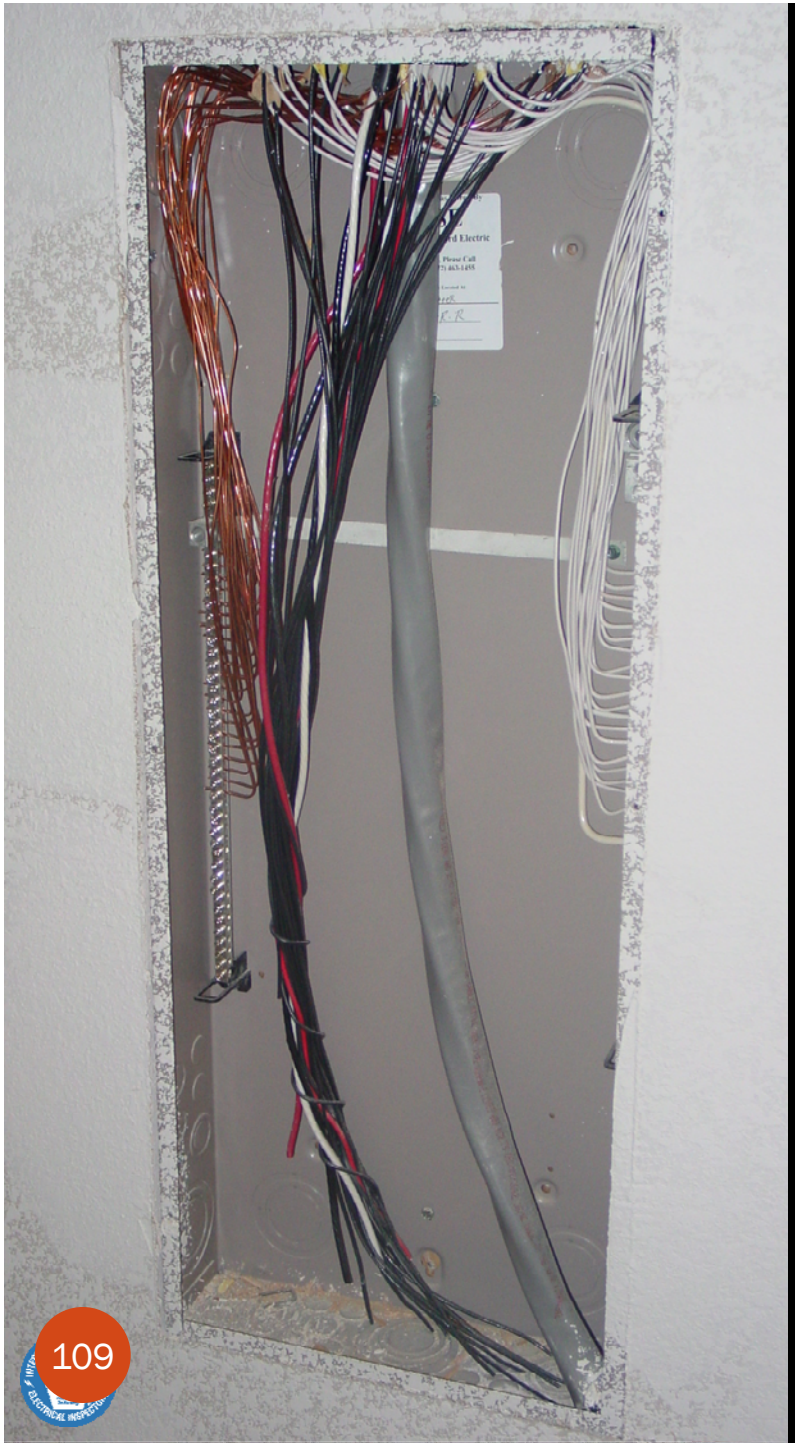
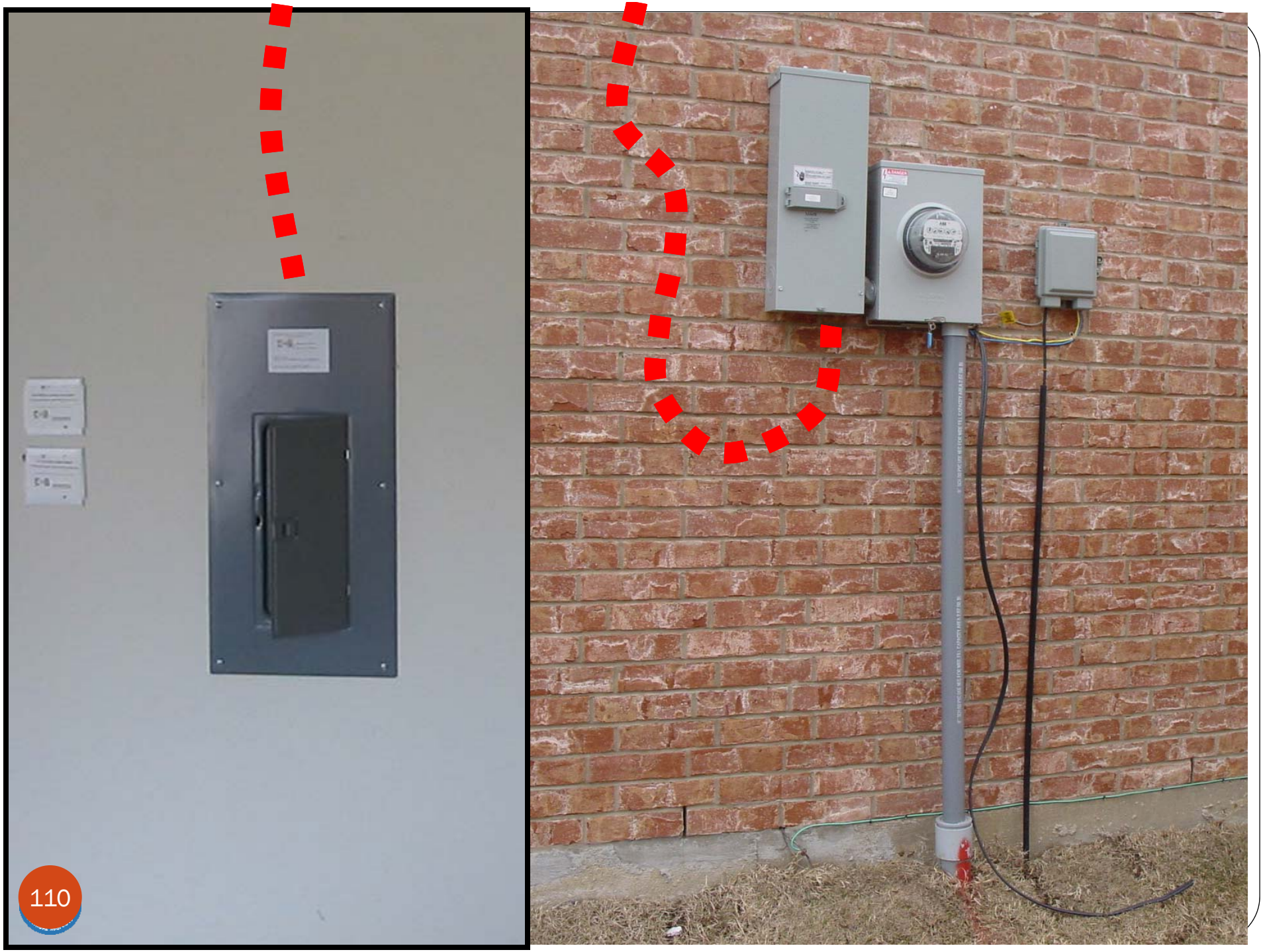
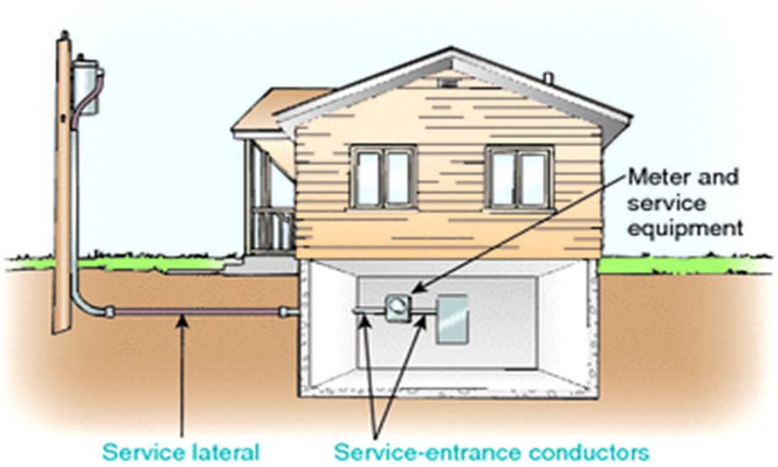




SERVICE-ENTRANCE CONDUCTORS, UNDERGROUND SYSTEM

- The service conductors between the terminals of the service equipment and the point of connection to the service lateral.



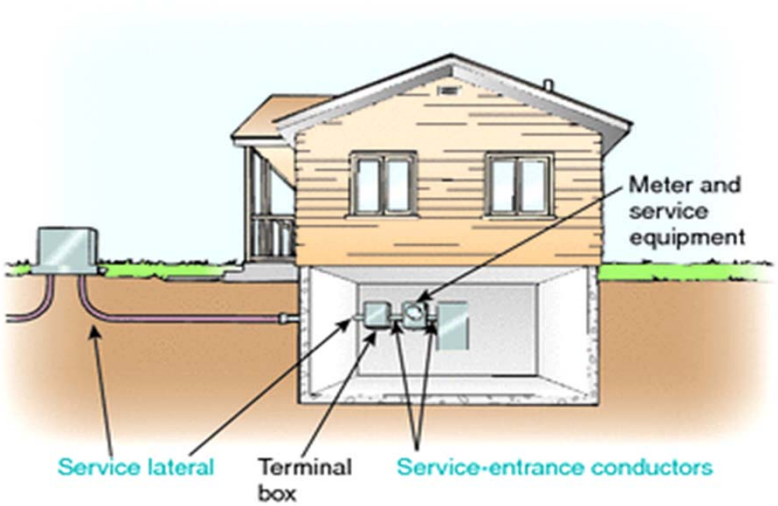


Photo: IAEI Archives
DANGER

TABLE 310.15(B)(6) PERMITTED TO BE USED

Table 310.15(B)(6) Conductors Types and Sizes for 120/240-Volt, 3-Wire, Single-Phase Dwelling Service and Feeders.

Conductor (AWG or kcmil)		
Copper	Aluminum or Copper-Clad Aluminum	Service or Feeder Rating (Amperes)
4	2	100
3	1	110
2	1/0	125
1	2/0	150
1/0	3/0	175
2/0	4/0	200
3/0	250	225
4/0	300	250
250	350	300
350	500	350
400	600	400

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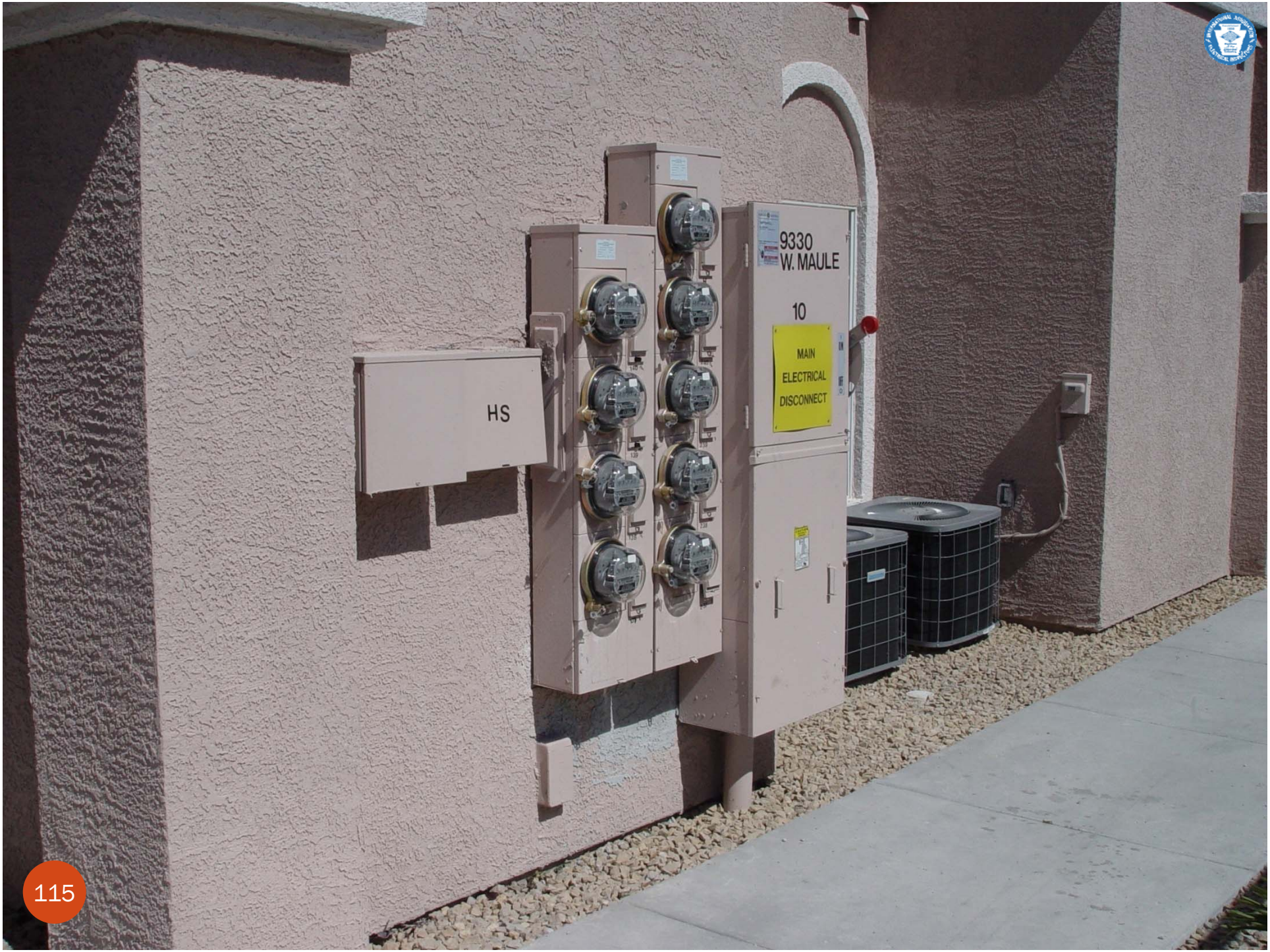
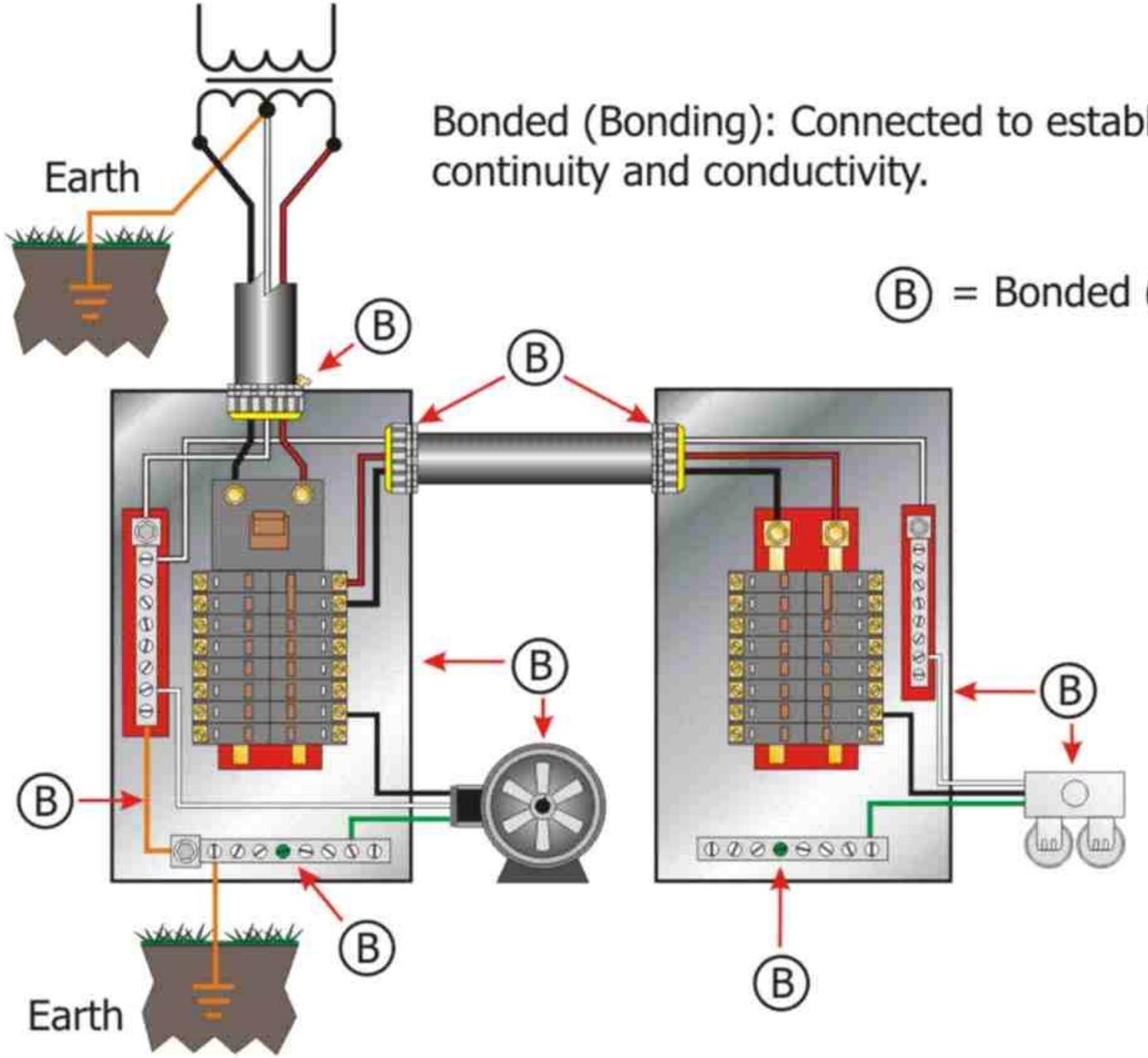

9330
W. MAULE
10
MAIN
ELECTRICAL
DISCONNECT
HS

Photo: IAEI Archives

Article 100 Bonded (Bonding)



Bonded (Bonding): Connected to establish electrical continuity and conductivity.

B = Bonded (Bonding)

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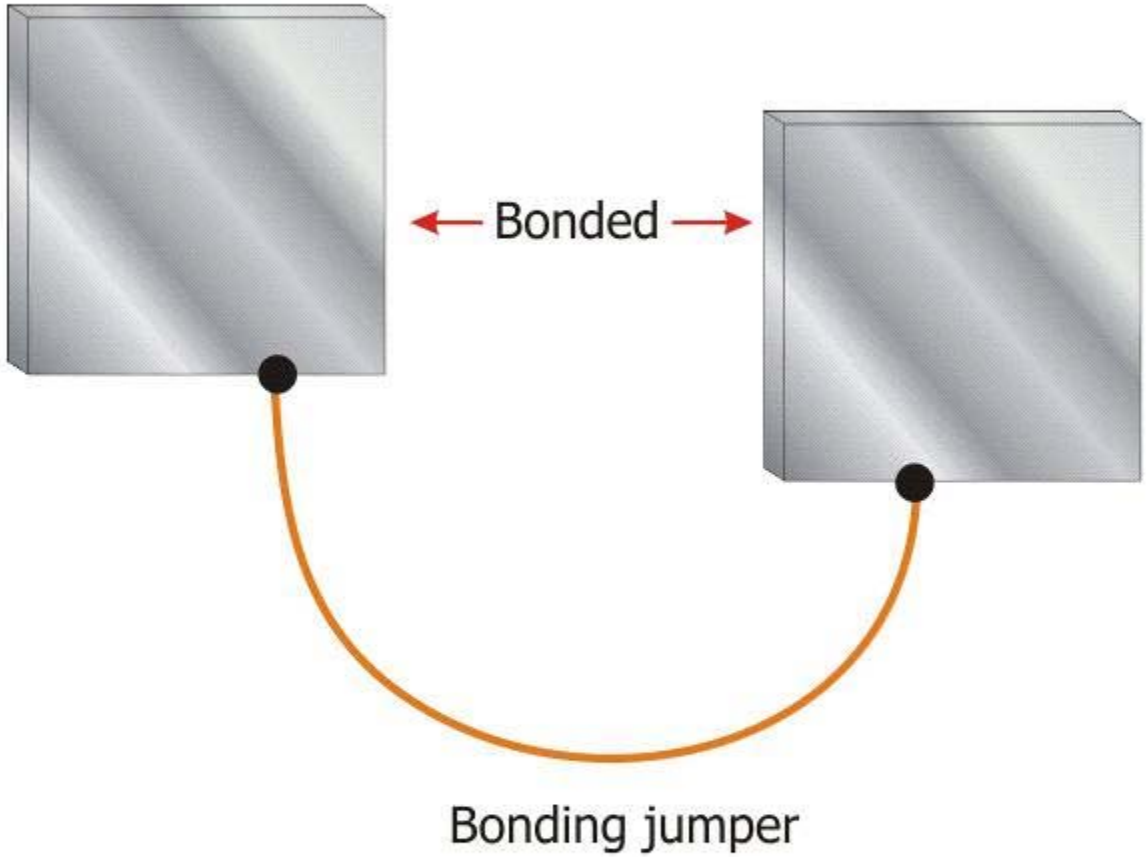
Article 100 Bonded (Bonding)



Bonded (Bonding): Connected to establish electrical continuity and conductivity.

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Photo: IAEI Archives

ARTICLE 100 – GROUND

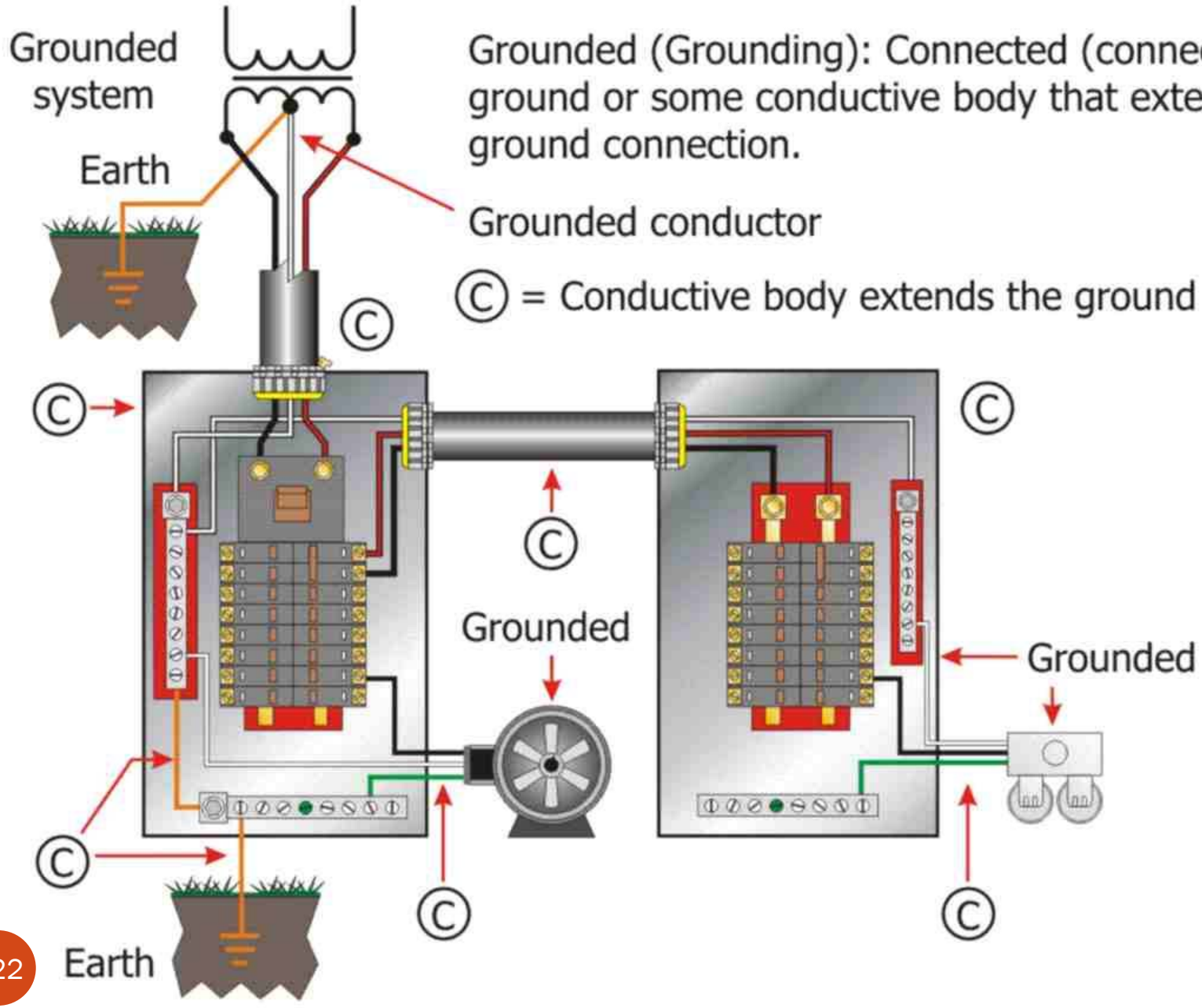
- Ground = The earth.

- The term *ground* has been revised and simplified for clarity and improved usability.

Article 100 – Ground

The earth

Article 100 Grounded (Grounding)



Grounded (Grounding): Connected (connecting) to ground or some conductive body that extends the ground connection.

Grounded conductor

Ⓒ = Conductive body extends the ground connection

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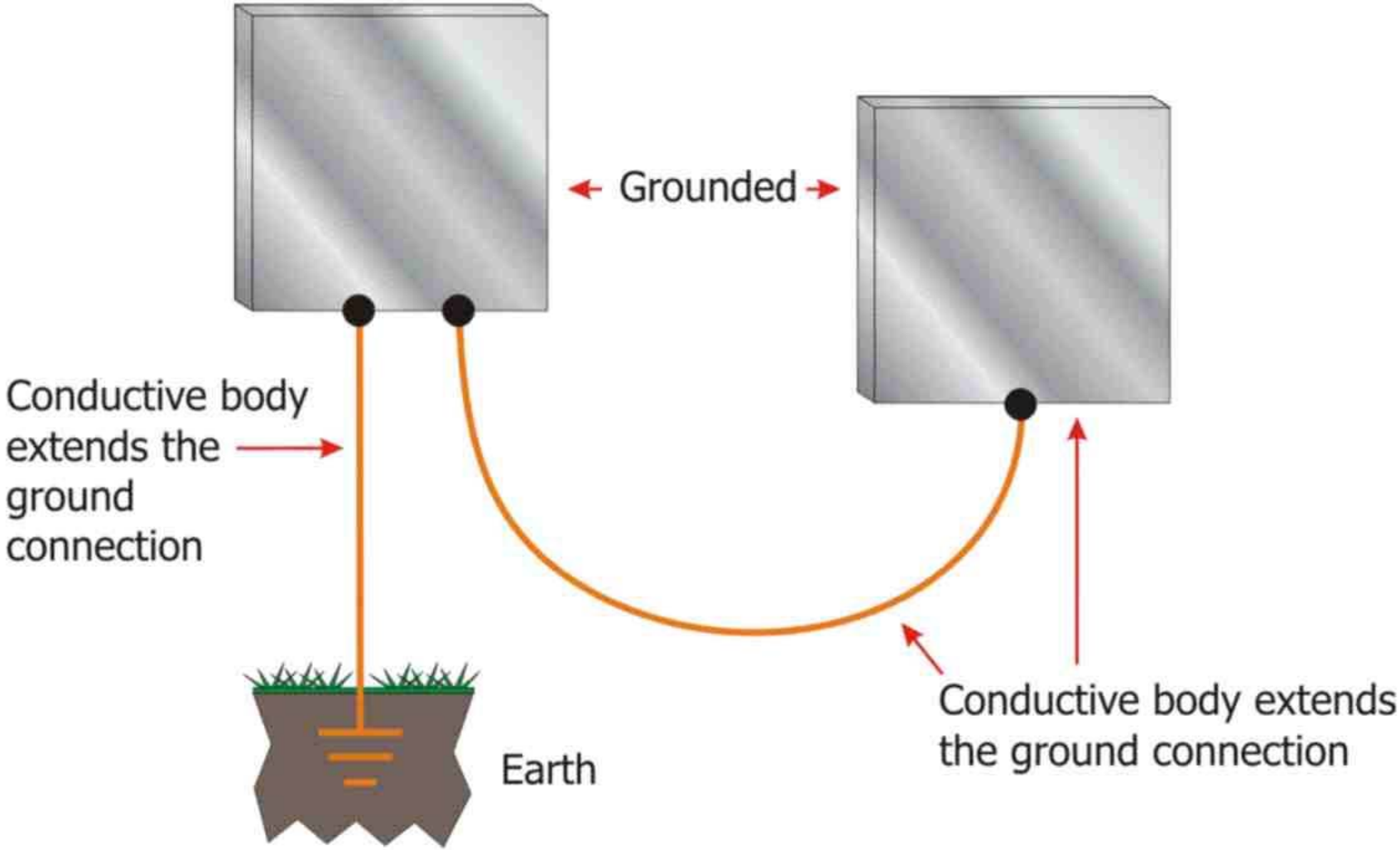
Article 100 Grounded (Grounding)



Grounded (Grounding): Connected (connecting) to ground or to some conductive body that extends the ground connection.

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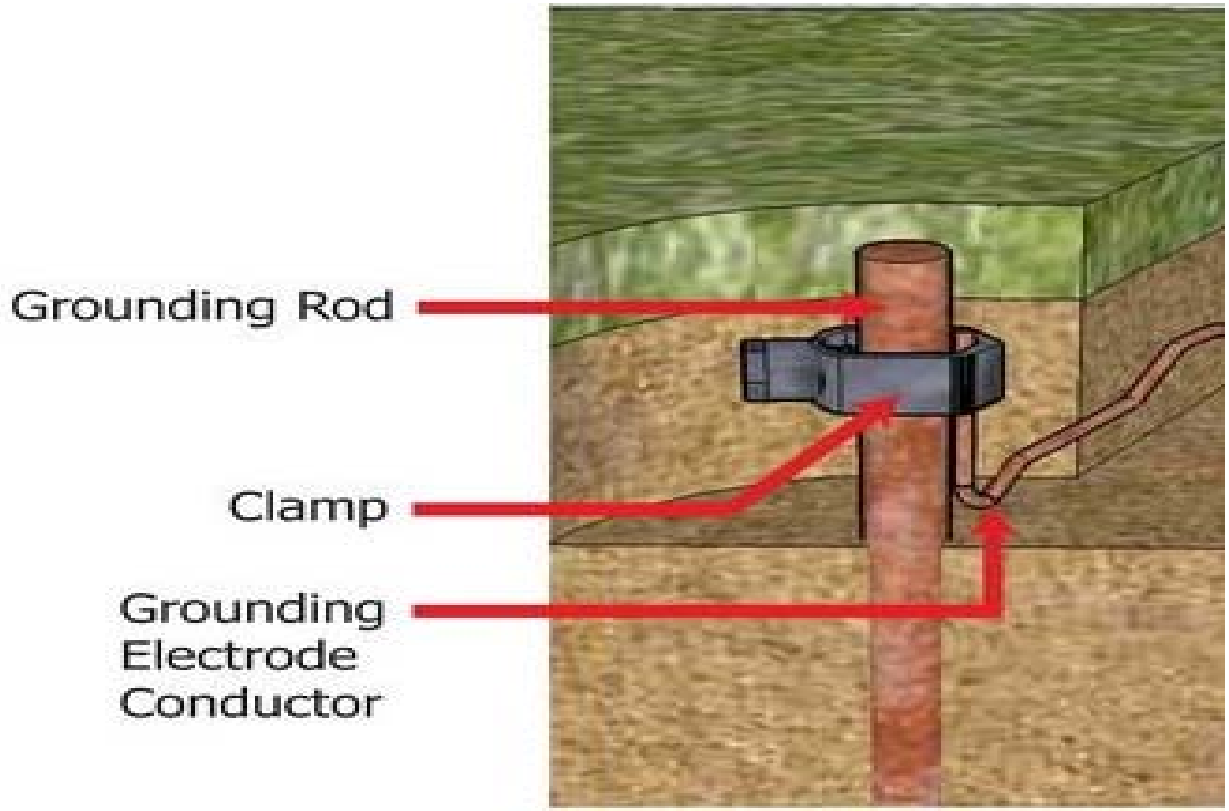
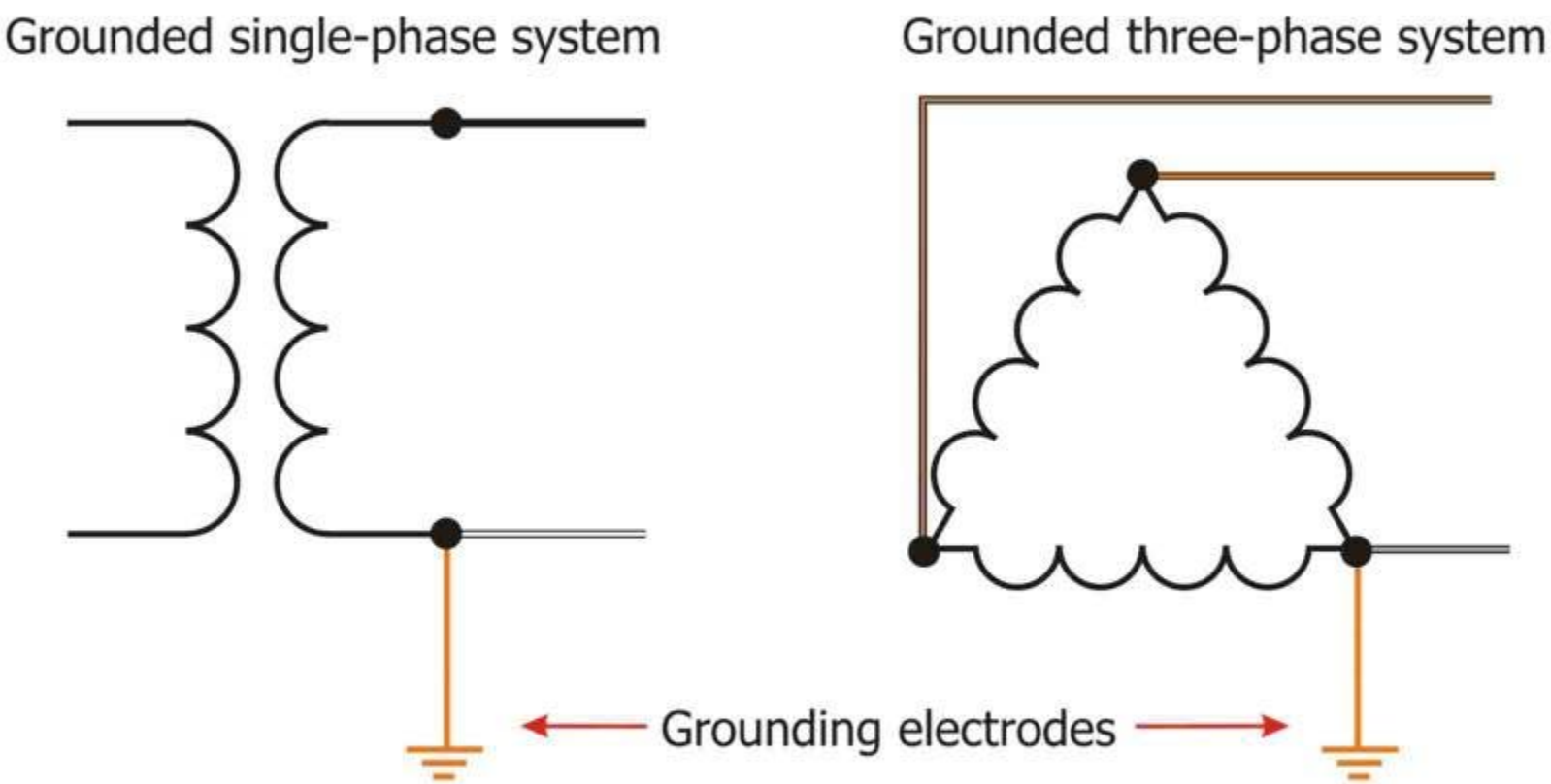
ARTICLE 100
GROUNDING ELECTRODE

- Grounding Electrode. A conducting object through which a direct connection to earth is established.



Article 100 Grounded Conductors (Not Neutrals)



Grounded conductors are not always neutral conductors

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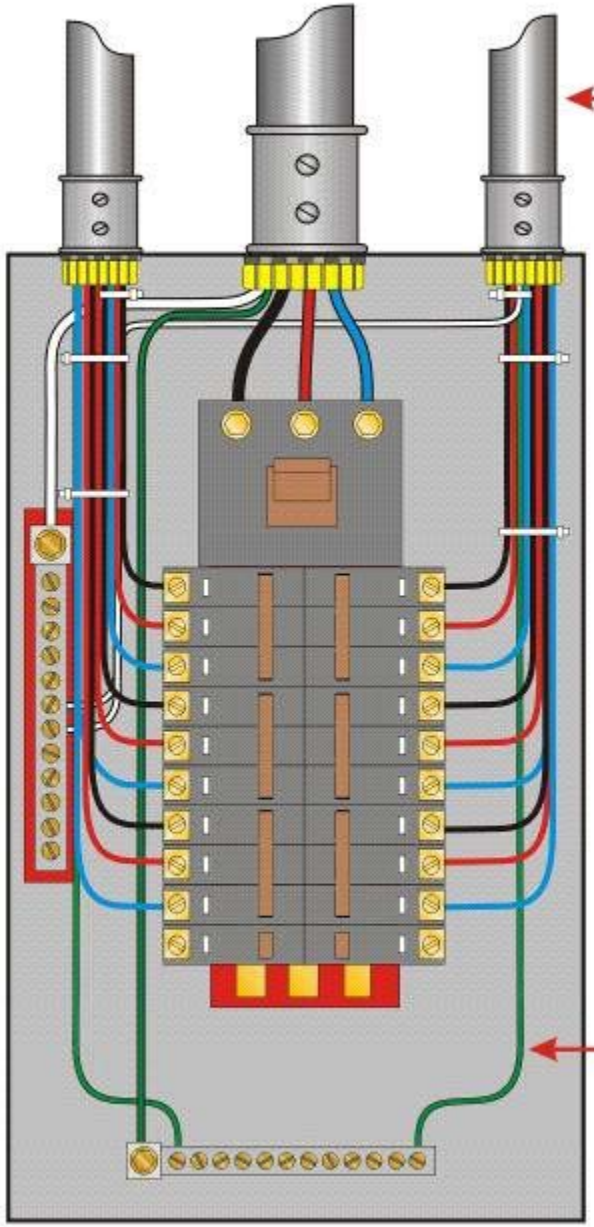
Photo: IAEI Archives

Article 100 Grounding Conductor, Equipment (EGC)



The conductive path installed to connect normally non-current-carrying metal parts of equipment together and to the system grounded conductor or to the grounding electrode conductor, or both.

The EGC also performs bonding functions.

The EGC types are provided in 250.118.

Equipment grounding conductors sized in accordance with Table 250.122.

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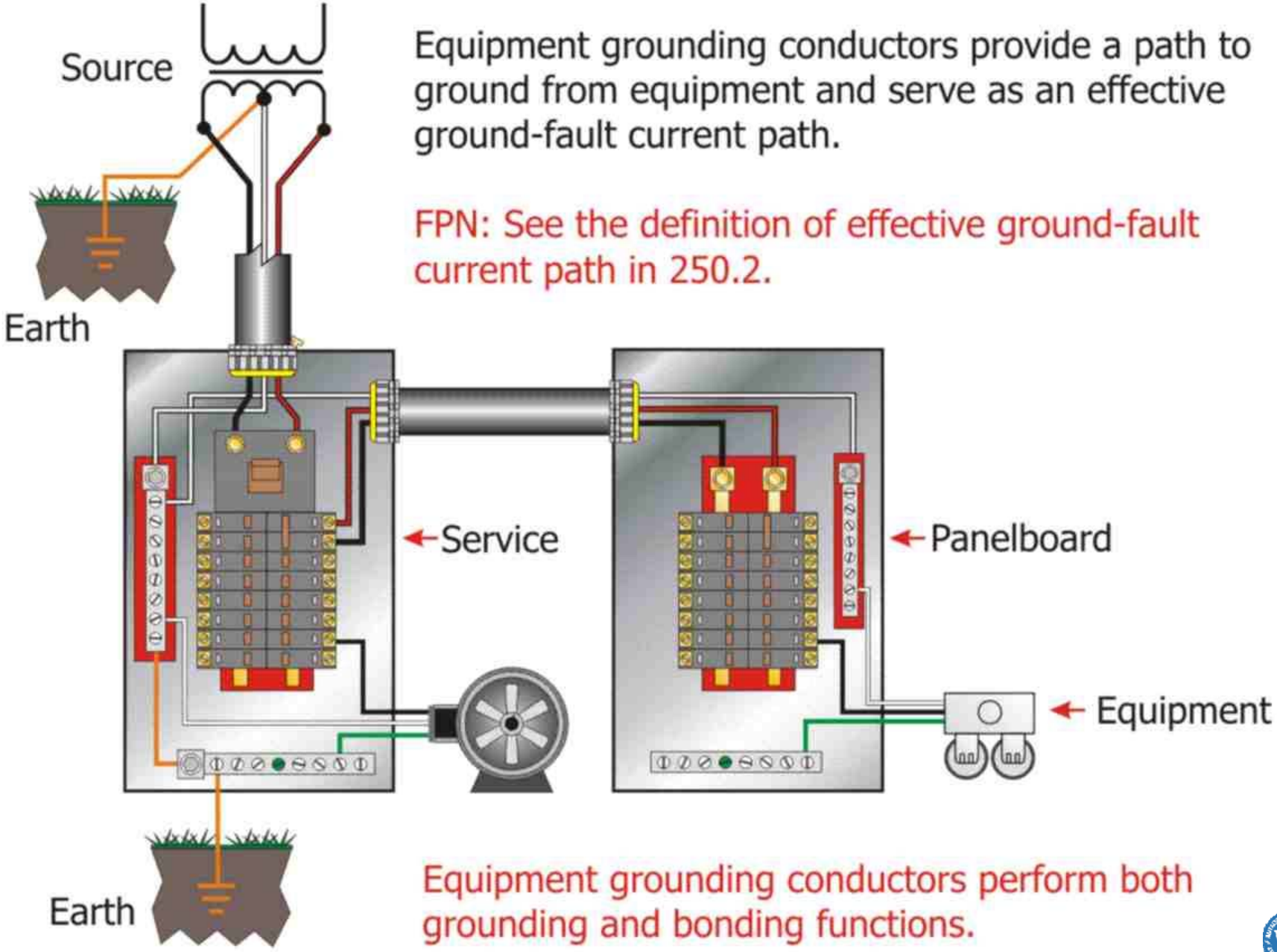
250.118 Types of Equipment Grounding Conductors

Equipment grounding conductors provide a path to ground from equipment and serve as an effective ground-fault current path.

FPN: See the definition of effective ground-fault current path in 250.2.



Equipment grounding conductors perform both grounding and bonding functions.

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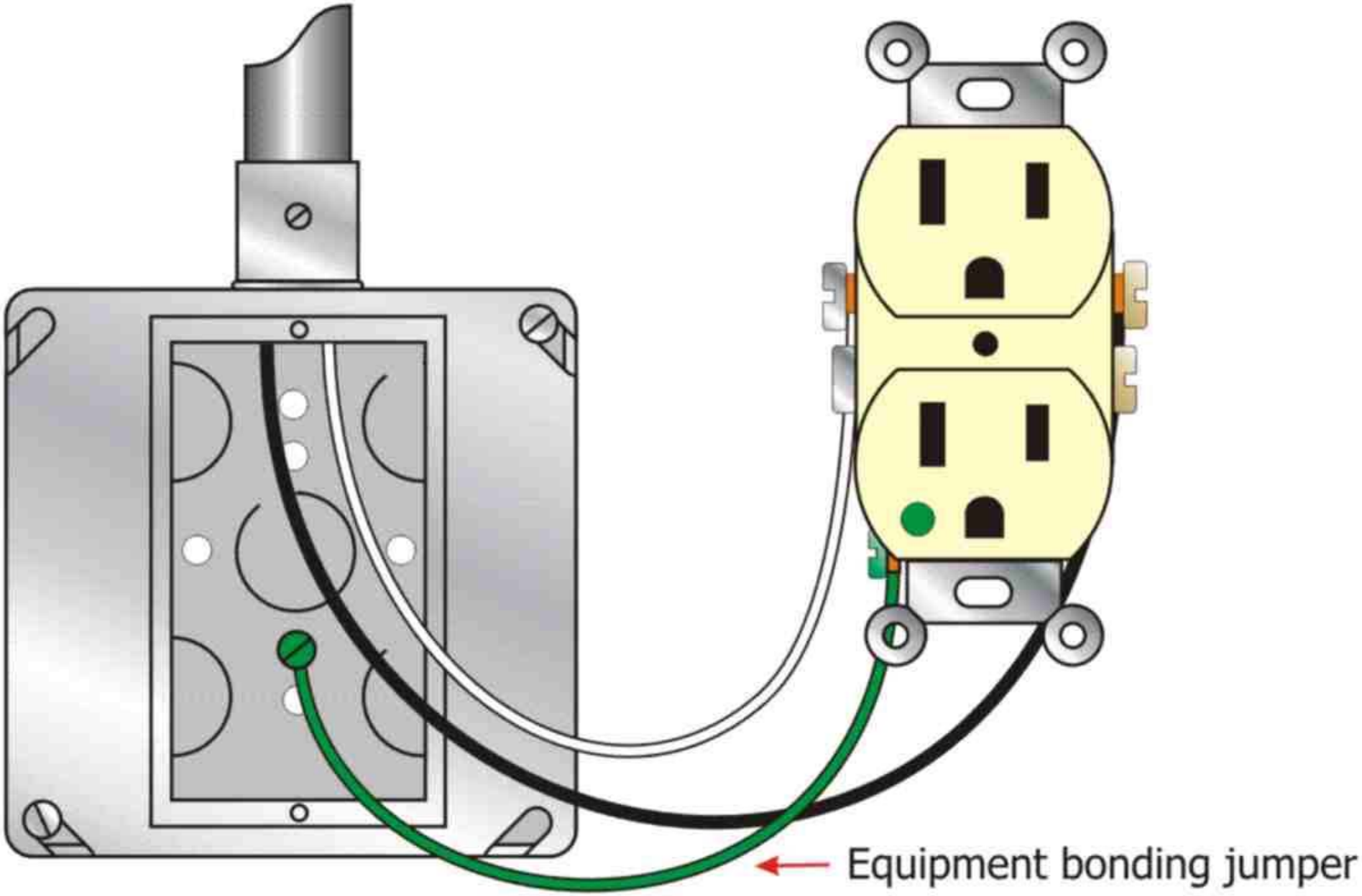
250.146 Connecting Grounding Terminal to Box



Equipment bonding jumper is sized based on the branch-circuit overcurrent device rating using Table 250.122.

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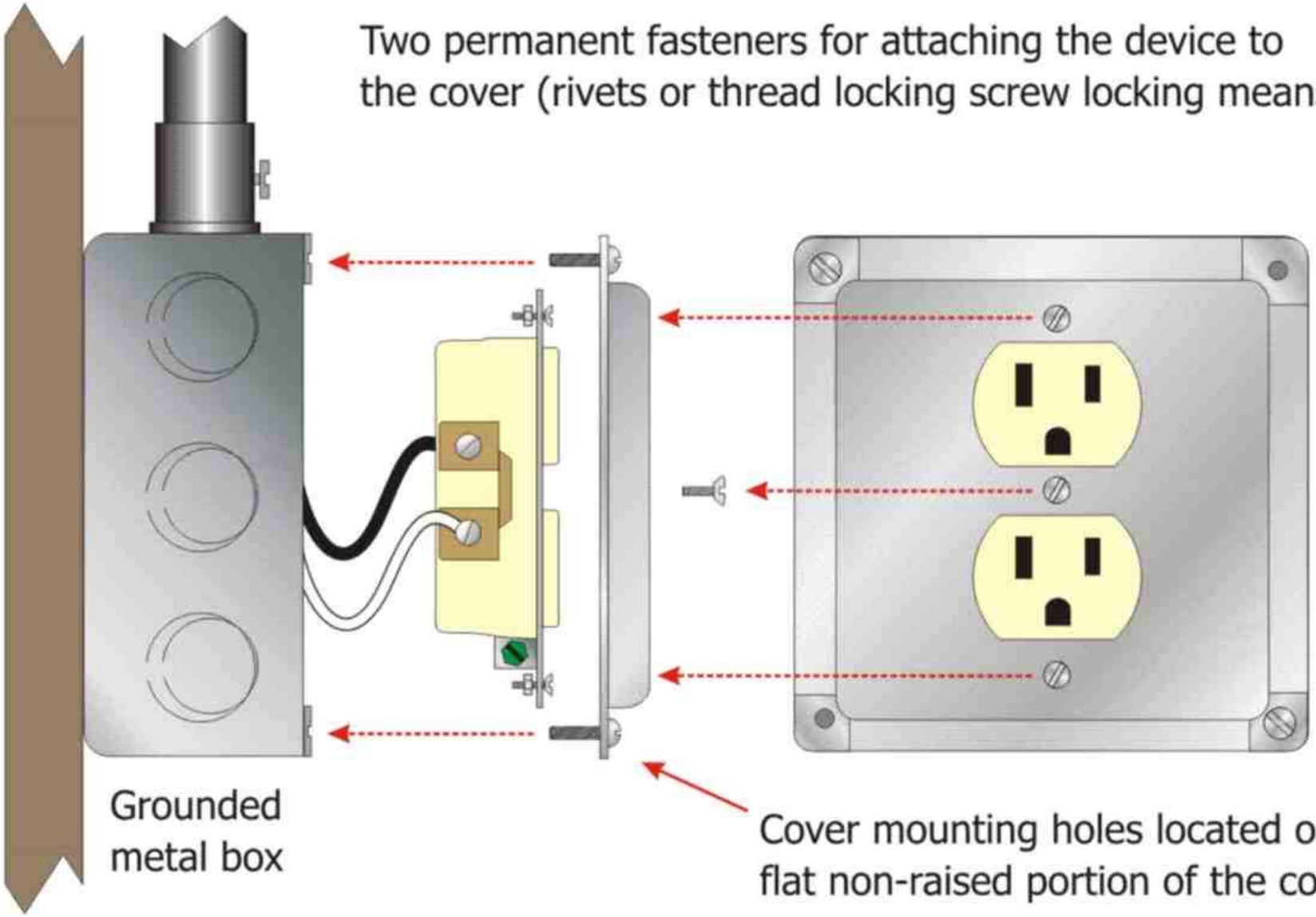
250.146(A) Surface-Mounted Box

Two permanent fasteners for attaching the device to the cover (rivets or thread locking screw locking means)



Listed exposed work cover is permitted as the grounding and bonding means

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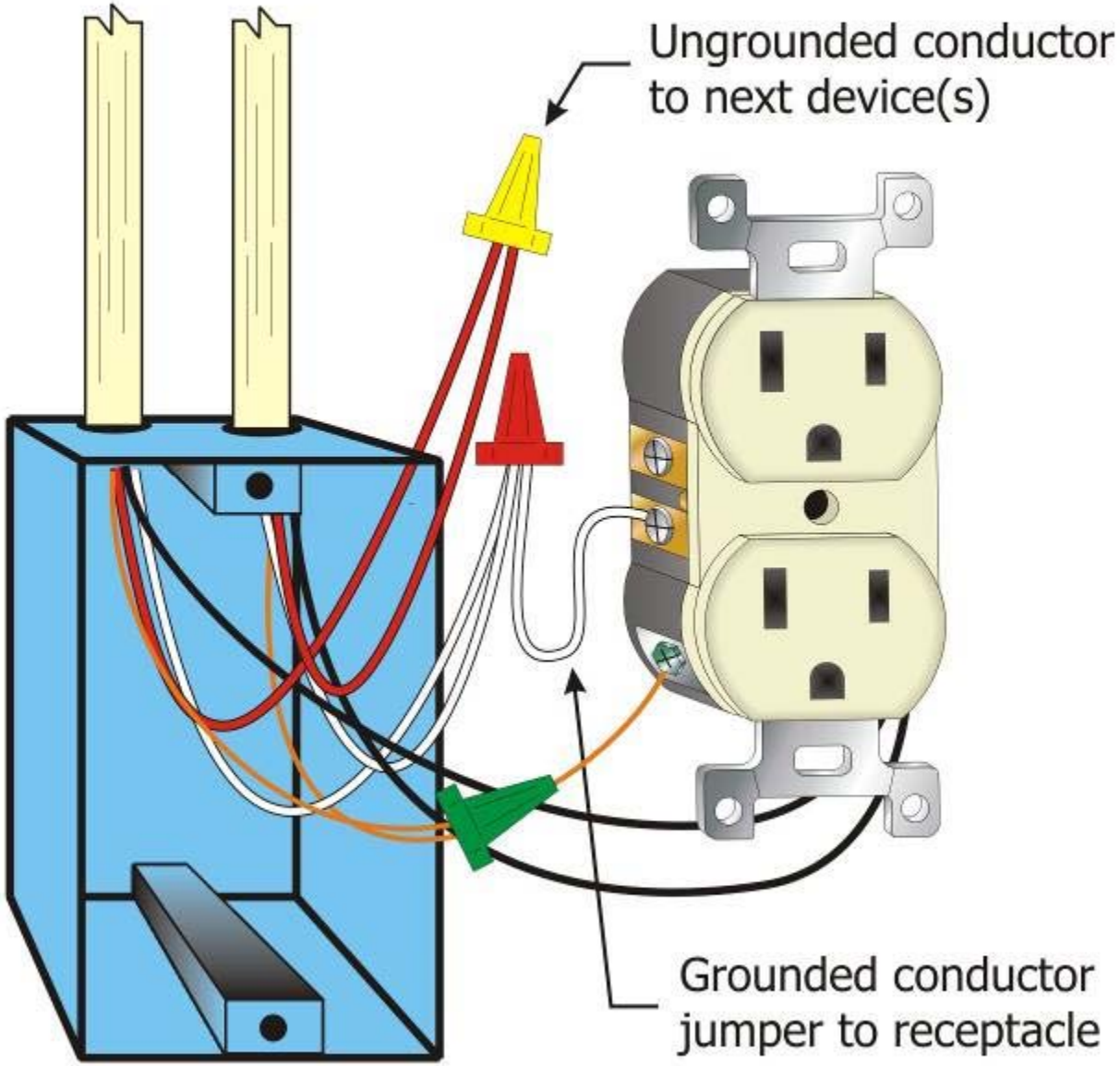
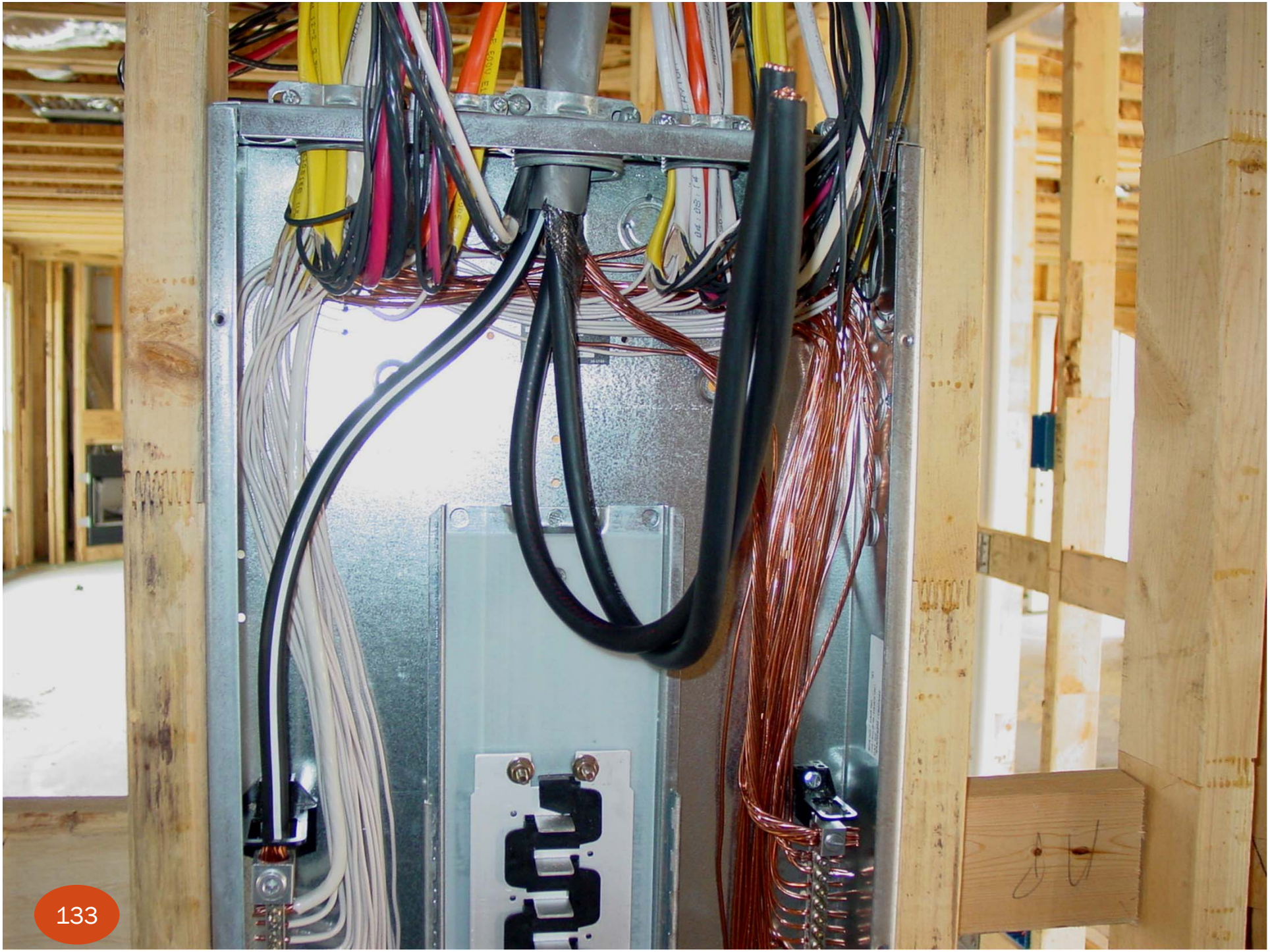
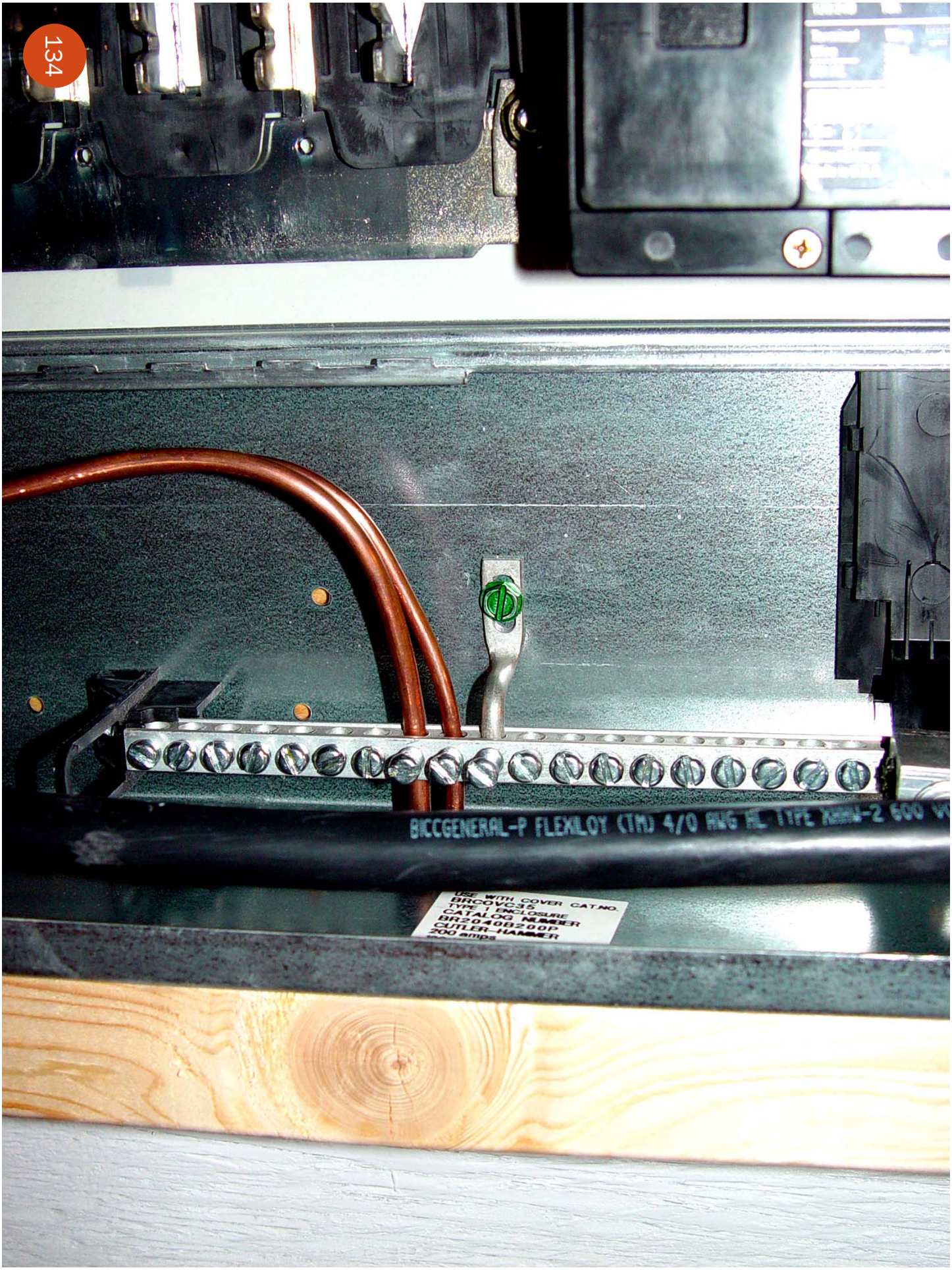
CONTINUITY OF GROUNDED CONDUCTOR

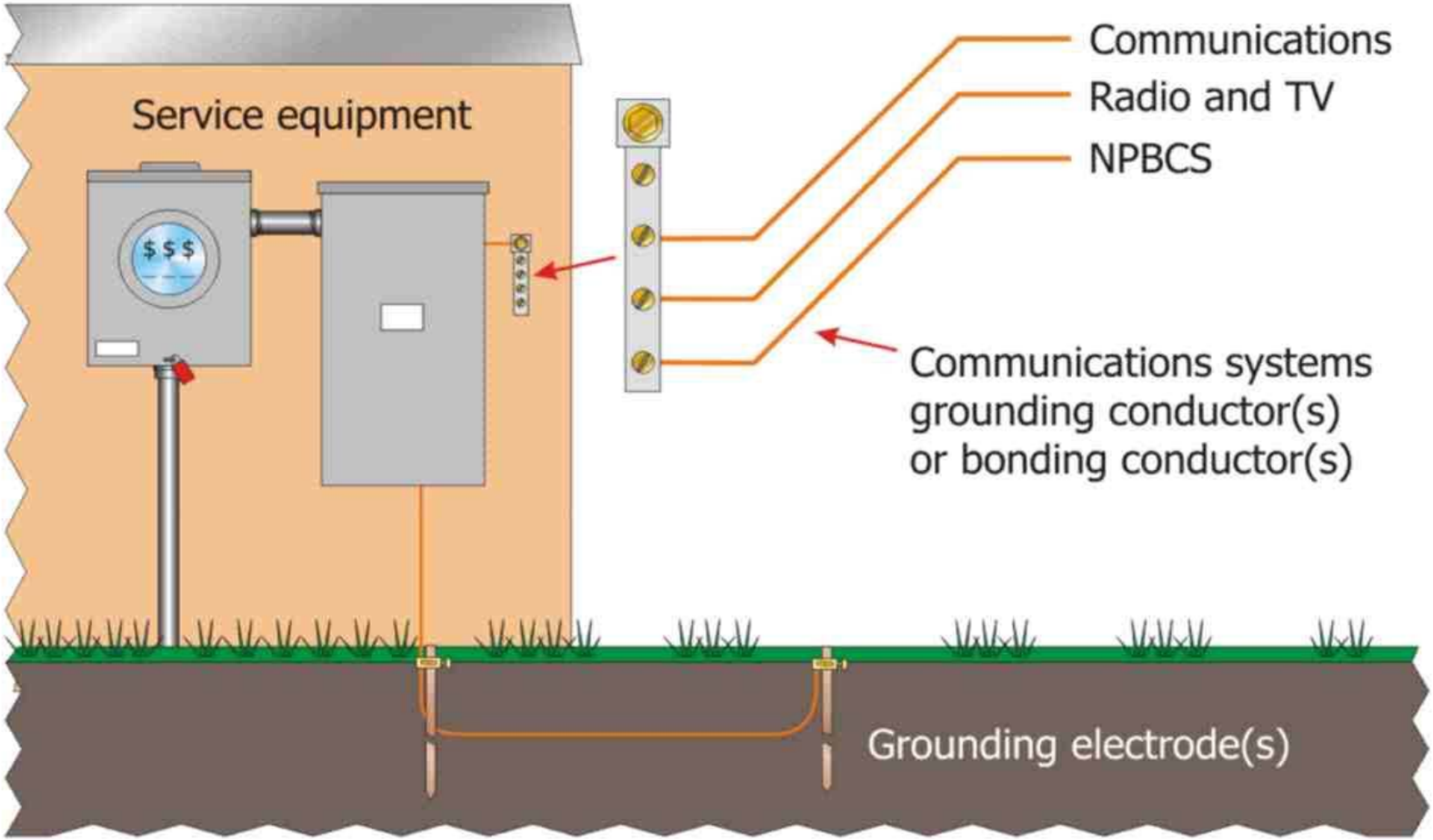


Copyright © IAEI 2007




BICCGENERAL-P FLEXLOY (TM) 4/0 AWG
USE WITH COVER CAT.NO.
BRCOVC36
TYPE 1 ENCLOSURE
CATALOG NUMBER
BR204B2200P
CUTLER-HAMMER
200 amps

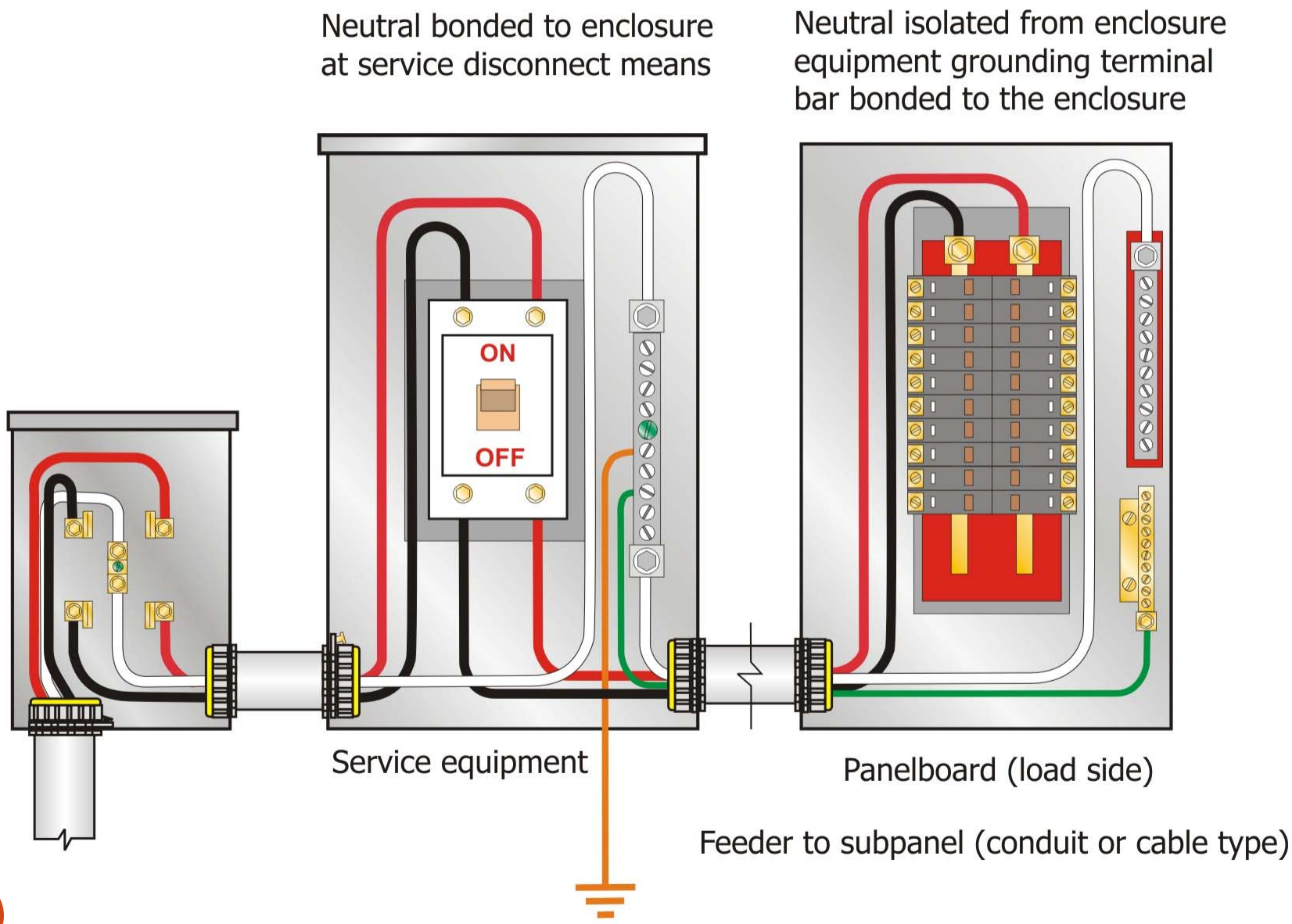
Article 100 Intersystem Bonding Termination



A device that provides a means for connecting communications system(s) grounding conductor(s) and bonding conductor(s) at the service equipment or at the disconnecting means for buildings or structures supplied by a feeder or branch circuit.

yright © IAEI 2007

SEPARATE NEUTRALS AND GROUNDS



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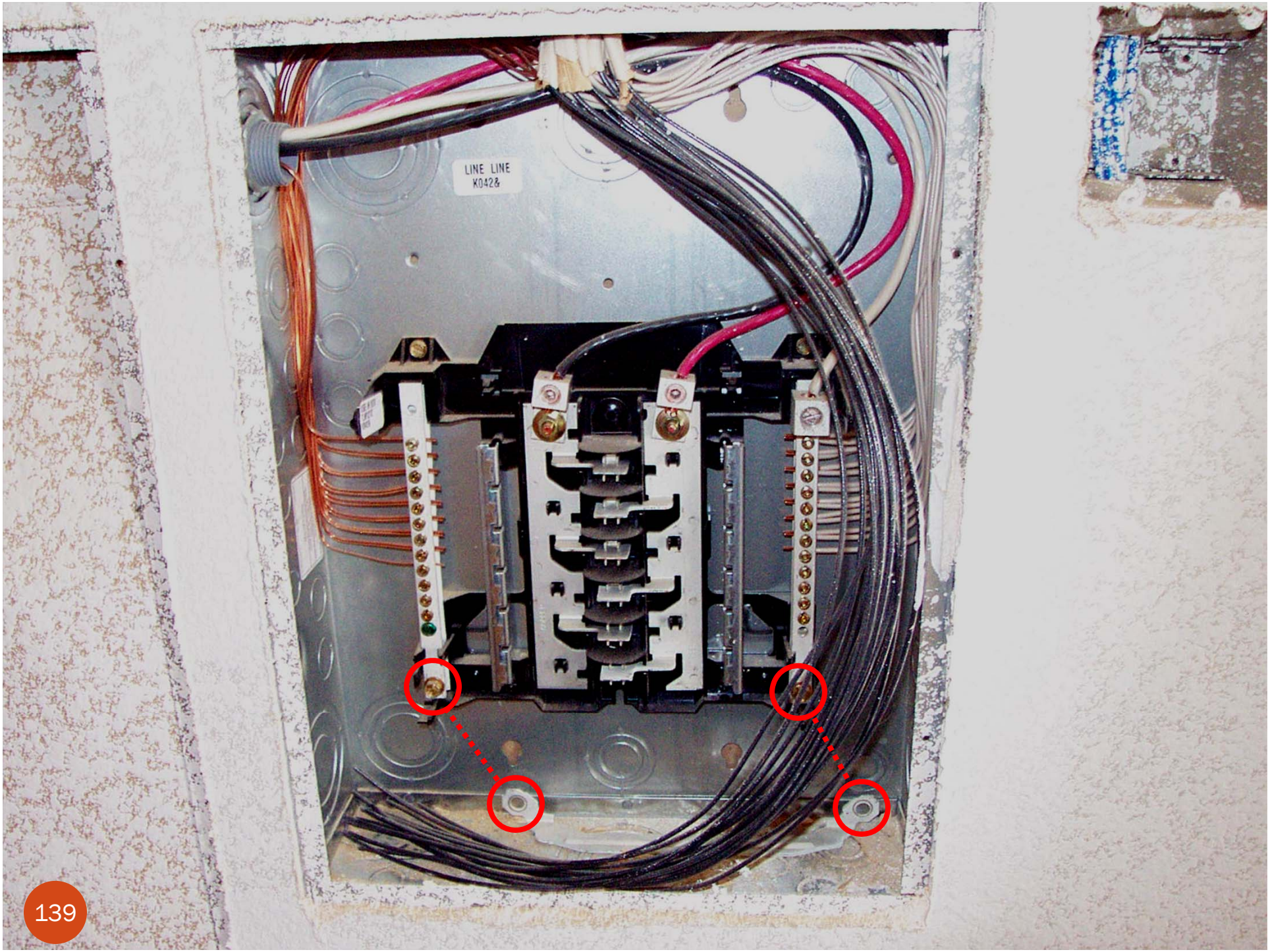
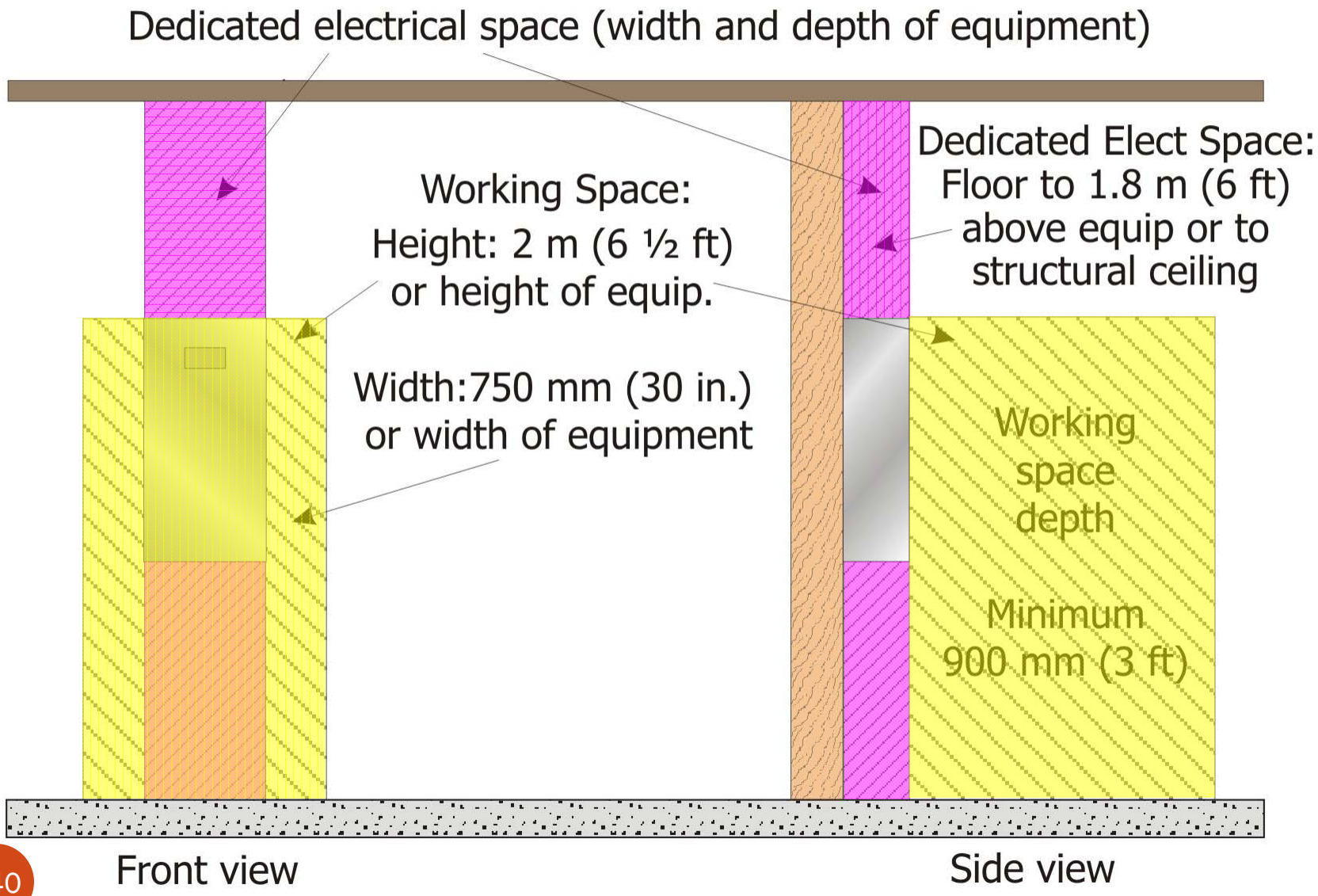

LINE LINE
K042&

WORKING SPACE REQUIRED



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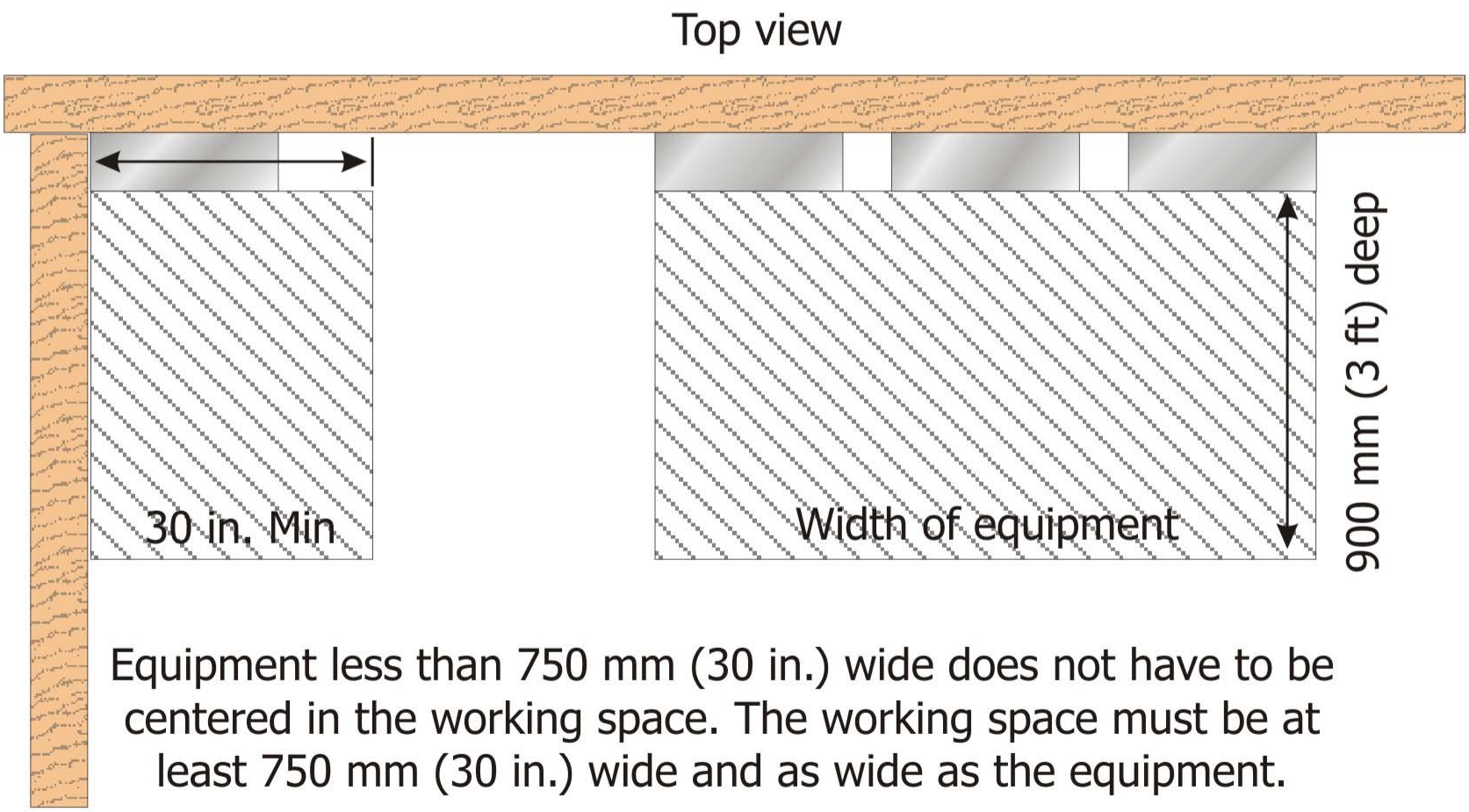
WIDTH OF WORKING SPACE



Equipment less than 750 mm (30 in.) wide does not have to be centered in the working space. The working space must be at least 750 mm (30 in.) wide and as wide as the equipment.

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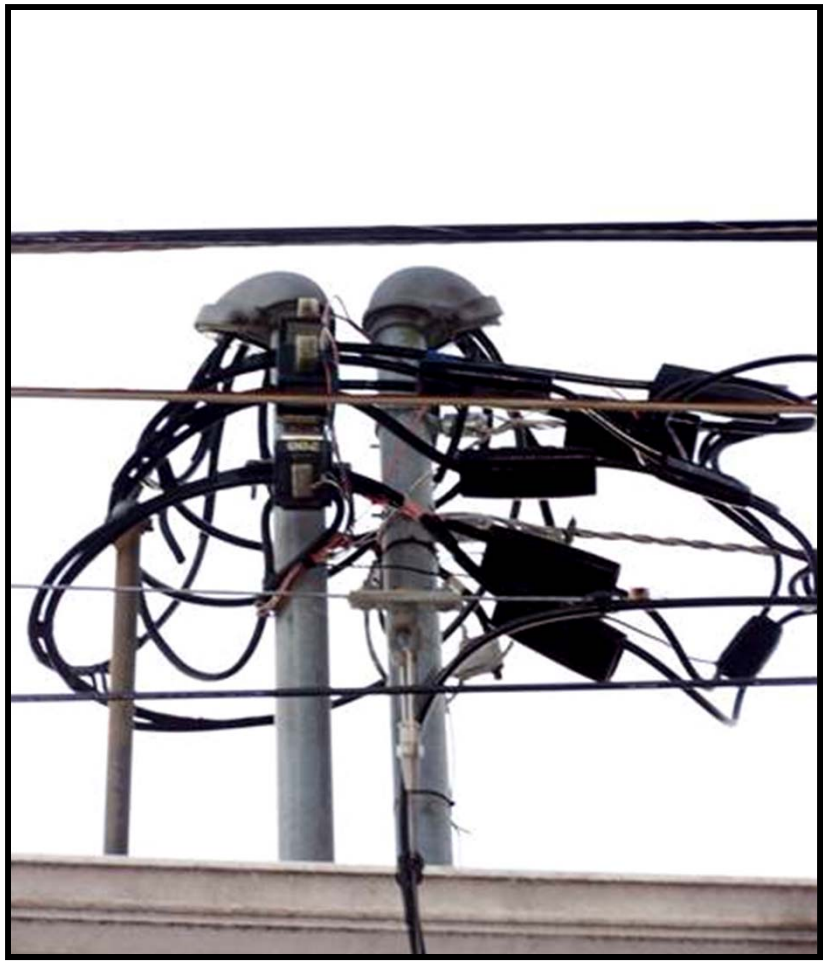
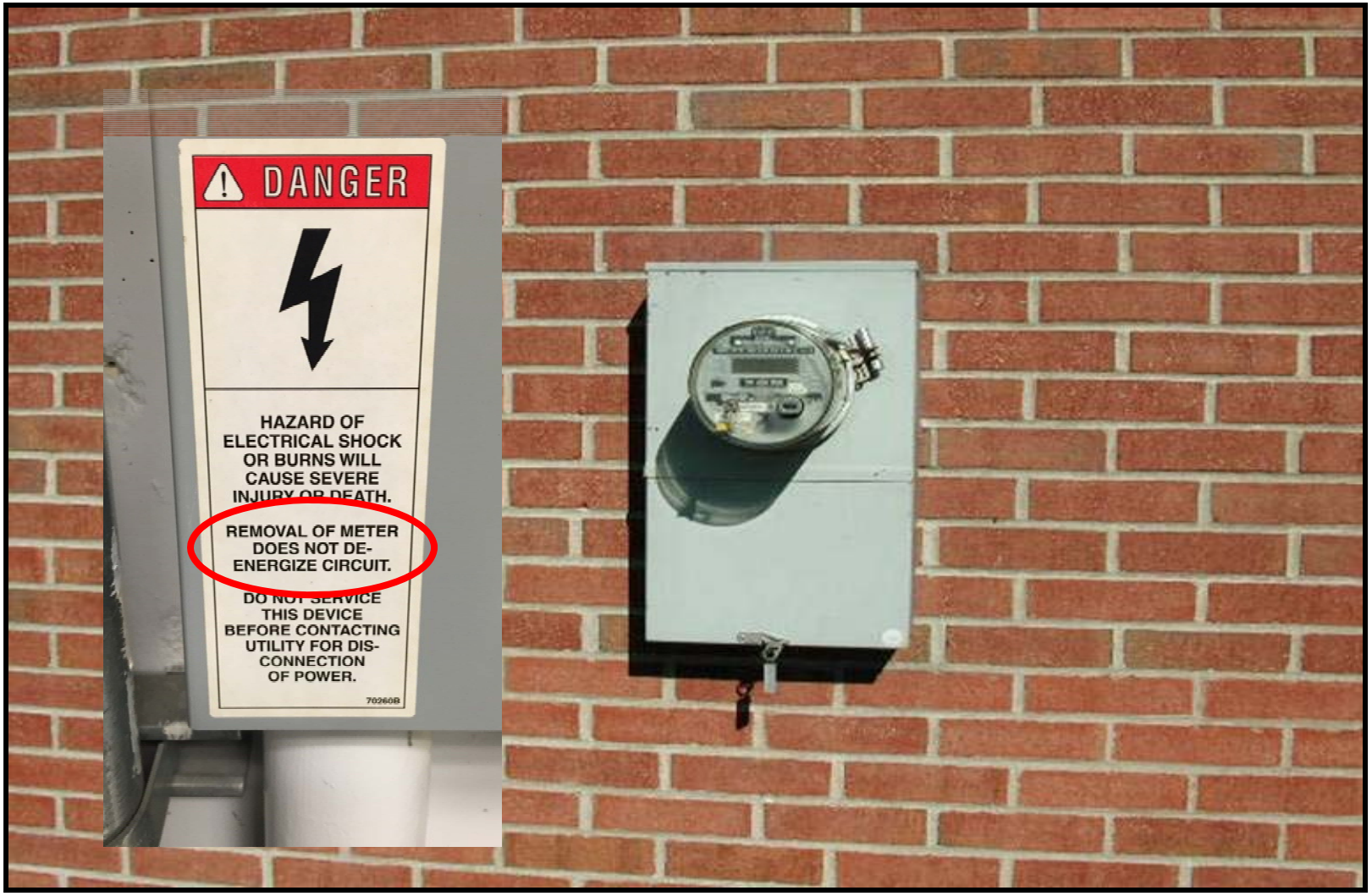
ELECTRICAL SERVICES

- Exposed current transformer metering
- Can also be found in an enclosure
- Used when service is greater than 400 amps



DEMAND METER

NO DISCONNECTION MEANS



METERING

Two functional types

- Current transformer
- Socket mount watt-hour meter

ELECTRICAL SERVICES

- Main disconnects
- Used when service panel is distant from location where service conductors enter the building
- Used to supply multiple panels
- 6 throws of the handle (NEC)

SERVICE PANELS

- Fuses, circuit breakers or a combination of both
- Provide over current protection for building and branch circuits

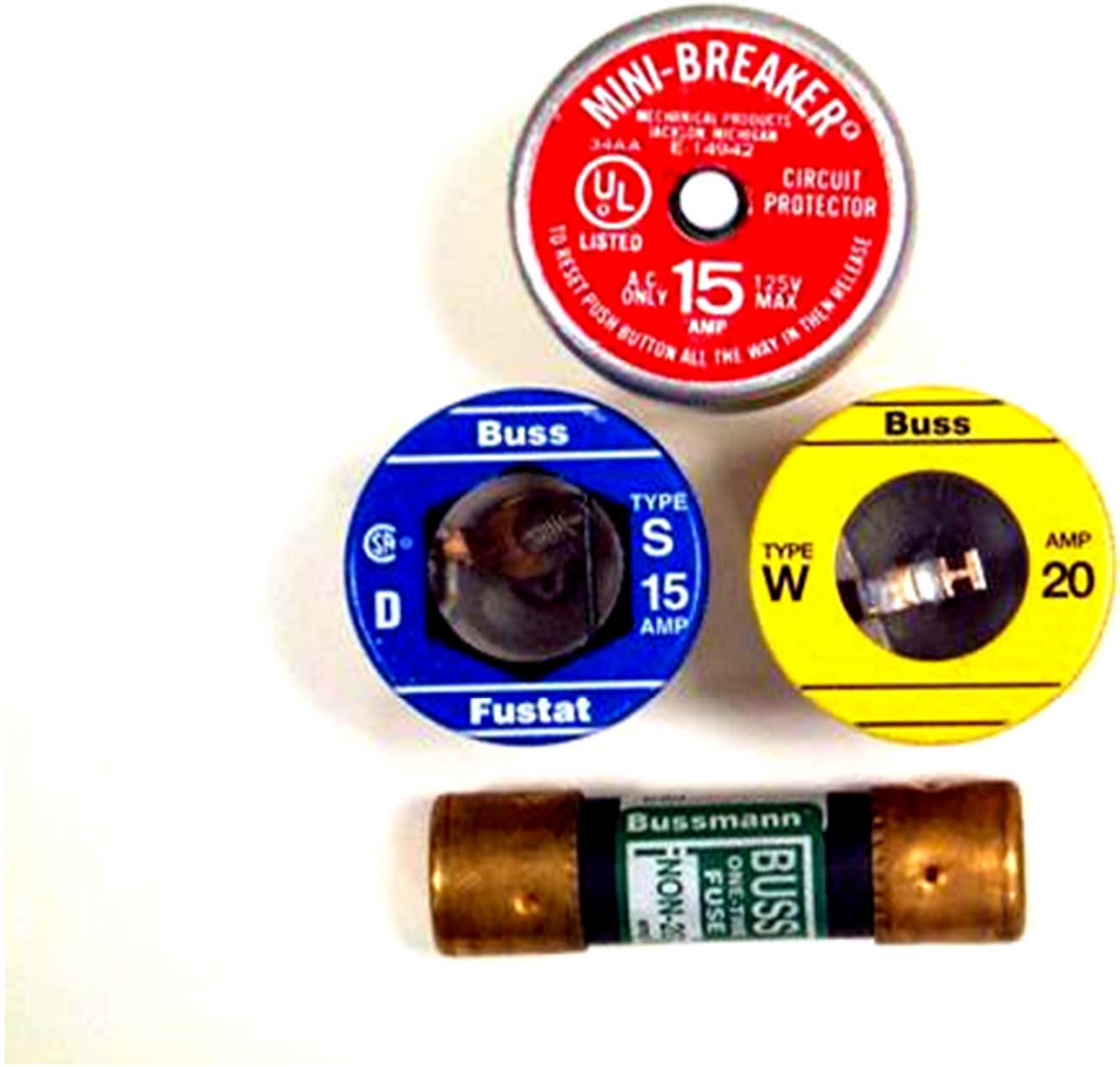
MURRAY FUSE

CIRCUIT PROTECTION METHODS AND DEVICES

OVERCURRENT PROTECTION

Devices that are designed and installed to protect circuit components from exceeding a specific amperage value

FUSES


MINI-BREAKER
CIRCUIT PROTECTOR
LISTED
A.C. ONLY
15
AMP
125V MAX
Buss
TYPE
S
15
AMP
D
Fustat
Buss
TYPE
W
AMP
20
Bussmann
BUSS
FUSE

"Edison Base" screw-in fuses & breaker conversion adapter

S-Type screw-in fuses & Edison Base adapter

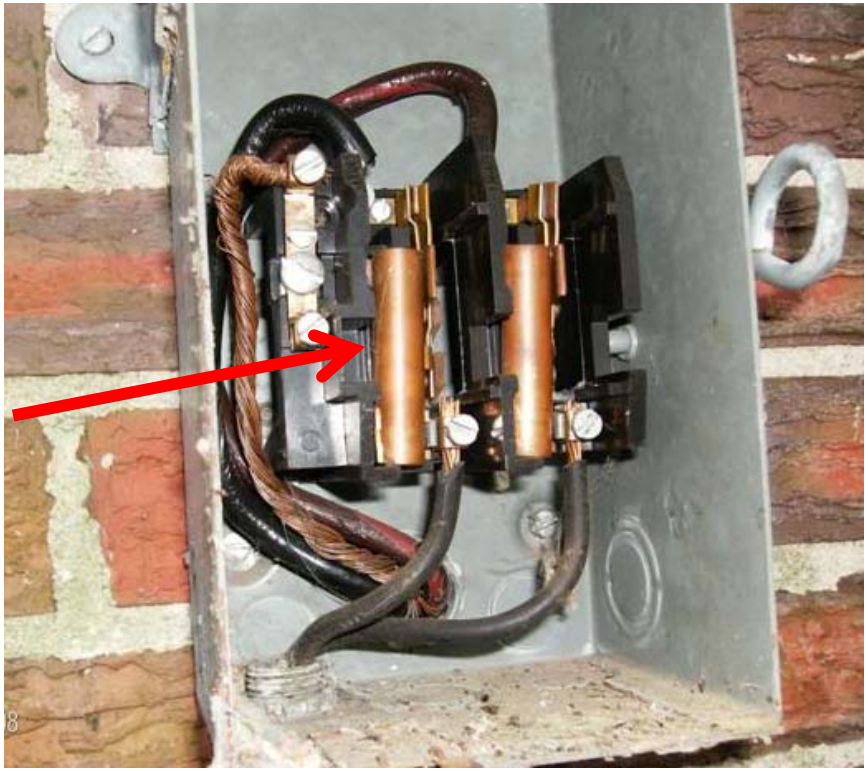
CARTRIDGE FUSE

30 AMP
No. 1015
BUSS
SUPER-LAG
RENEWABLE
FUSE
30 AMP
No. 1015
BUSS
SUPER-LAG
RENEWABLE
FUSE
13 5:16PM

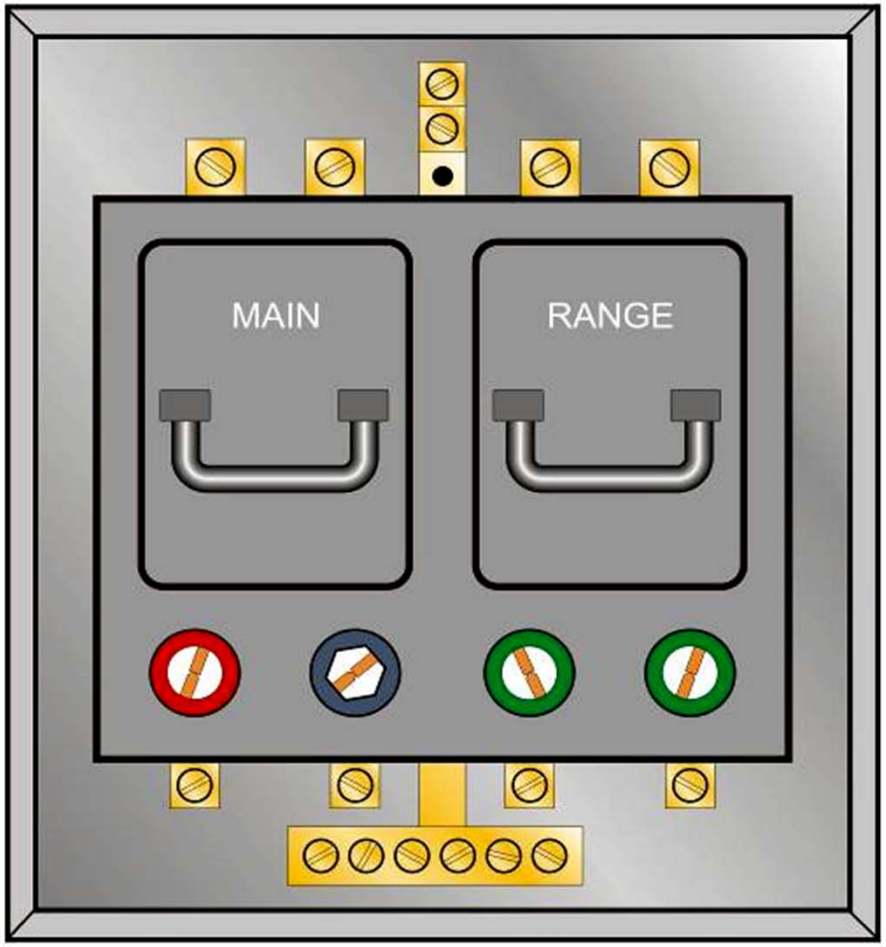
ECONOMY
13 5:14PM

2:00AM CARTRIDGE FUSE "REPAIR"

Copper Pipe



OLD STYLE SERVICE WITH FUSES



Old style panel with fuses for main, range, and four fuses for branch circuits

Often, the electrical service is upgraded and old style panel becomes subpanel with feeder from new panelboard

Caution should be exercised to not violate *NEC* Section 250.24(A)(5) (load-side grounding connection on grounded conductor)

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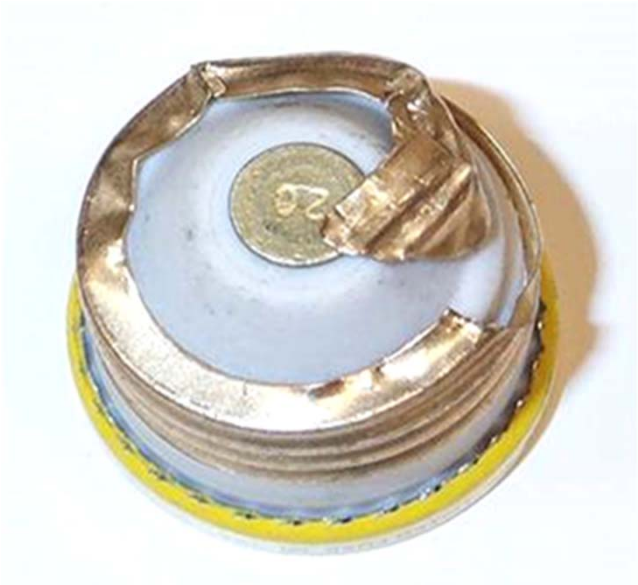
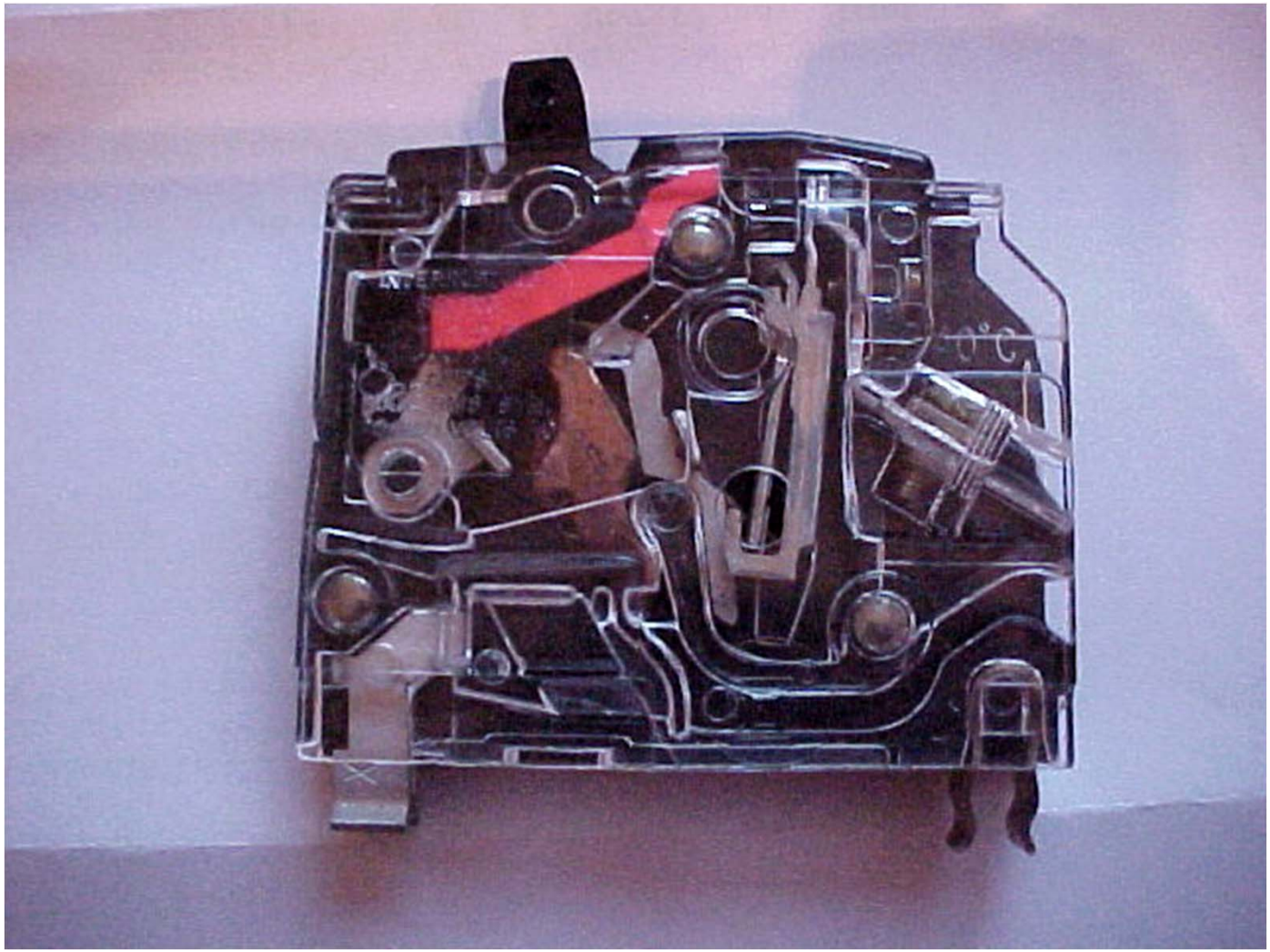
FUSE
FAST ACTING
30
FUSETRON
TRON
TIME-DELAY FUSE
FUSETRON
FUSETRON
FUSETRON
TIME DELAY FUSE

2:00AM SCREW-TYPE FUSE "REPAIR"



If a fuse is blowing, there is a reason for it… and the fuse is doing it's job!

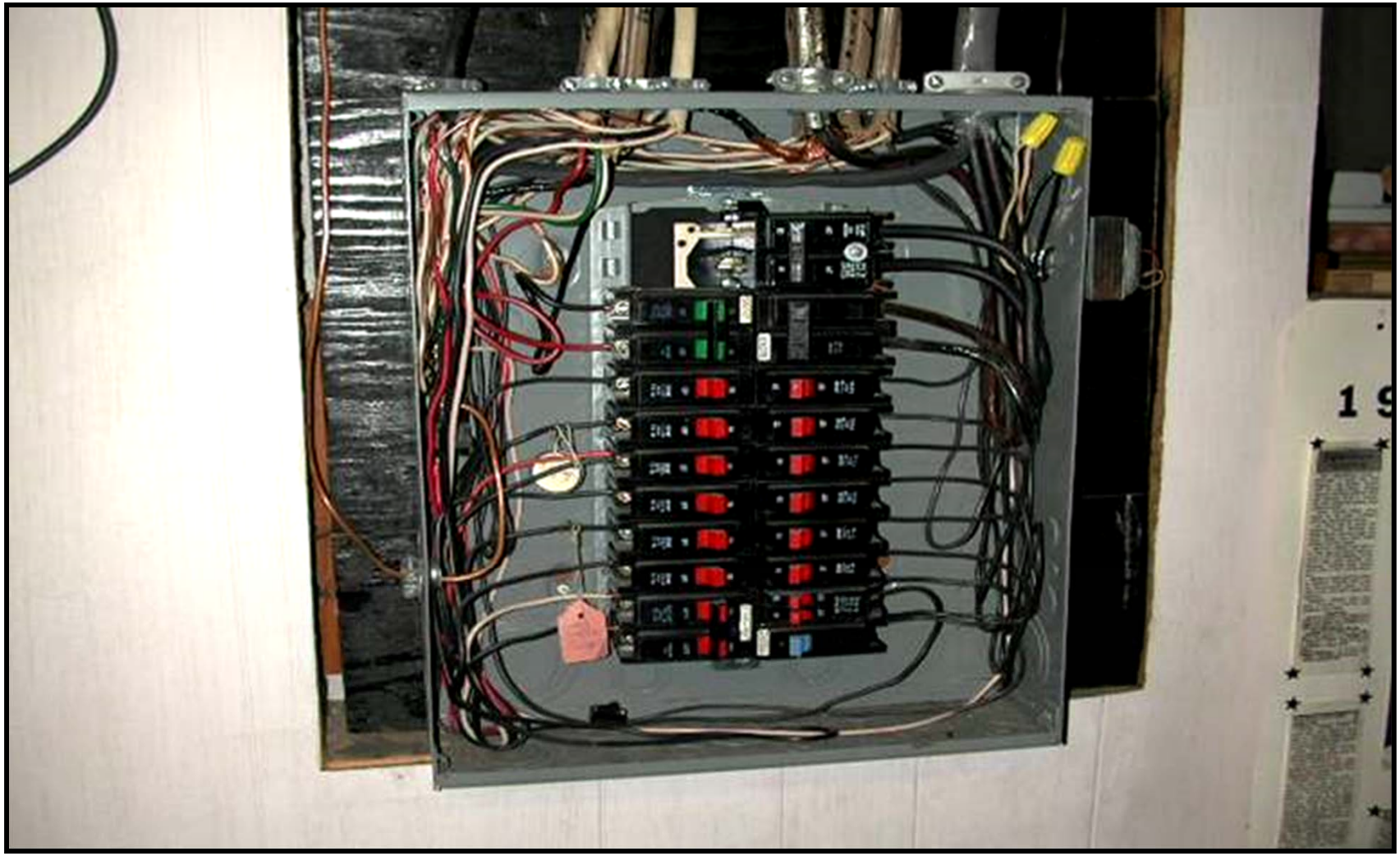
CIRCUIT BREAKERS

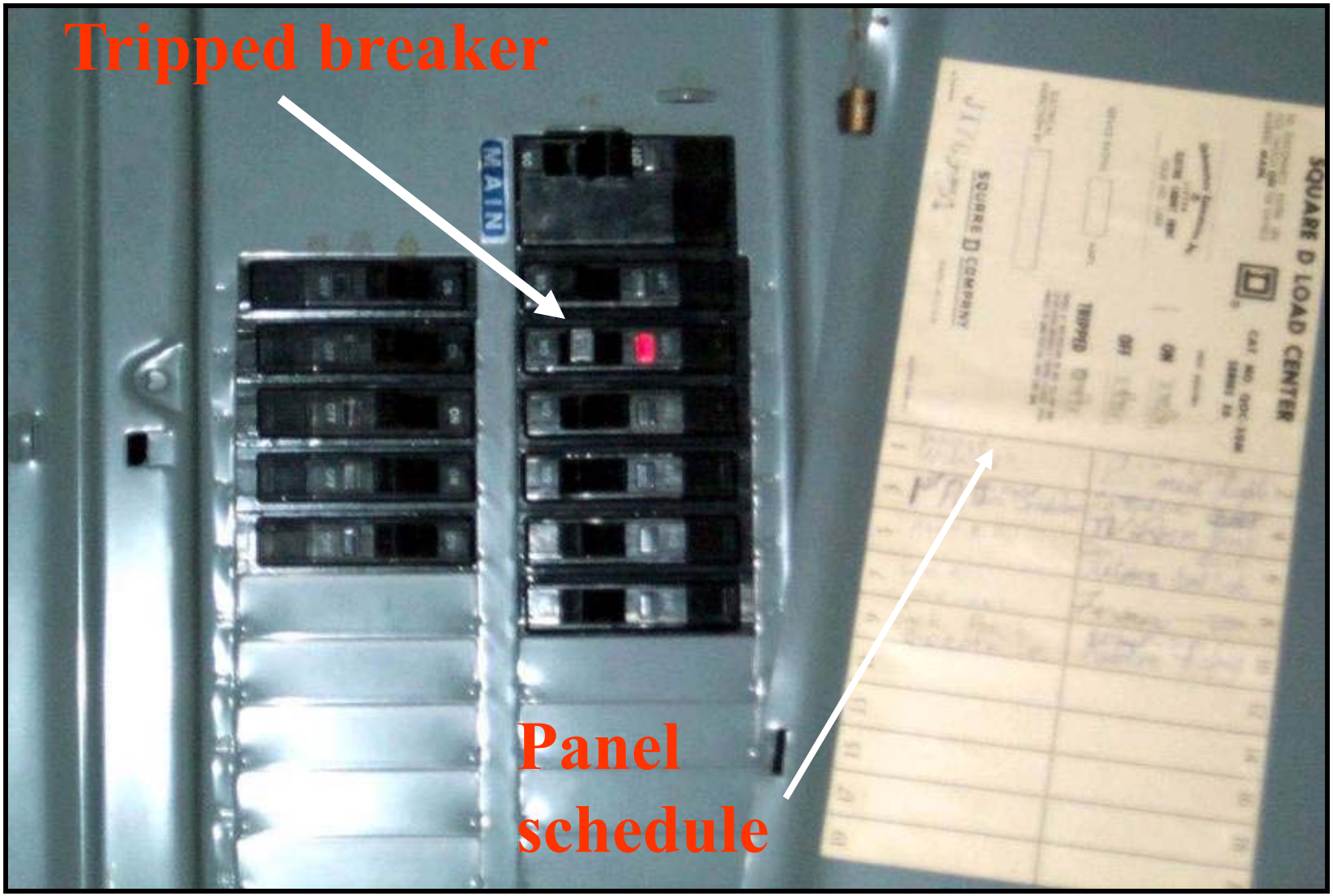


CIRCUIT BREAKERS

CIRCUIT BREAKER PANEL

CIRCUIT BREAKER PANEL




Tripped breaker
MAIN
Panel schedule
SQUARE D LOAD CENTER
SQUARE D COMPANY

CIRCUIT BREAKERS

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

- **Thermal** *(overloads)*

and

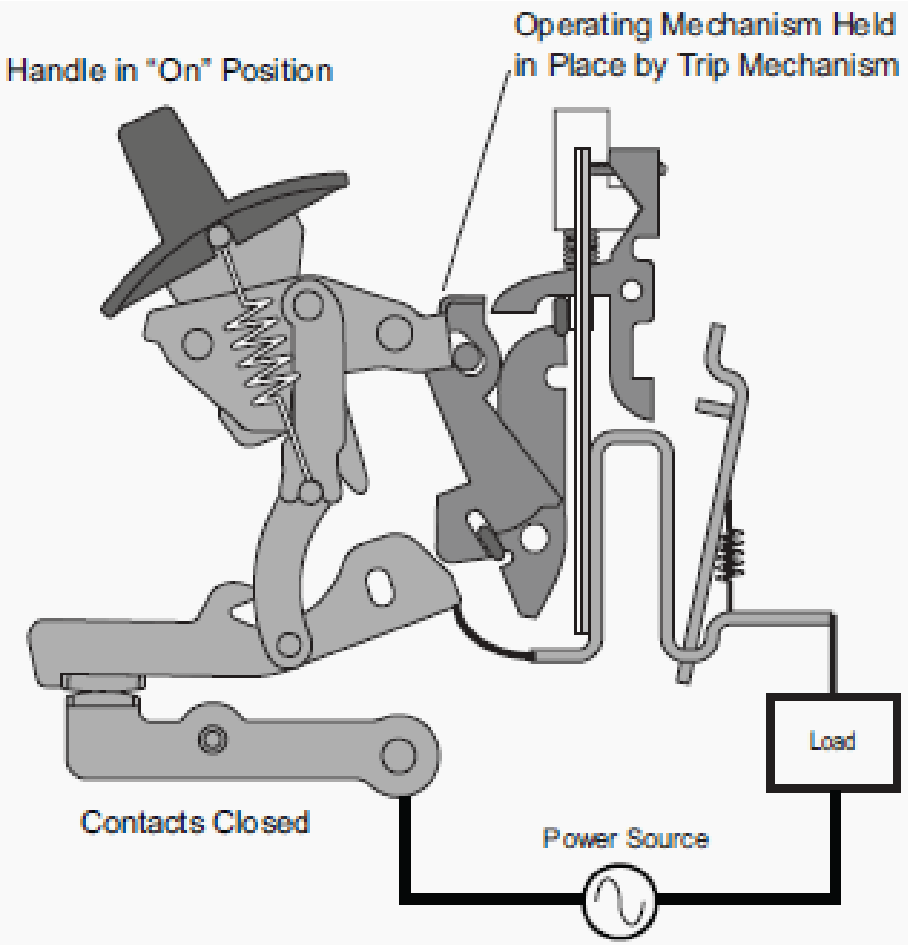
- **Magnetic** *(short circuits)*

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

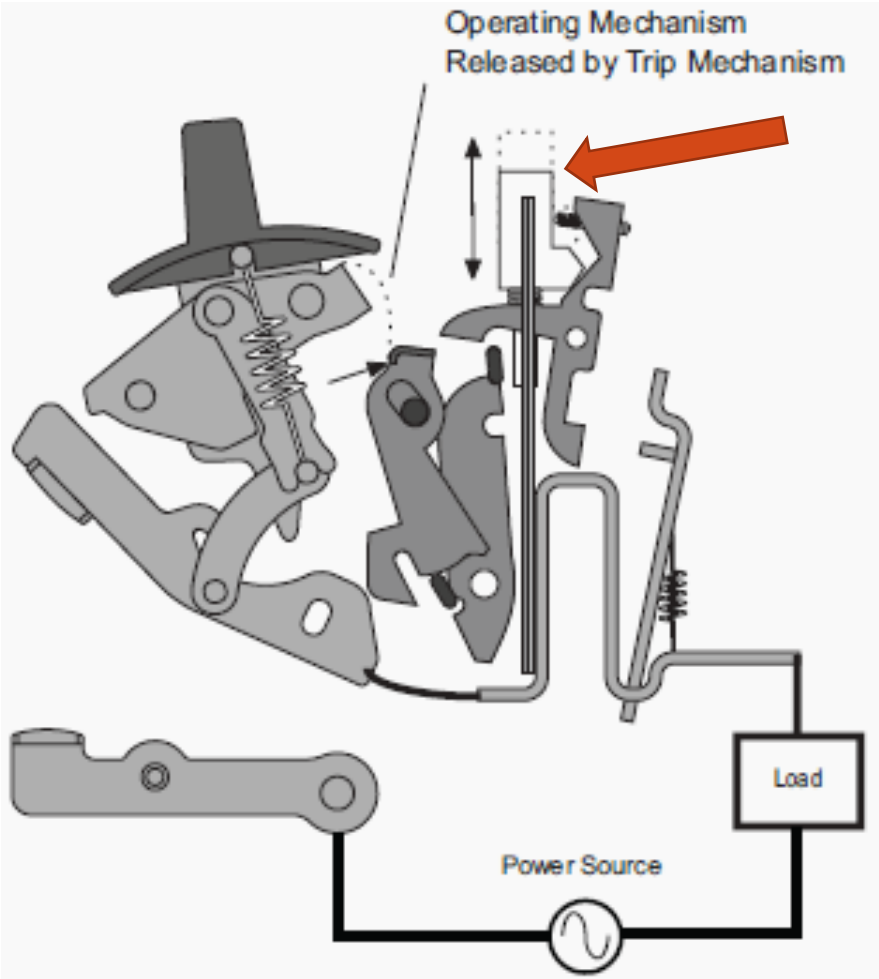
- **<u>Thermal</u>** activation works like a thermostat – a bimetallic strip expands with heat, created by current passing through it; when it reaches a certain temperature it will cause the latching mechanism of the breaker to trip, and then a spring then pulls the contact lever into the **OFF** position, breaking the circuit.
  - Thermal protection sensitivity is affected by ambient temperature; higher ambient = less time to trip; cooler ambient = more time to trip – think of an outside combination meter/panel enclosure in Alaska!
- **<u>Magnetic</u>** activation uses the magnetic field created by a large instantaneous load (i.e. a short circuit) to activate the same mechanism the thermal component moves, breaking the circuit.

CIRCUIT BREAKERS



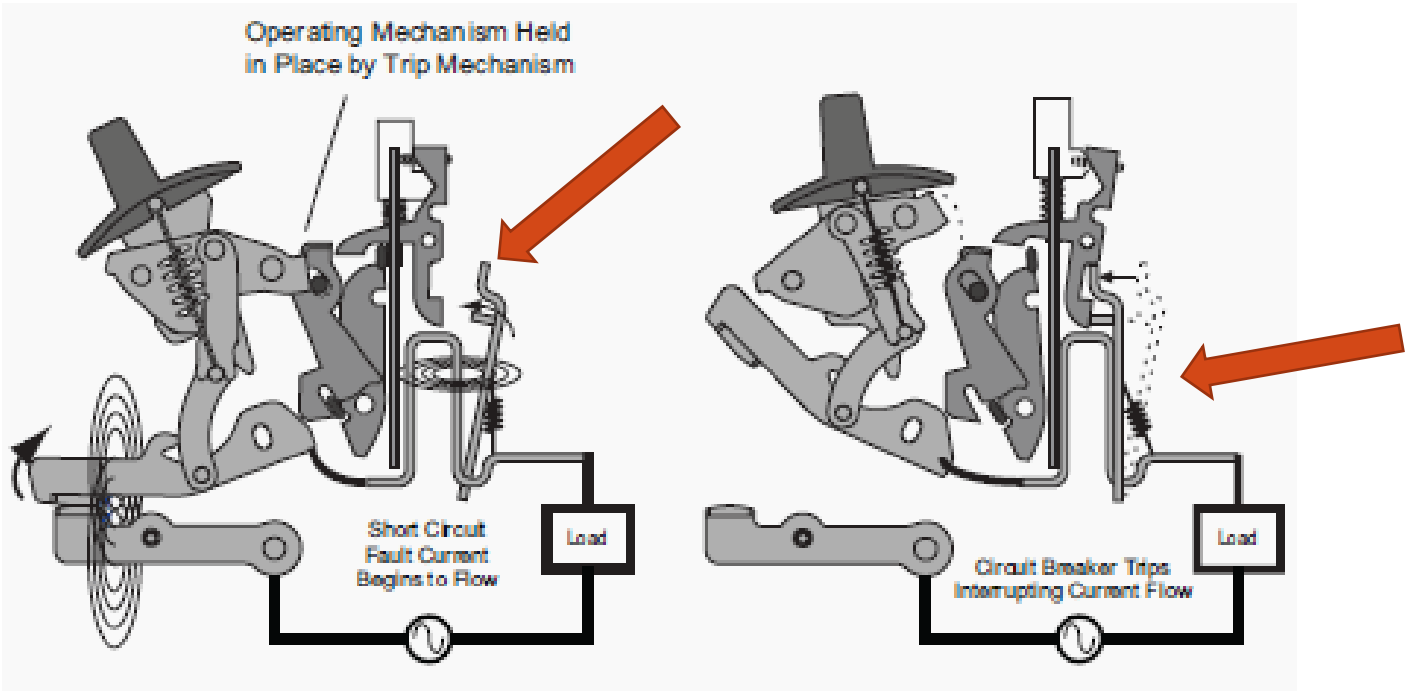
- Breaker in ON position, no overload

CIRCUIT BREAKERS

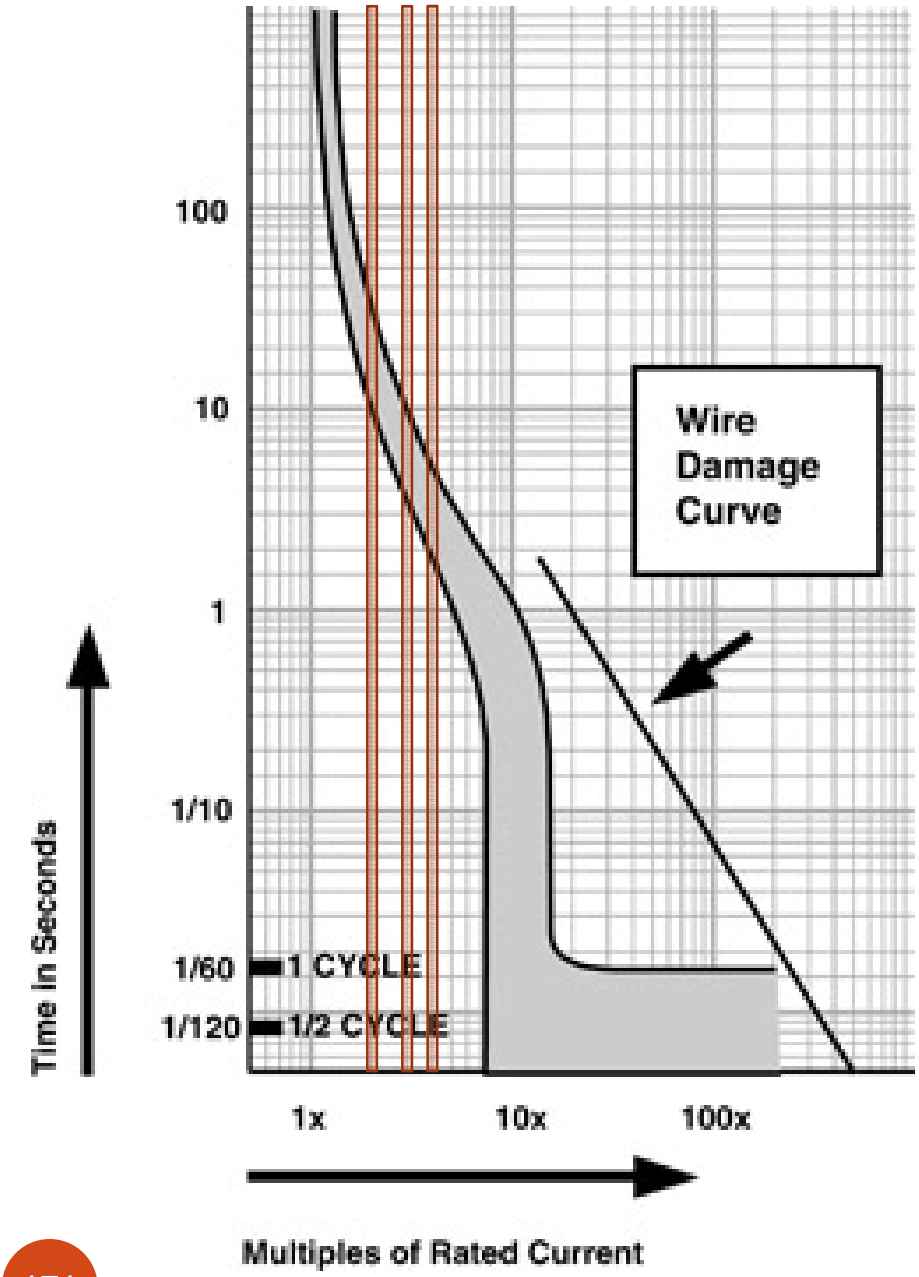


- Breaker tripped by **thermal** expansion of bi-metal strip

CIRCUIT BREAKERS



- Breaker tripped by **magnetic** activation



CIRCUIT BREAKER TRIP CURVES

Every circuit breaker has a “trip curve”

The “trip curve” shows how long, minimum and maximum, of time that it will take for a breaker to trip at a specific level of overcurrent.

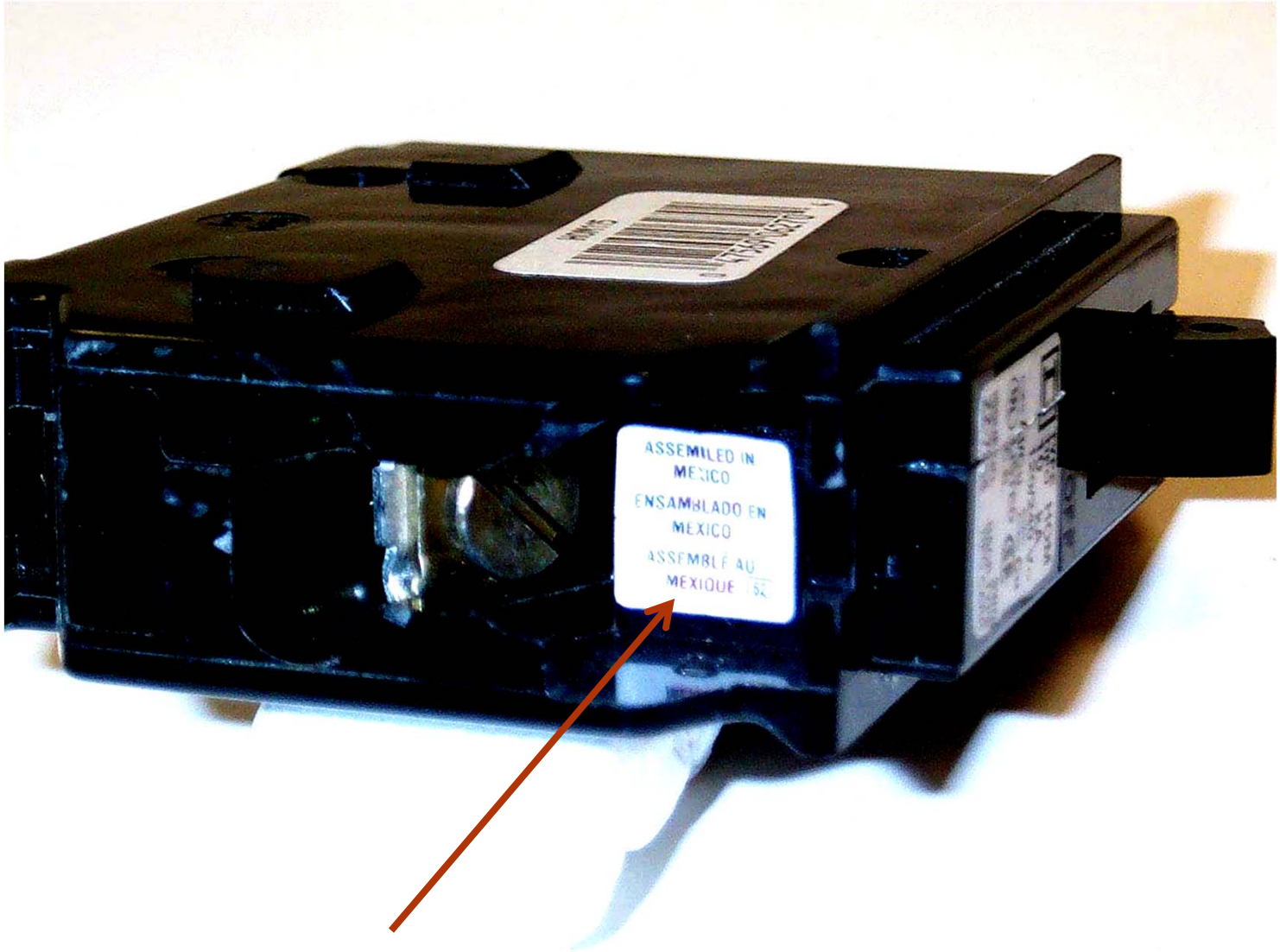
For example with this trip curve, a 20 amp breaker may take:

10 to **50** seconds to trip @ 40 amps

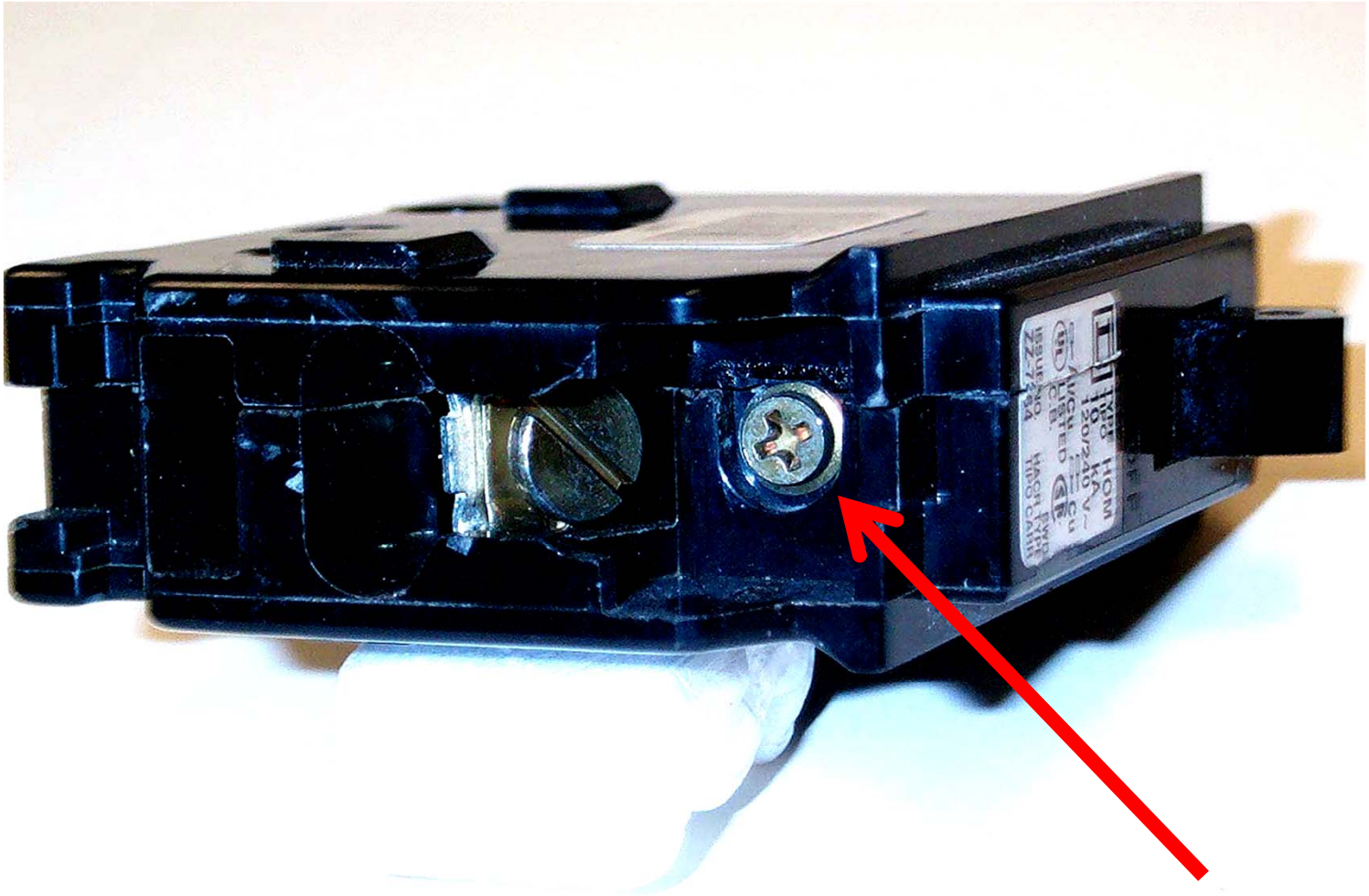
5 to **10** seconds to trip @ 60 amps

and

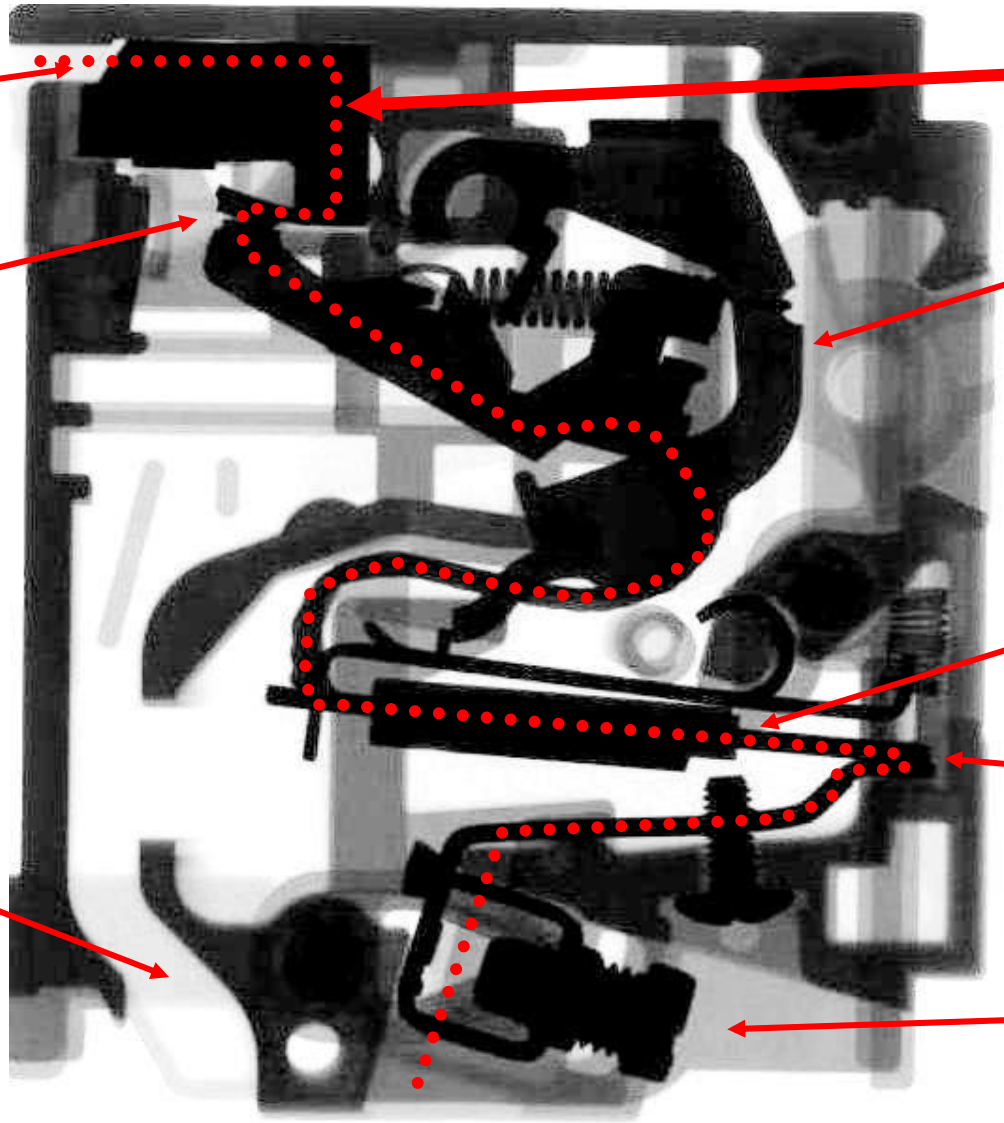
2 to **5** seconds @ 80 amps



Factory-set trip point adjustment screw under label


HOM
120/240V
1 POLE
THIN
HACH CAN
100 CAN

CIRCUIT BREAKERS

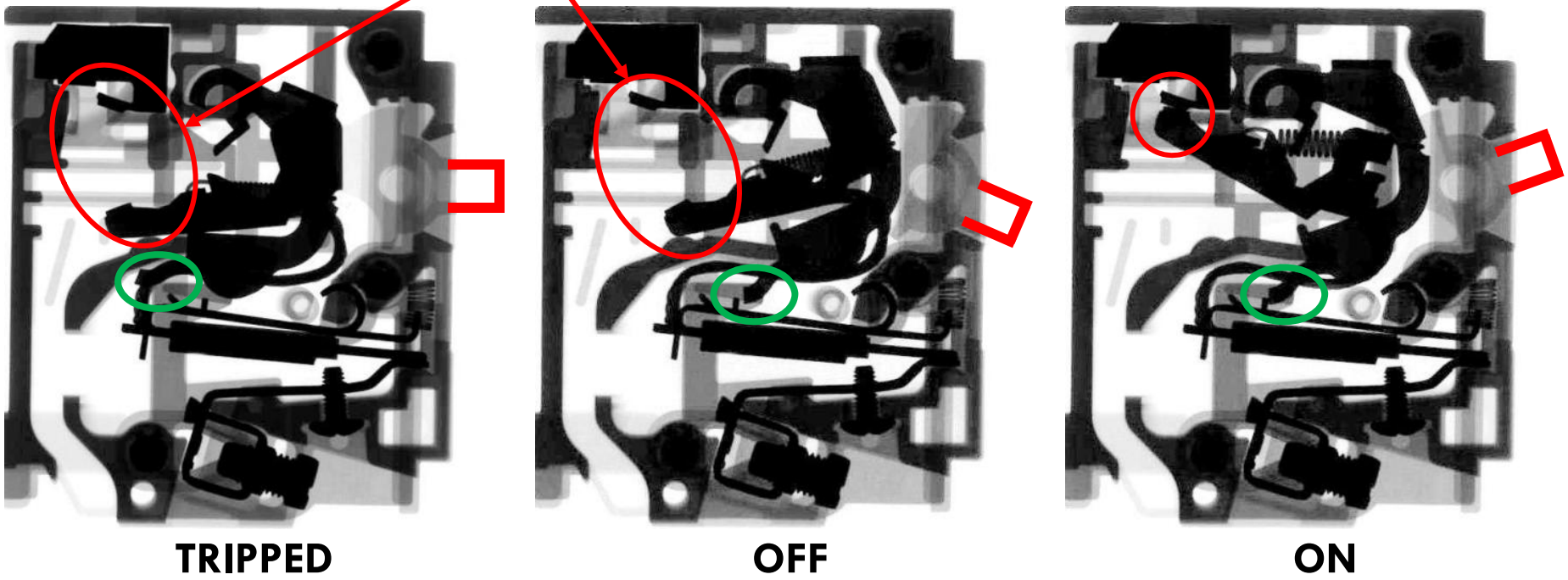


Courtesy Mike Keller, ATF-FRL

CIRCUIT BREAKERS

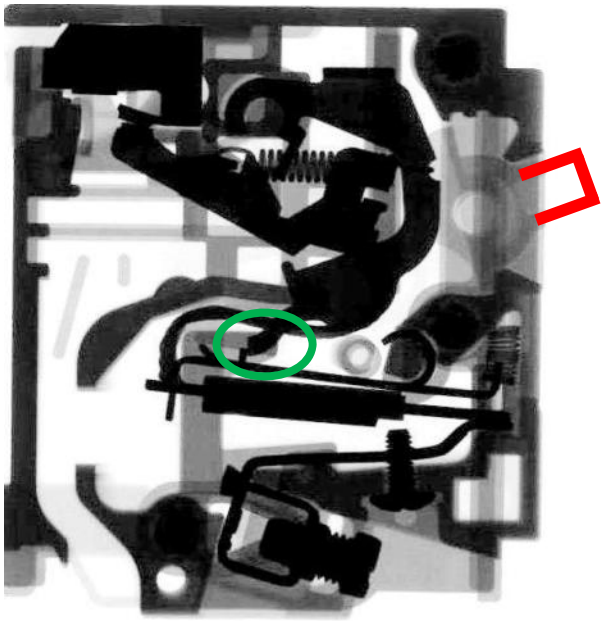
Contact Position – On or <u>NOT</u> on??

TRIPPED and OFF are nearly in the same position



Courtesy Mike Keller, ATF-FRL

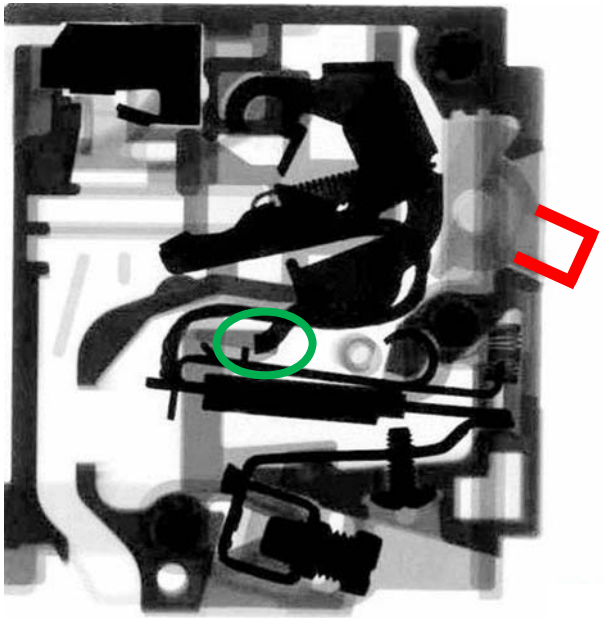
CIRCUIT BREAKERS



HANDLE MOVED TO **ON**

Courtesy Mike Keller, ATF-FRL

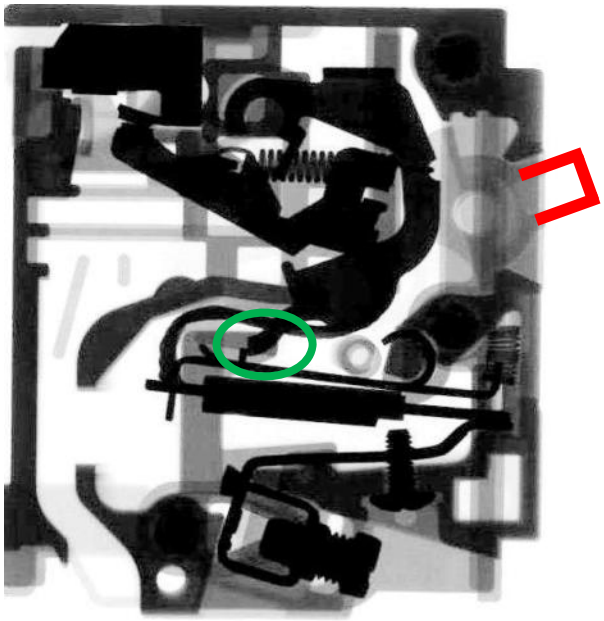
CIRCUIT BREAKERS



HANDLE MOVED TO **OFF**

Courtesy Mike Keller, ATF-FRL

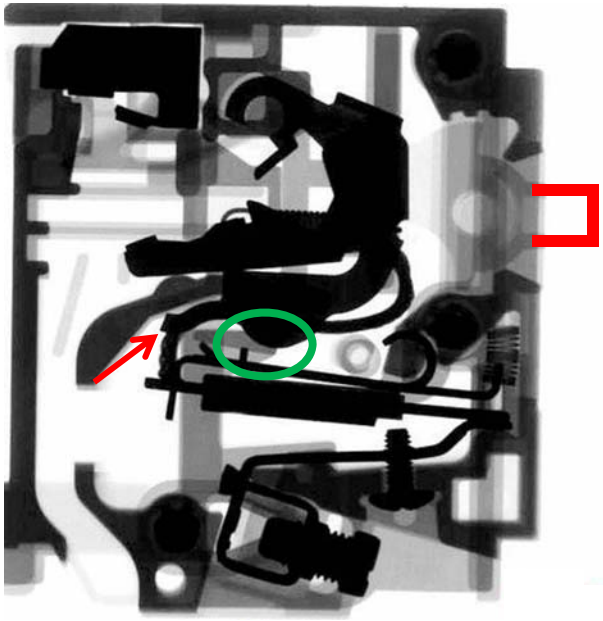
CIRCUIT BREAKERS



HANDLE MOVED TO **ON**

Courtesy Mike Keller, ATF-FRL

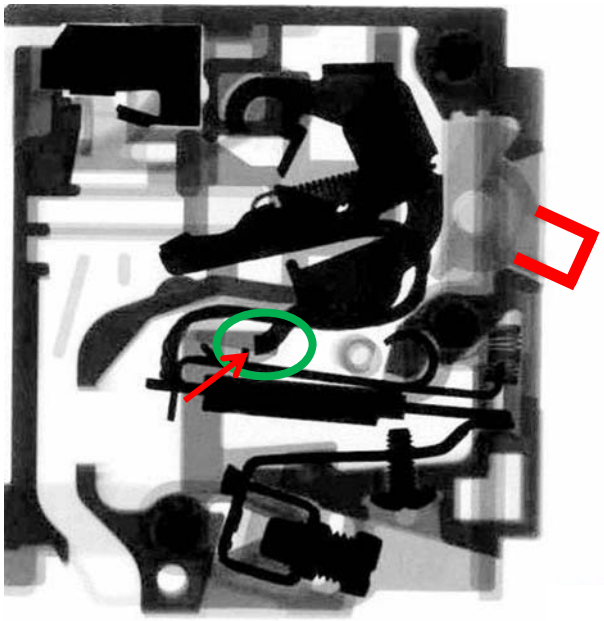
CIRCUIT BREAKERS



HANDLE TRIPPED TO **TRIPPED**

Courtesy Mike Keller, ATF-FRL

CIRCUIT BREAKERS



DIFFERENCE: TRIPPED VS. MOVED TO **OFF**

Courtesy Mike Keller, ATF-FRL

CIRCUIT BREAKERS

Play
“Circuit Breaker Open Slow Motion”
video

CIRCUIT BREAKERS

- Can you tell which cause (thermal vs. magnetic) tripped a circuit breaker by external examination?
- **NO!**
- Do not manipulate breaker handles!
- Remember: tripping mechanisms are also shock sensitive – handle and transport carefully if removing for further examination.
- Breakers can move from **OFF** or **ON** position to **TRIPPED** position from physical or thermal means.

SHUNT-TRIP BREAKERS

- Some breakers in industrial/commercial settings can be "tripped" remotely, usually for emergency shutoff purposes.
- This feature is commonly called a **shunt-trip** option, and is usually installed within the breaker itself, although there are external options available.
- Power required to activate the shunt-trip feature is usually EXTERNAL to the breaker – and therefore that control circuit is subject to fire impingement and unintended activation also - possibly remotely - regardless of the load on the breaker.

SHUNT-TRIP BREAKERS

- Can be identified in the panelboard by the presence of extra leads for the shunt-trip feature coming from the breaker – usually smaller gauge (16-18 AWG) wire.

SHUNT-TRIP BREAKERS

- This means that it is possible to find a breaker in a panelboard that is tripped, but was not overloaded or subjected to a short circuit.
- There is no way to determine, within the breaker itself if the shunt-trip feature was the cause of a tripped breaker.
- Supervisory control and data acquisition systems MAY record a shunt-trip input signal, especially in complex automated industrial systems. These control systems may be remotely located and undamaged by fire.

If there's a way to remotely turn a circuit breaker **OFF**…

Is there a way to remotely turn a circuit breaker **ON**?

Of course there is!

REMOTELY OPERATED BREAKERS

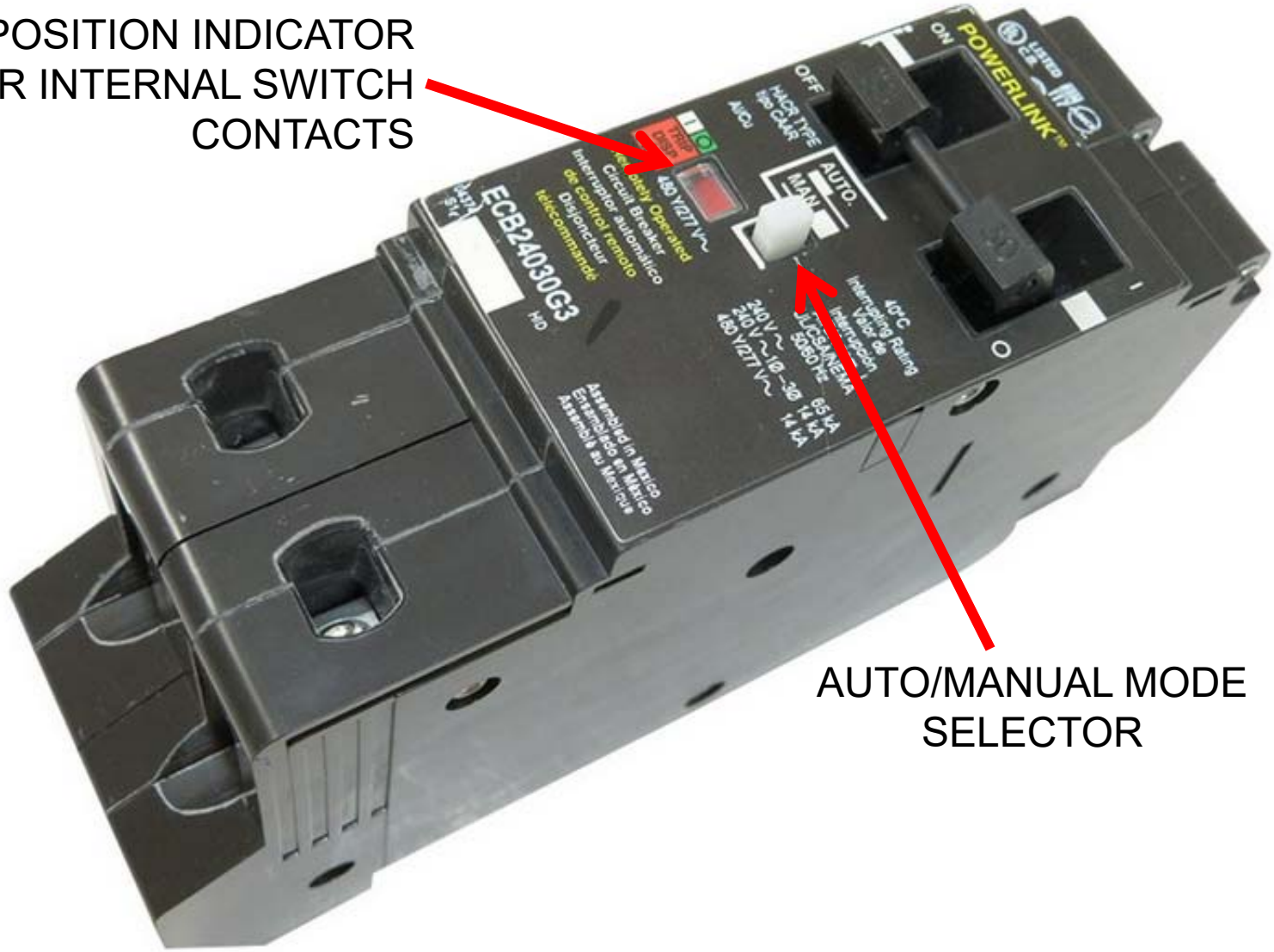
- An internal, electrically activated mechanism moves the contact mechanism INSIDE the breaker to the **ON** or **OFF** position, without moving the handle. The external switch handle must be in the **ON** position for remote ON/OFF capability.
- Similar appearance to a standard breaker when viewed from panel front.
- External switch handle can be in the **ON** position, but internally the circuit can be **OFF**. An external/viewable indicator of the internal contact position is usually present.
- Under normal operating conditions, the internal contacts of a remotely controlled circuit breaker cannot be moved to the **ON** position when the *HANDLE* is in **OFF** or **TRIPPED** position.

REMOTELY OPERATED BREAKERS

- Power to switch control mechanism may be internal or external to breaker – and mechanism can be activated multiple times in either direction due to fire impingement of remotely located control circuitry.
- Can be manually overridden and "bypassed" from any remote control capability.

REMOTELY OPERATED BREAKERS

POSITION INDICATOR
FOR INTERNAL SWITCH
CONTACTS



AUTO/MANUAL MODE
SELECTOR

REMOTELY OPERATED BREAKERS

- Most commonly used for control of lighting circuits, but can be used for switching any load.

Is there another way a circuit breaker can be tripped?

Of course there is!

LOW VOLTAGE DROPOUT BREAKERS

- Some breakers in industrial/commercial settings can also be configured to trip due to low voltage situations, aka: "brownouts", or undervoltage situations
- The intention of this feature is to prevent damage to equipment that may occur from it operating at less than the designed voltage.
- Similar panel-front appearance to "standard" breakers
- Similar tripping mechanism as shunt-trip breaker – breaker will move to "tripped" position, giving a false indication that it may have tripped from overload or short-circuit.
- Voltage loss or reduction can be caused by fire-induced faults.

KNOWN
“PROBLEM CHILD”
BREAKER PANEL STYLES

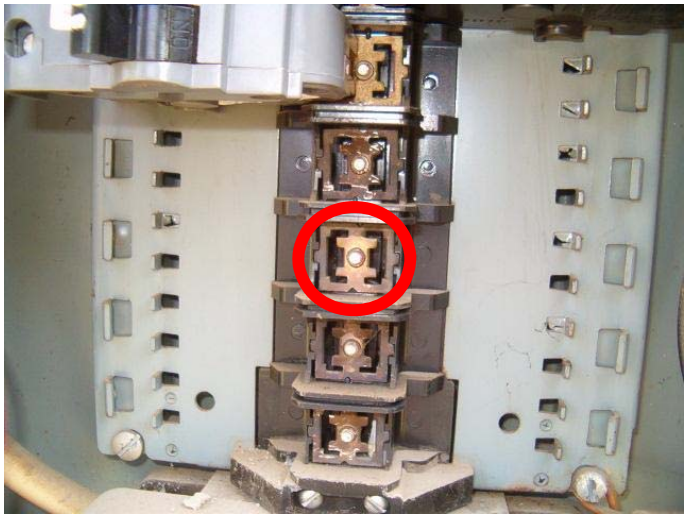
CIRCUIT BREAKERS

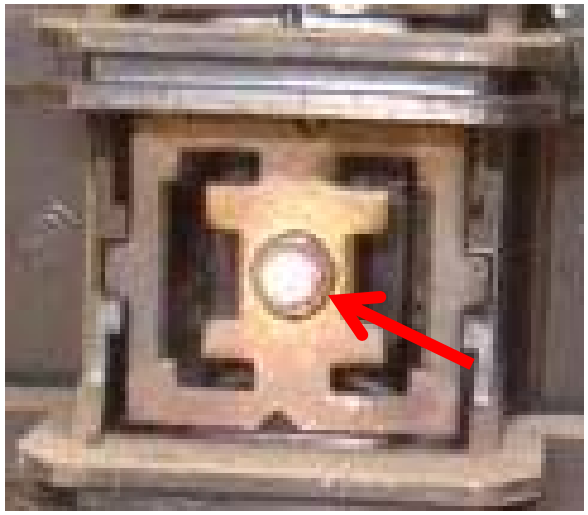
FEDERAL PACIFIC "STAB-LOK" PANELS

CIRCUIT BREAKERS

FEDERAL PACIFIC "STAB-LOK" PANELS

- Multiple design problems that resulted in multiple possible points of failure.
- Poorly designed bus bar connection resulted in resistance and resulting heat, which then affected breaker to bus bar connection.





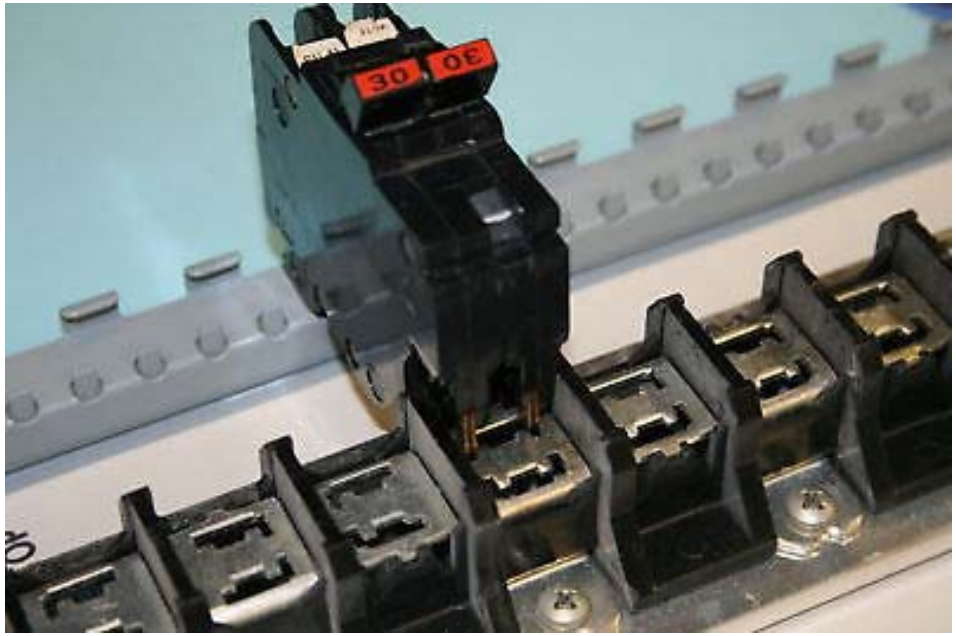
#12 machine screw only point of contact for potential load of up to 140 amps!

(1 leg each of opposite 70A breakers on same bus bar terminal)

CIRCUIT BREAKERS

FEDERAL PACIFIC "STAB-LOK" PANELS

- The "fix" addressed the bus bar issue, but the breaker to bus bar connection is still a problem



More surface contact of terminal block with bus bar

CIRCUIT BREAKERS

FEDERAL PACIFIC "STAB-LOK" PANELS

- Breaker "tab" connection at bus bar remains a problem
- Subject to loss of connection pressure, corrosion, and increased resistance and heat as a result.

CIRCUIT BREAKERS

FEDERAL PACIFIC "STAB-LOK" PANELS

- Breaker "tab" connection at bus bar remains a problem
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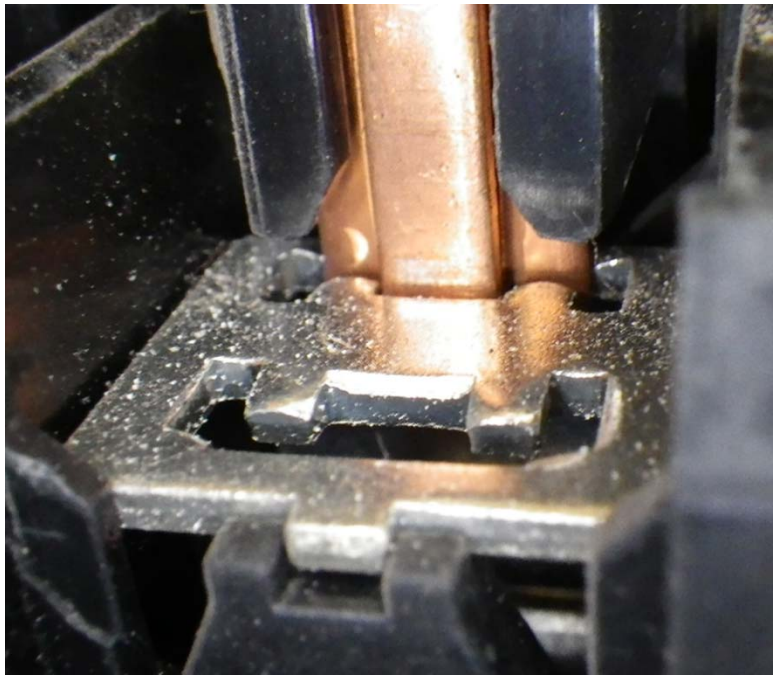
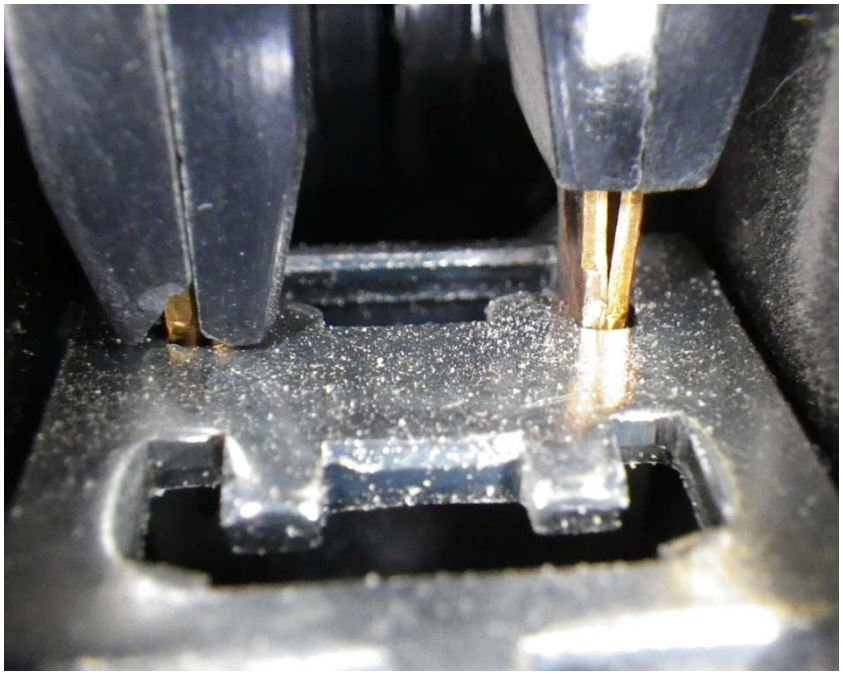
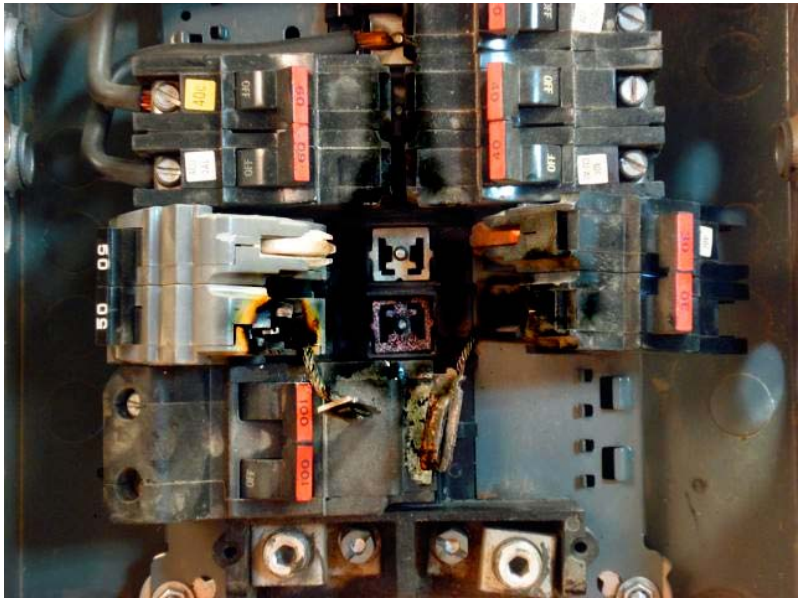




Photos courtesy of Cameron Novak

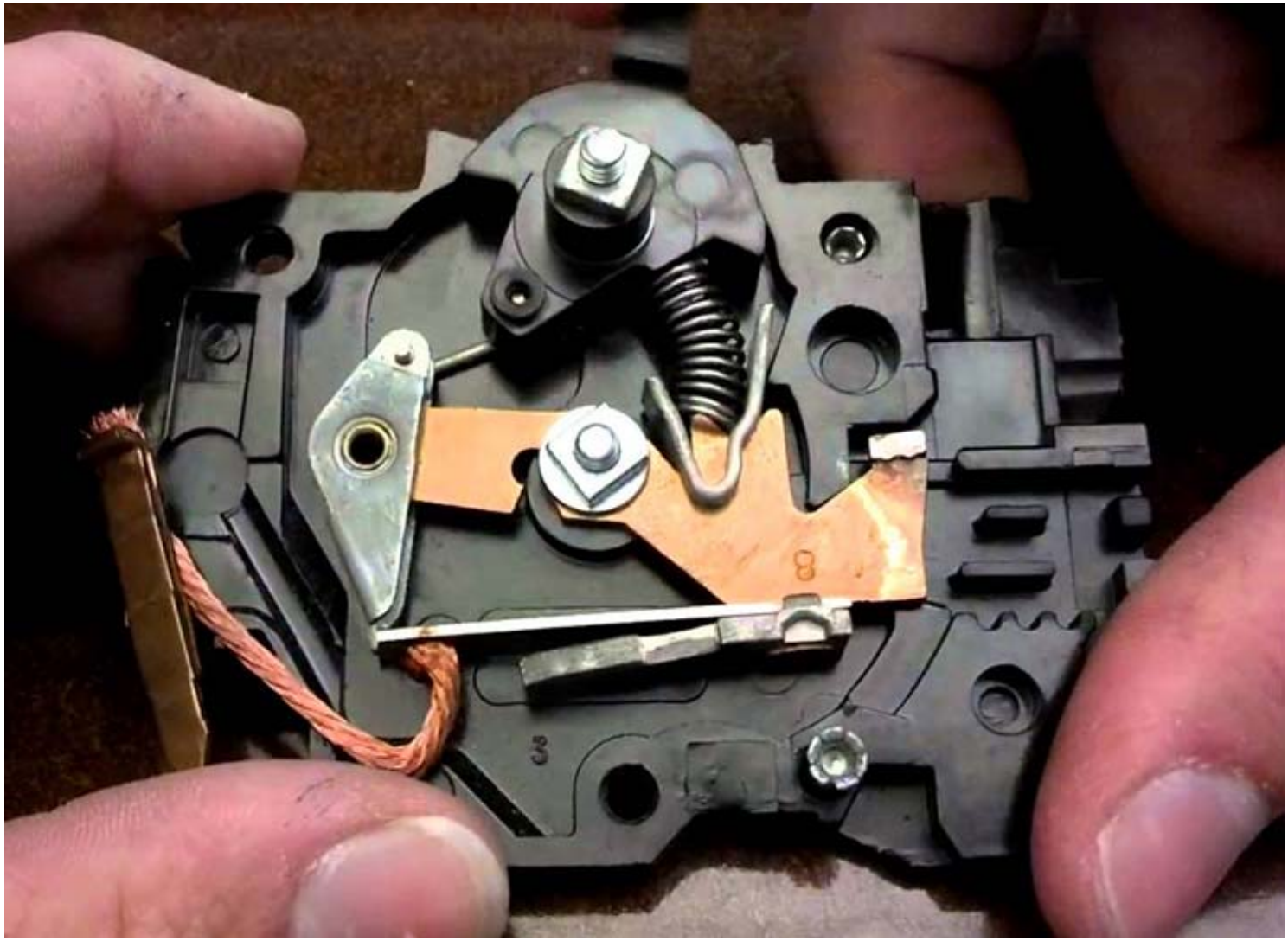
CIRCUIT BREAKERS

FEDERAL PACIFIC "STAB-LOK" PANELS



CIRCUIT BREAKERS

FEDERAL PACIFIC "STAB-LOK" PANELS



CIRCUIT BREAKERS

FEDERAL PACIFIC "STAB-LOK" PANELS

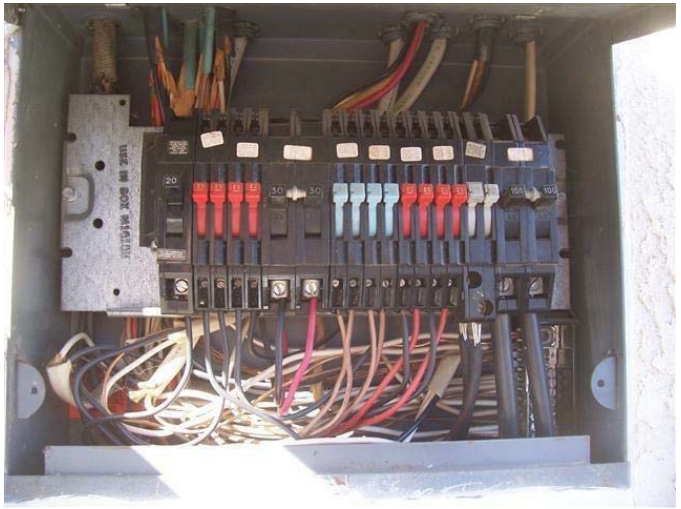
CIRCUIT BREAKERS

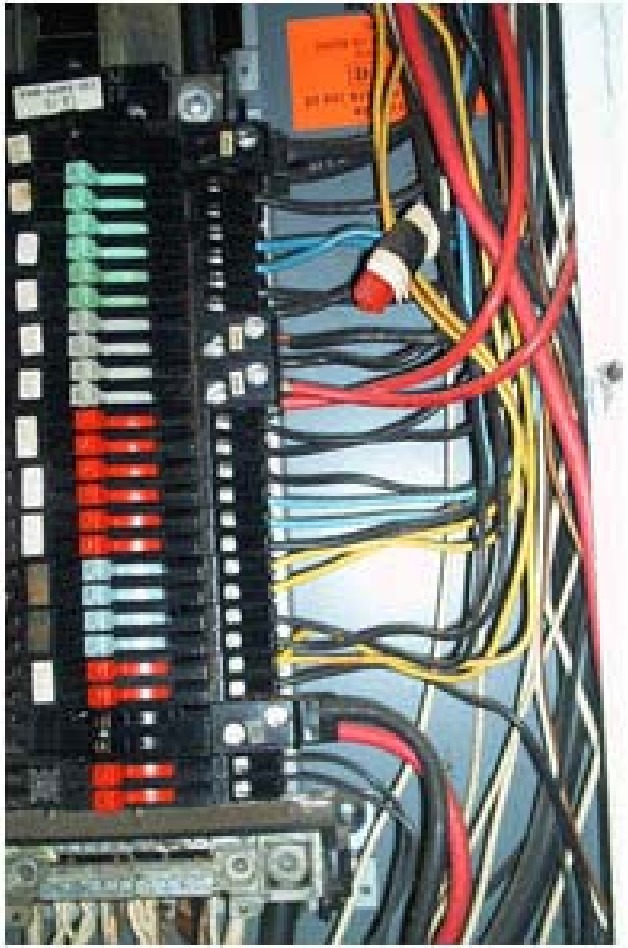
FEDERAL PACIFIC "STAB-LOK" PANELS

- Double-pole breakers have a potential issue with the internal mechanism jamming when only one leg/side of breaker trips – other leg remains in **ON** position and unable to trip at <u>any</u> current level – creating an obvious problem if there is an overcurrent situation!

CIRCUIT BREAKERS

GTE/ SYLVANIA "ZINSCO" PANELS

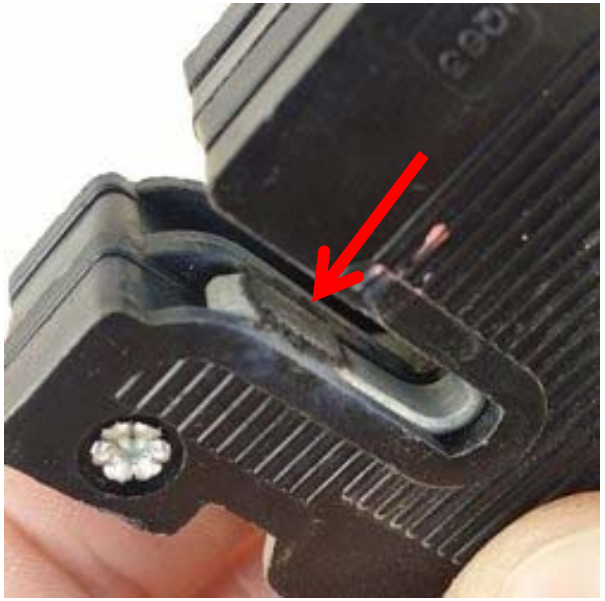




CIRCUIT BREAKERS

GTE/ SYLVANIA "ZINSCO" PANELS

- Poor contact with bus bar resulting in arcing, increased resistance, and resultant heat at connection.
- Feed bar choice for single pole breakers was "field-selectable" and held in place by a tiny machine screw.



CIRCUIT BREAKERS

GTE/ SYLVANIA "ZINSCO" PANELS

- Bus bar came in both aluminum and copper versions, but connection issue exists for both.

CIRCUIT BREAKERS

GTE/ SYLVANIA "ZINSCO" PANELS

CIRCUIT BREAKERS

GTE/ SYLVANIA "ZINSCO" PANELS

CIRCUIT BREAKERS

GTE/ SYLVANIA "ZINSCO" PANELS

- Breaker internal failure – may not trip at rated current - if at all - resulting in failures that can develop elsewhere.

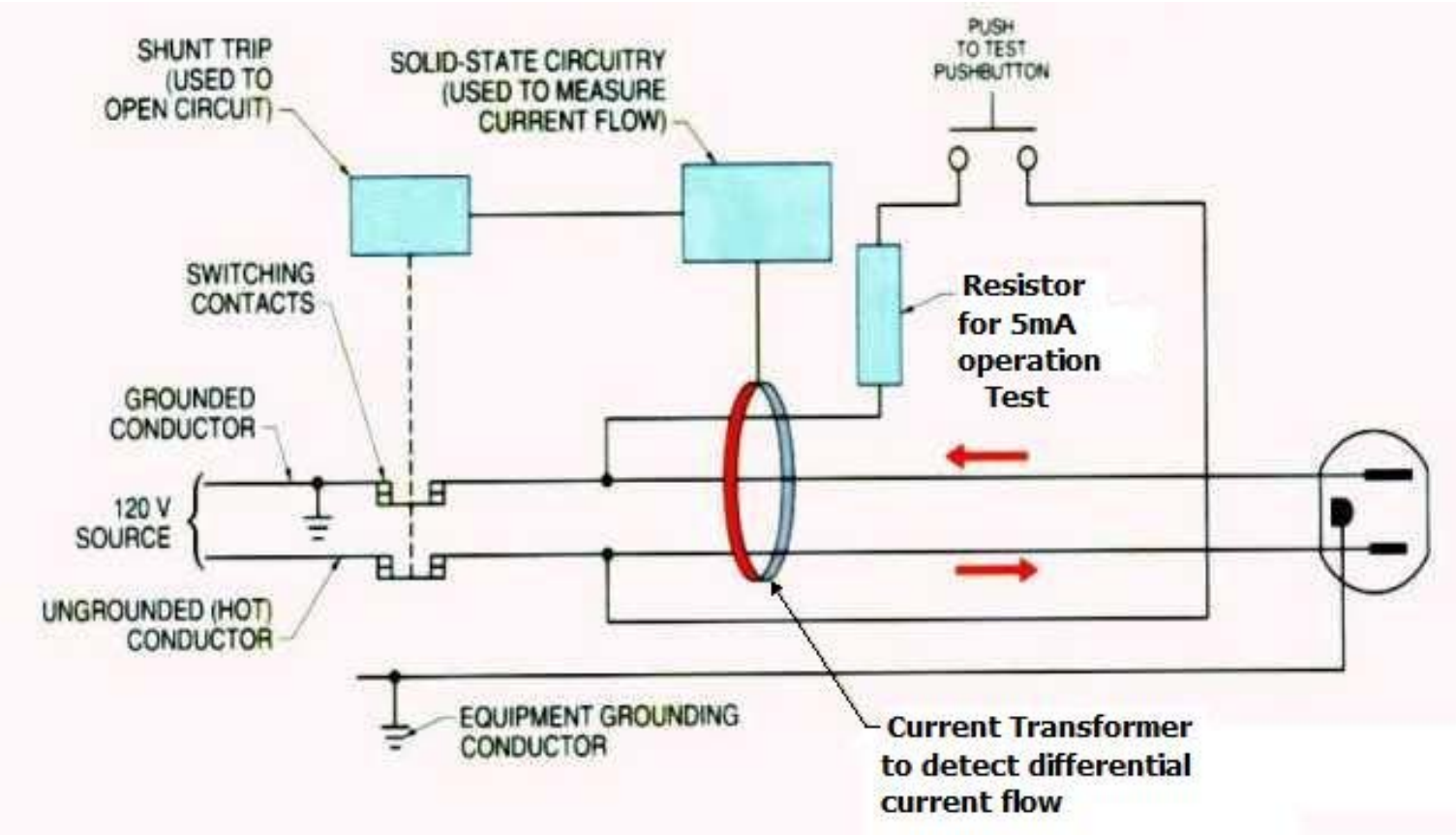
CIRCUIT BREAKERS

REMEMBER

A breaker may fail to trip, but that does not necessarily mean the breaker is the cause of the fire – it means the breaker merely allowed another issue elsewhere to progress!

GFCI CIRCUIT BREAKERS

GFCI CIRCUIT BREAKERS



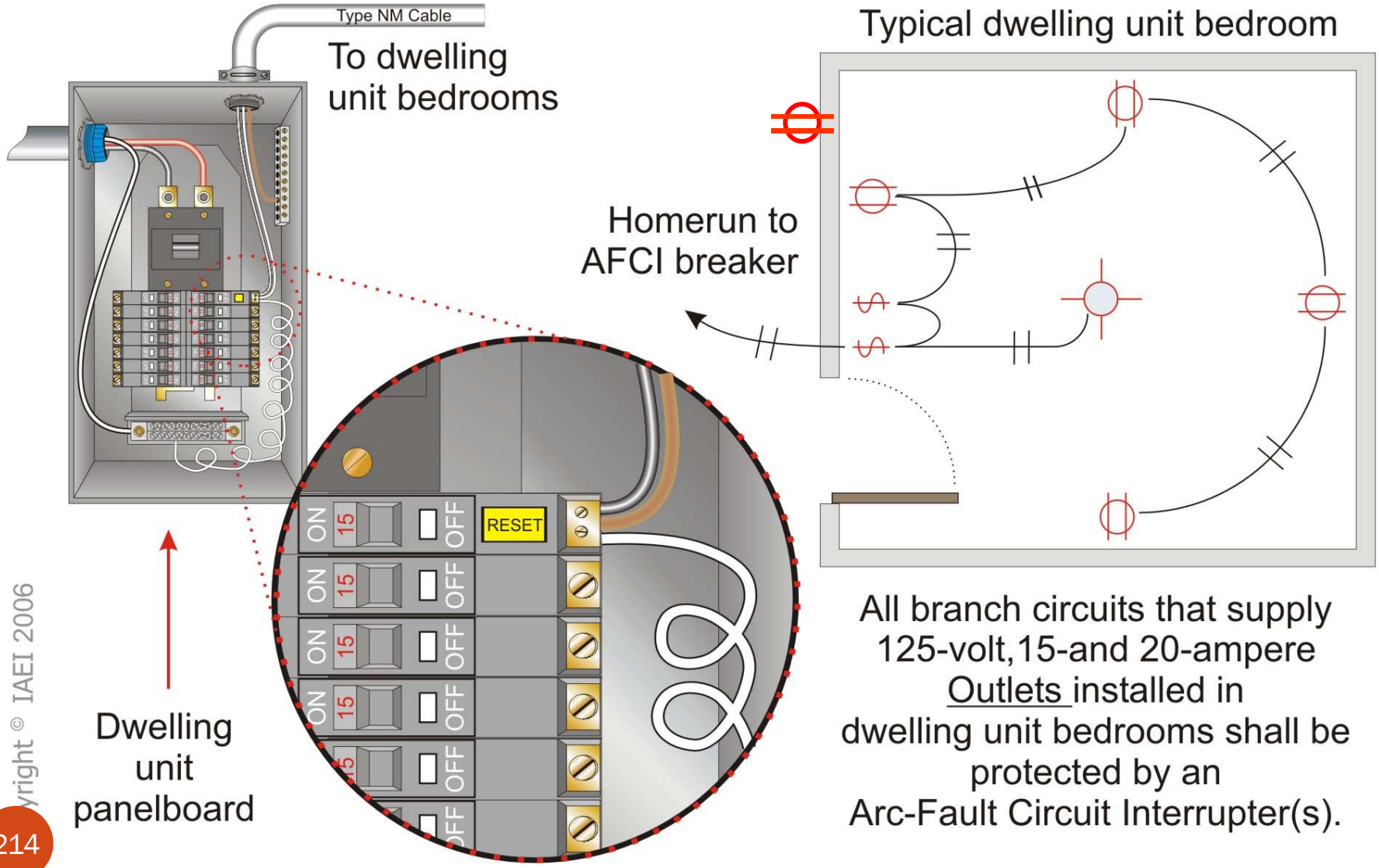
If current returning is not equal to current entering the circuit, that means it's finding another path to take!

ARC-FAULT CIRCUIT-INTERRUPTERS

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:

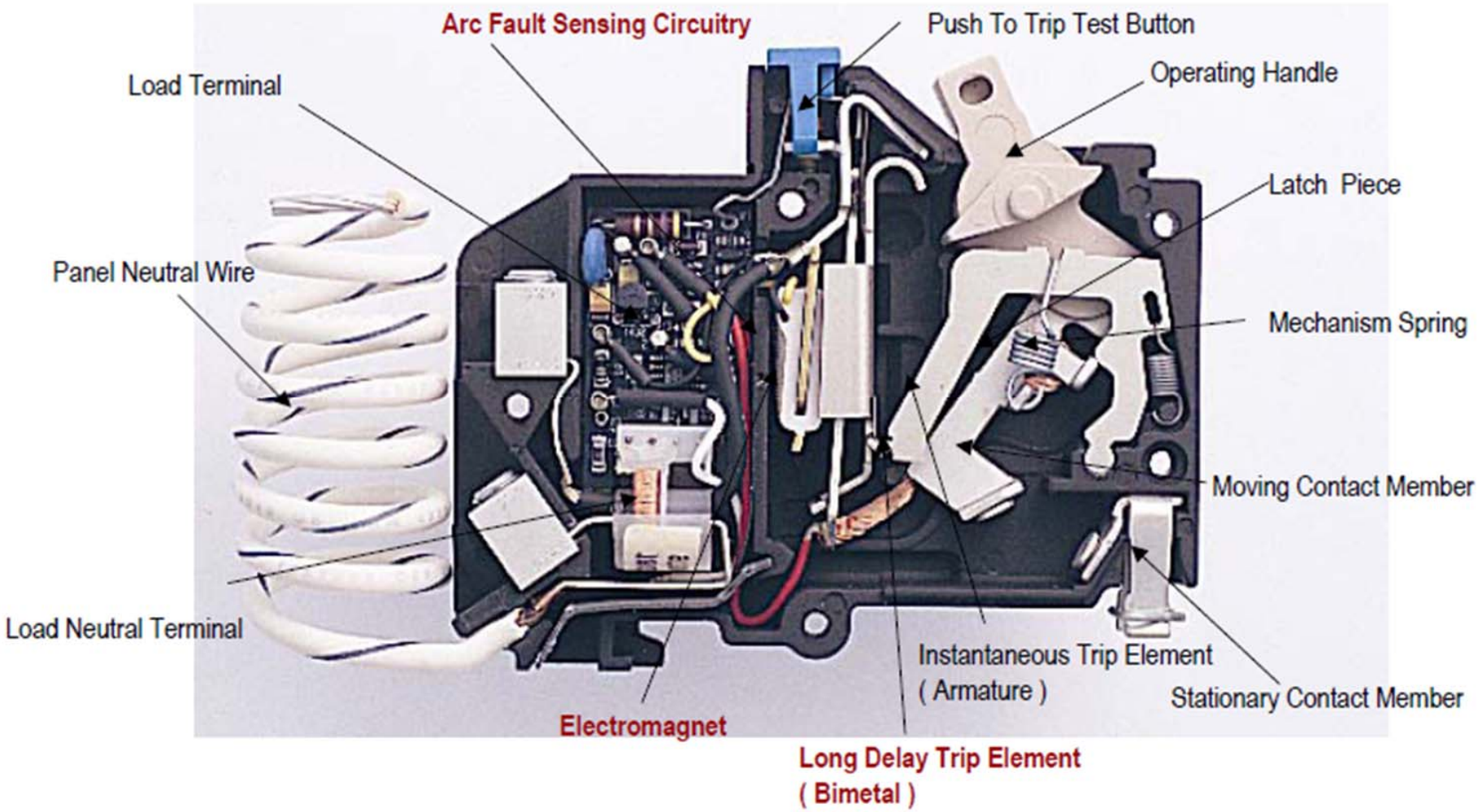
ARC-FAULT CIRCUIT-INTERRUPTER PROTECTION



All branch circuits that supply 125-volt,15-and 20-ampere Outlets installed in dwelling unit bedrooms shall be protected by an Arc-Fault Circuit Interrupter(s).

yright © IAEI 2006

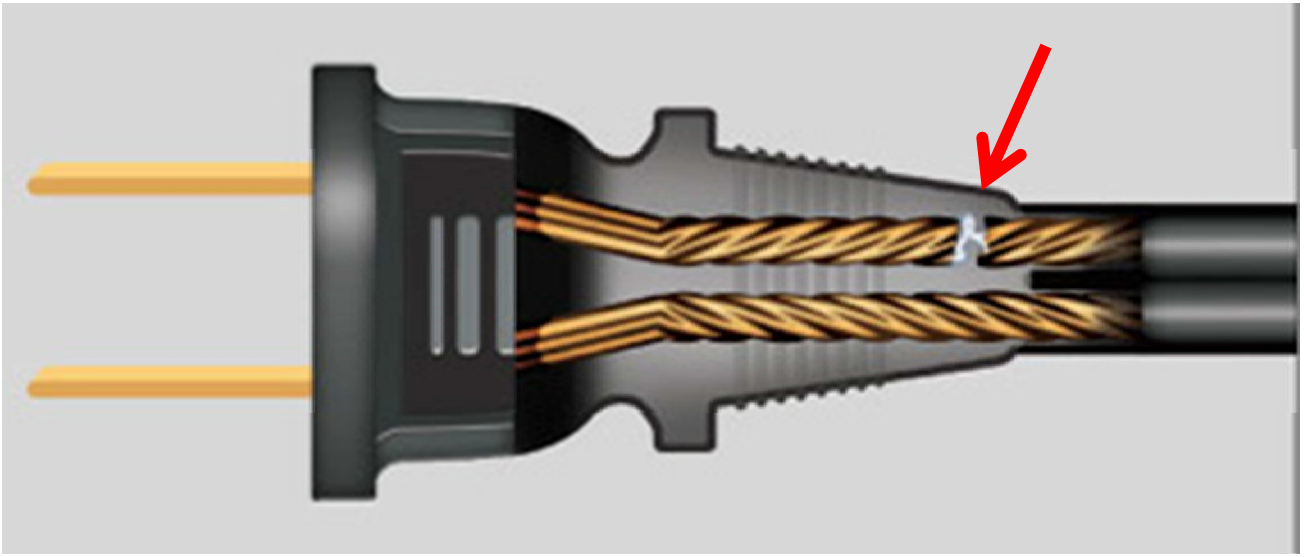
ARC-FAULT CIRCUIT-INTERRUPTER BREAKER INTERNAL COMPONENTS



ARC-FAULT CIRCUIT-INTERRUPTER BREAKERS

Listed "Combination" AFCI devices protect against two types of arcing:

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

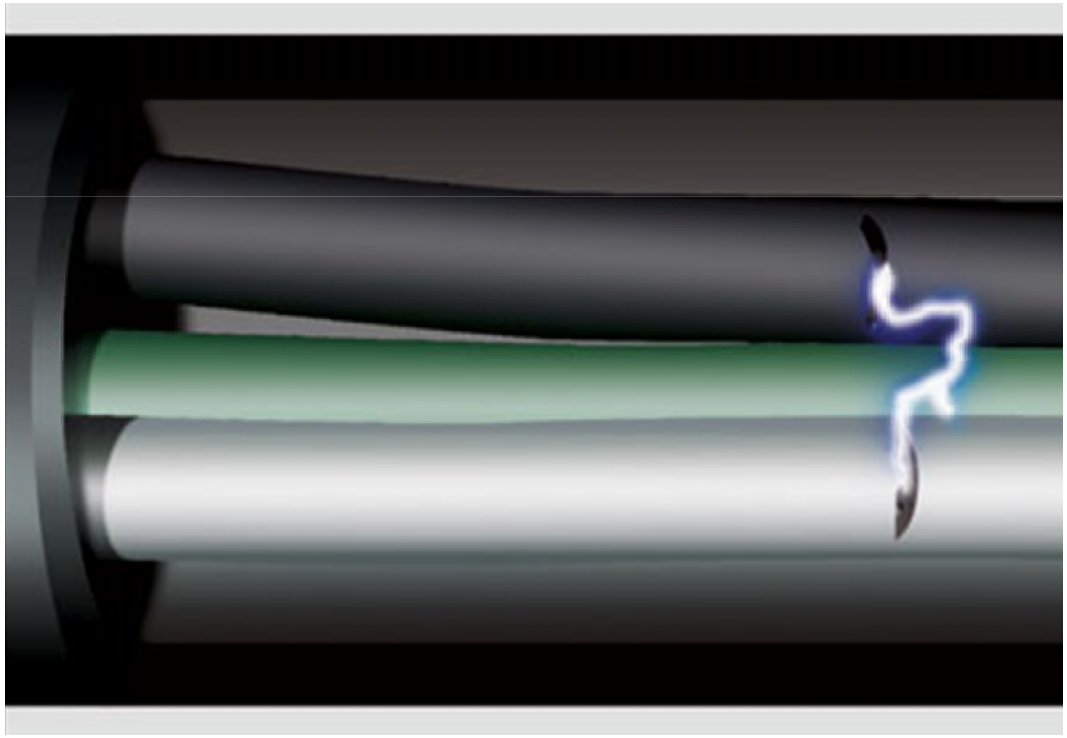


Usually self-current-limiting – once conductor is severed, current flow and arcing stops.

ARC-FAULT CIRCUIT-INTERRUPTER BREAKERS

Listed "Combination" AFCI devices protect against two types of arcing:

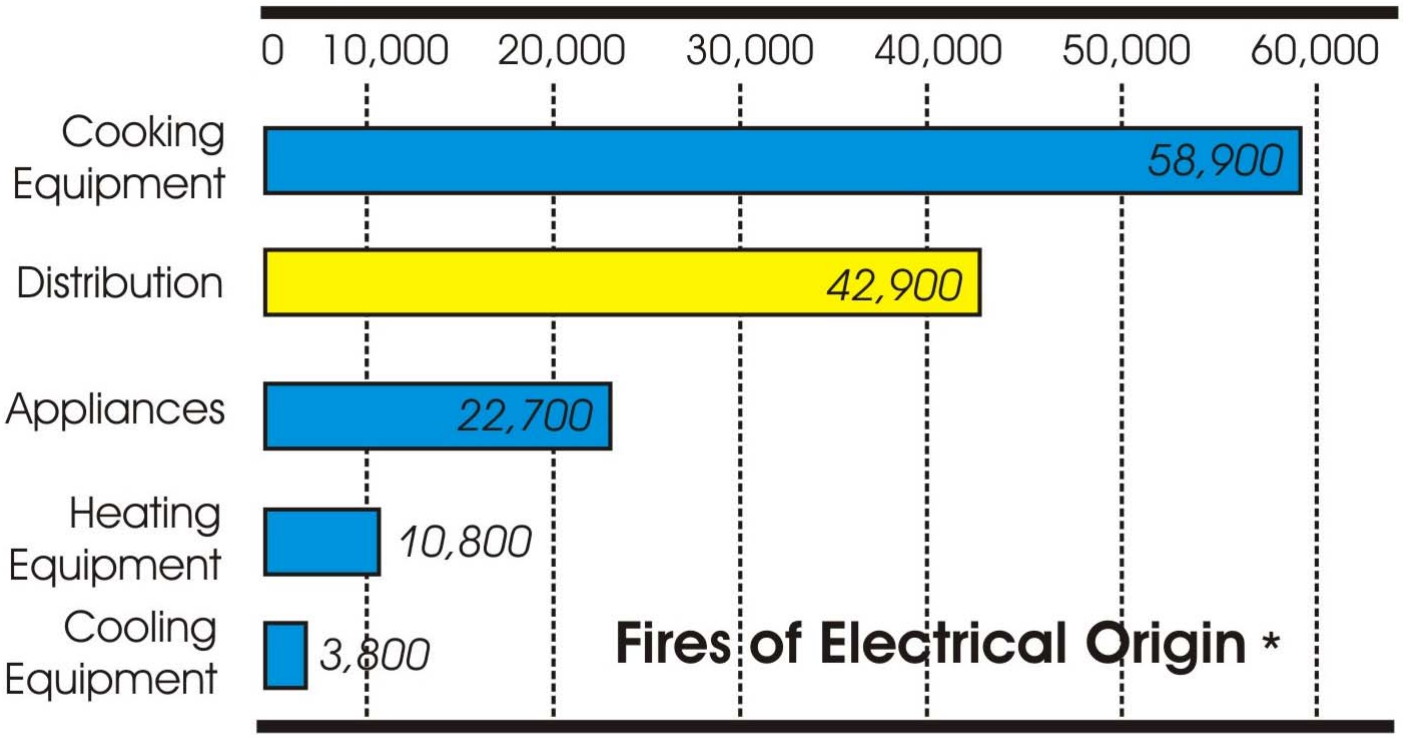
Parallel Arcing: Arcing between two conductors



More damaging, more dangerous – limited only by breaker and available fault current.

ORIGINAL SUBSTANTIATION FOR AFCI PROTECTION

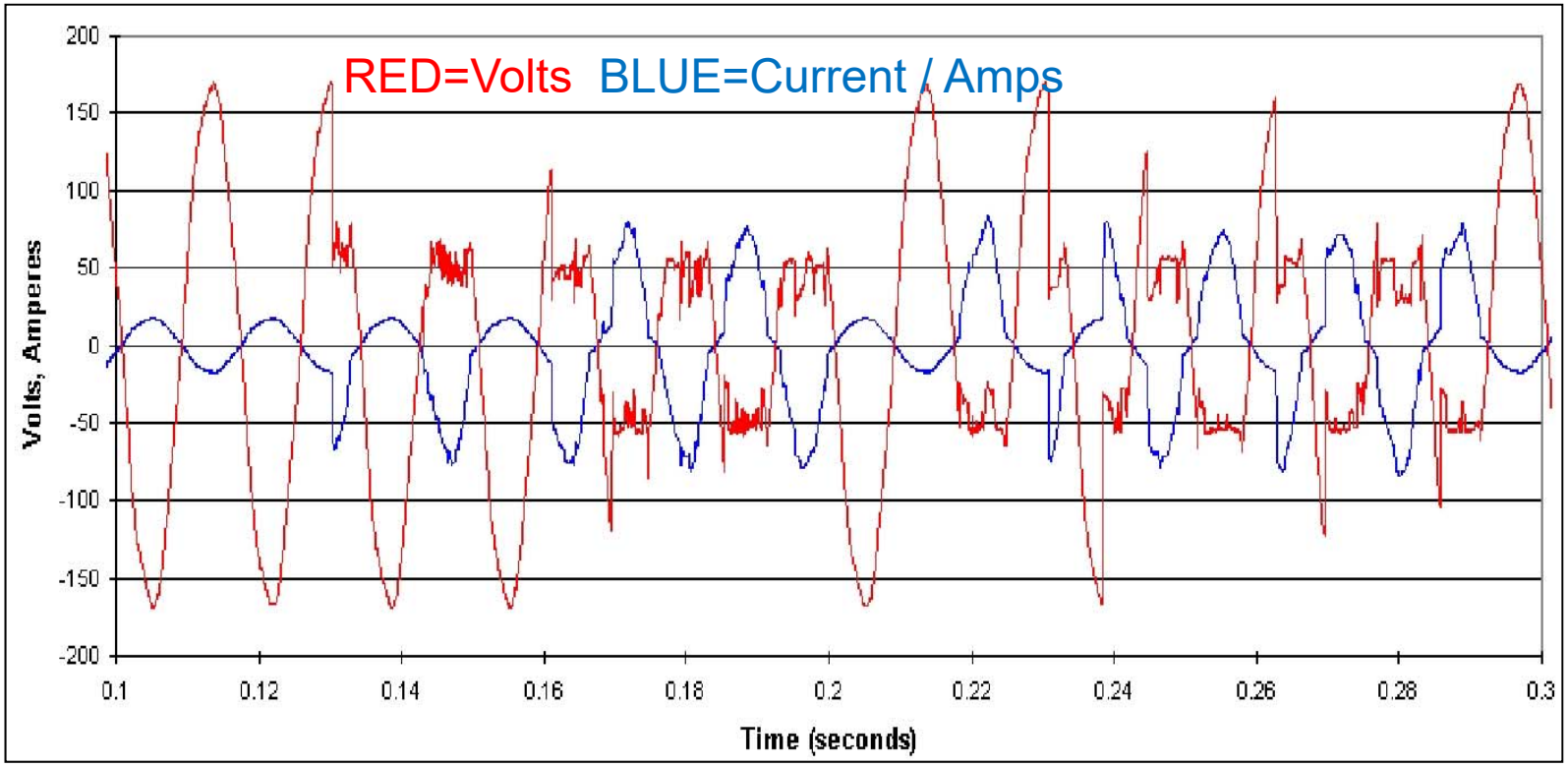
155,000 Total Electrical Fires
451,000 Total Residential Fires From All Causes



Many distribution fires are believed to have been started by arcing faults

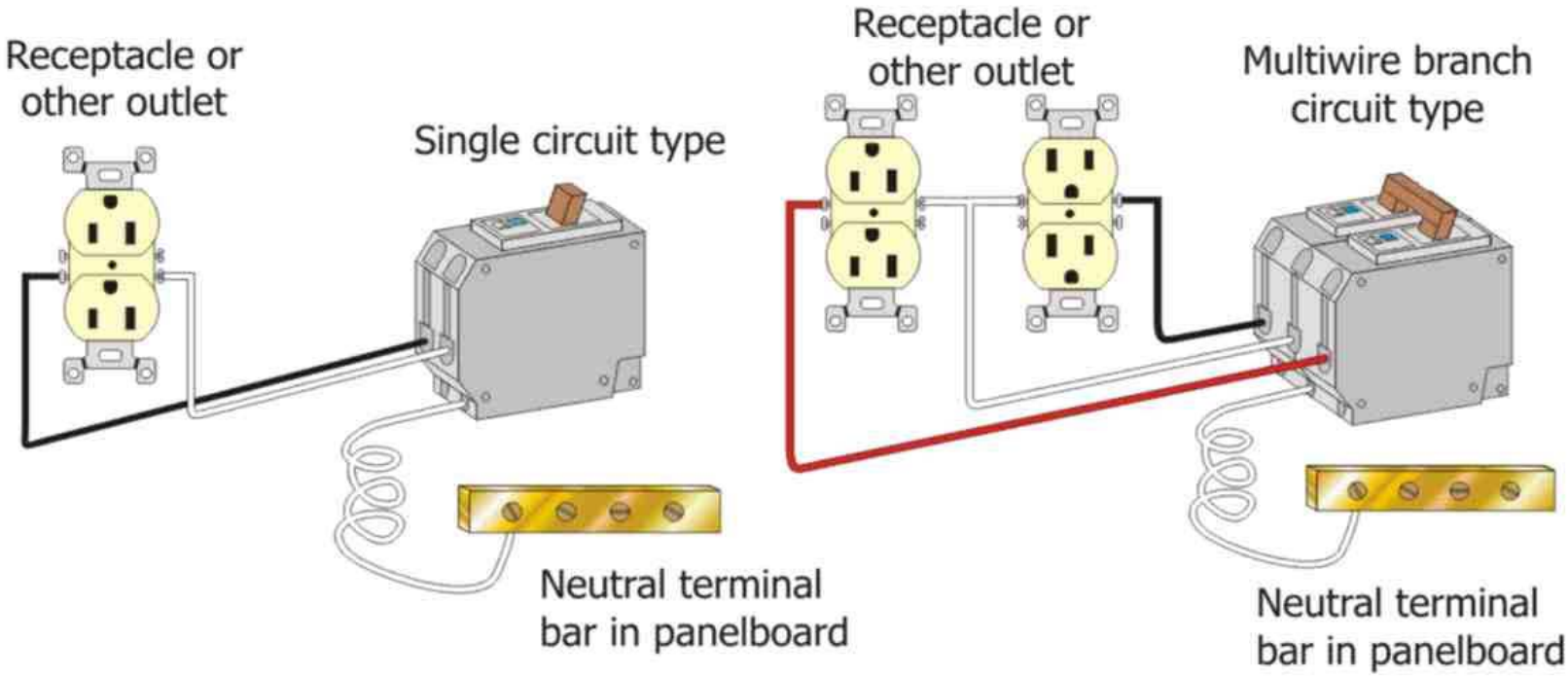
* ***1994 Consumer Products Safety Commission estimates***

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

210.12(B) Dwelling Units



AFCI protection required for 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets installed in dwelling unit family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sun rooms, recreation rooms, closets, hallways, or similar rooms or areas.

A listed arc-fault circuit interrupter, combination-type, shall be installed to provide protection of the branch circuit.

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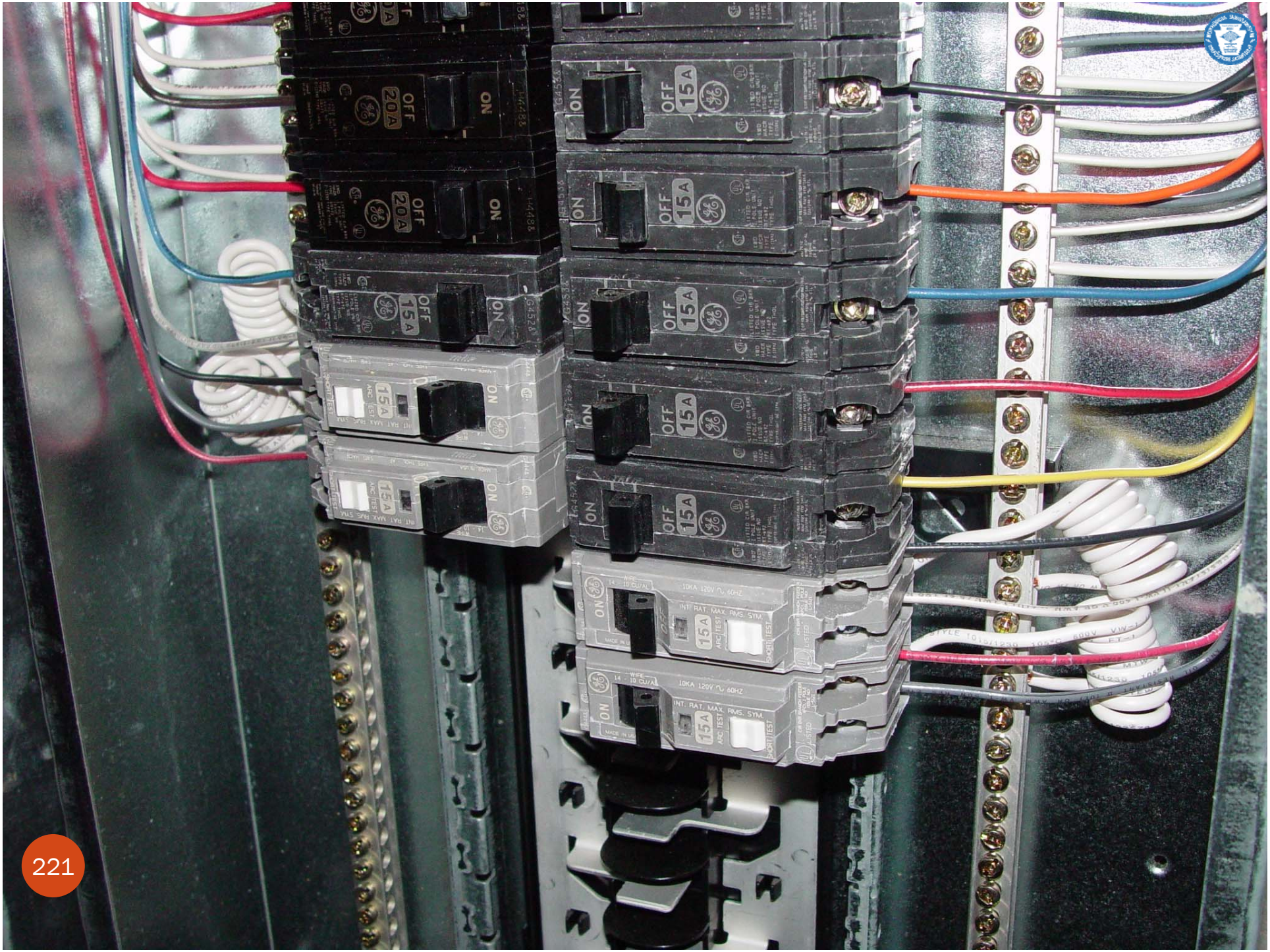
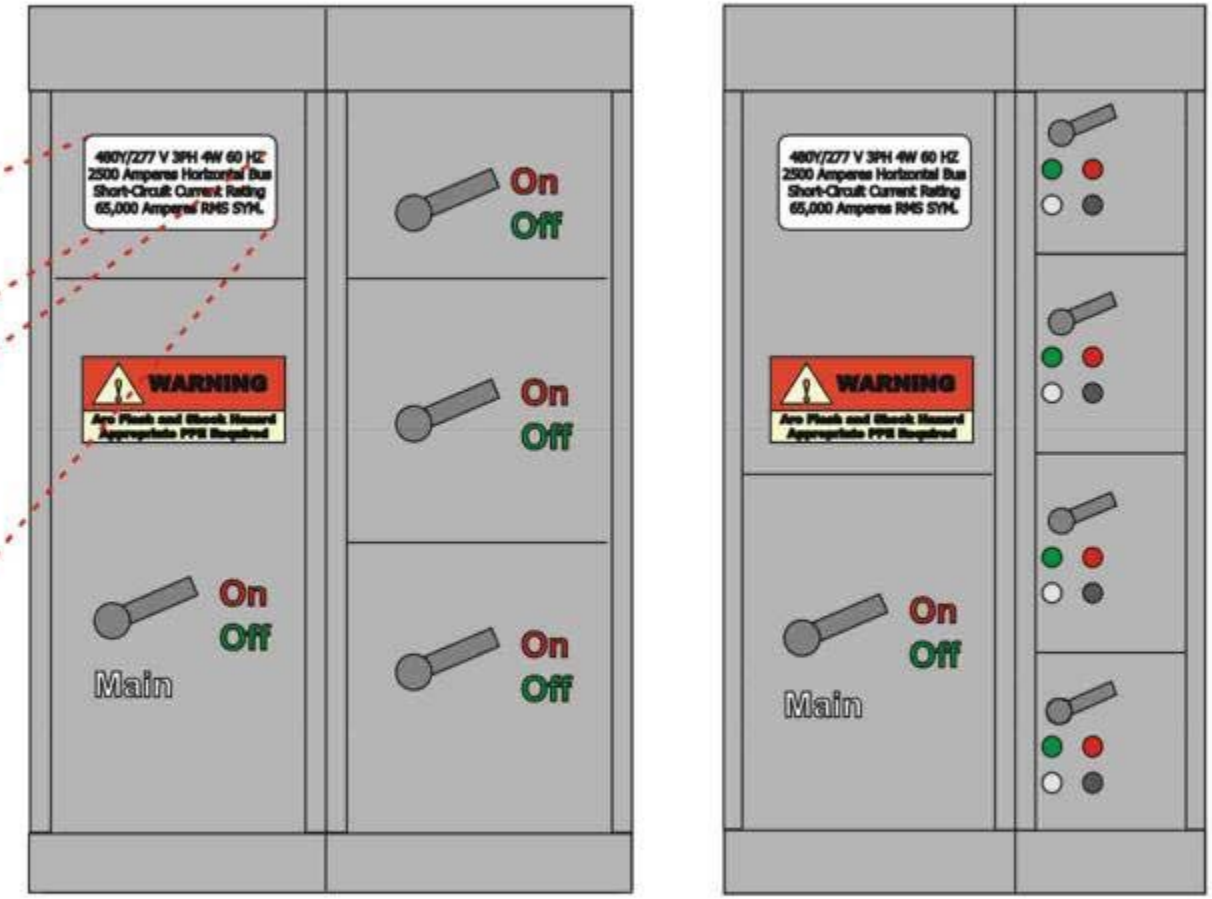

OFF
20A
ON
OFF
15A
ON
10KA 120V ~ 60HZ
INT. RAT. MAX. RMS. SYM.
ARC TEST
SHORT TEST

Article 100 Short-Circuit Current Rating

Short-circuit current ratings marked on equipment

480Y/277 V 3PH 4W 60 HZ
2500 Amperes Horizontal Bus
Short-Circuit Current Rating
65,000 Amperes RMS SYM.



The prospective symmetrical fault current at a nominal voltage to which an apparatus or system is able to be connected without sustaining damage exceeding defined acceptance criteria.

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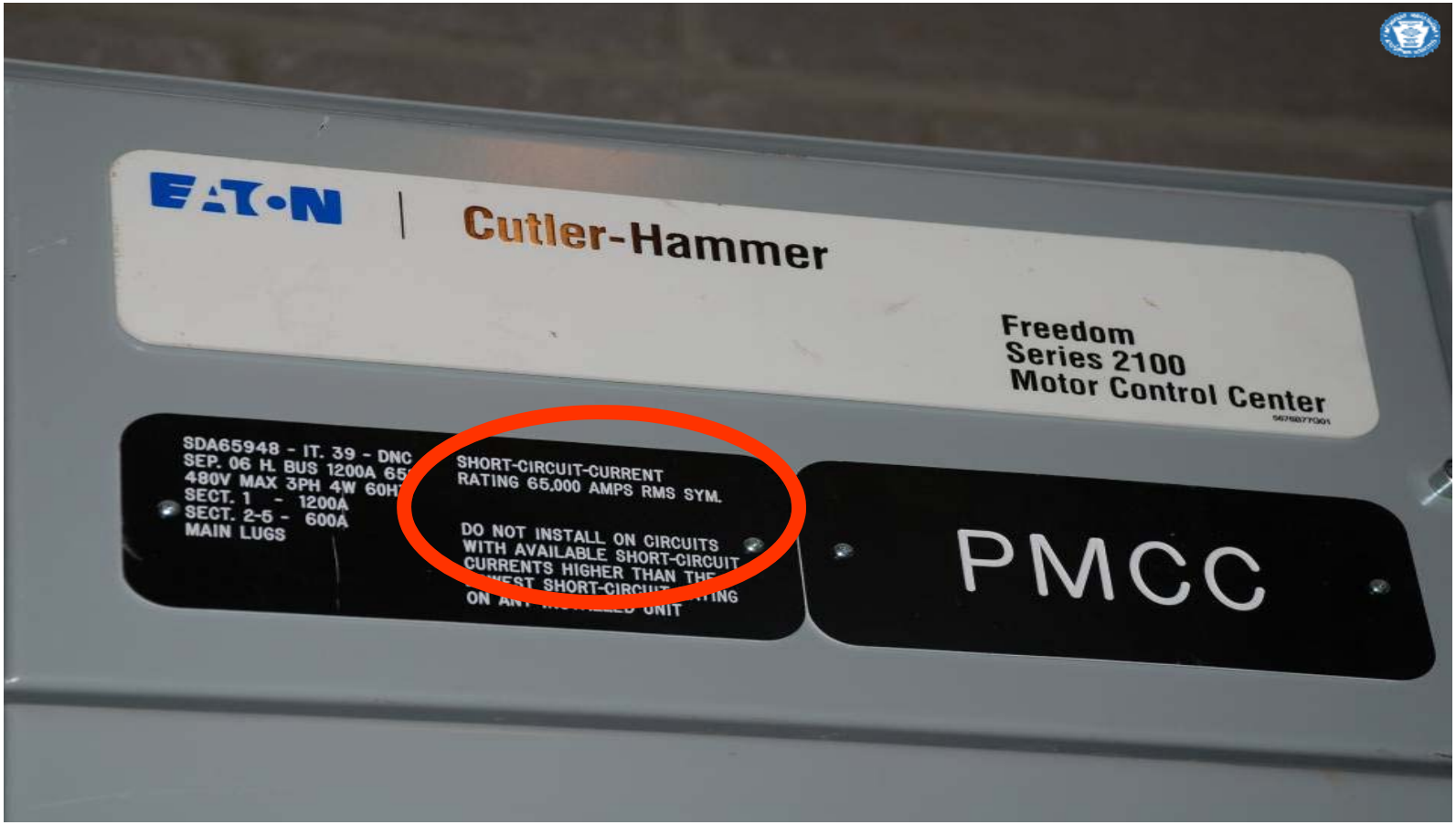


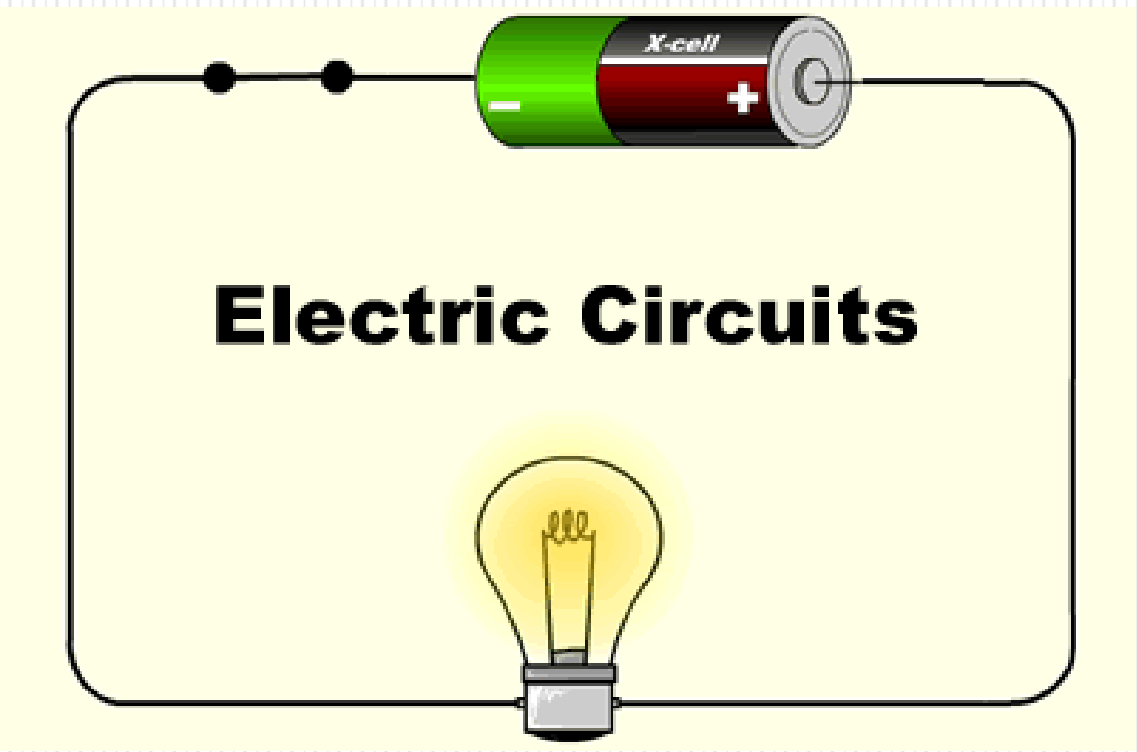
Simply described, the short circuit current rating is how much current the equipment can handle before it loses electrical integrity… in other words: it blows apart!

CIRCUIT BREAKERS

A tripped breaker, by itself, does not tell you the cause or origin of a fire.

It is merely a piece of data in the larger puzzle.

TYPICAL CIRCUIT COMPONENTS

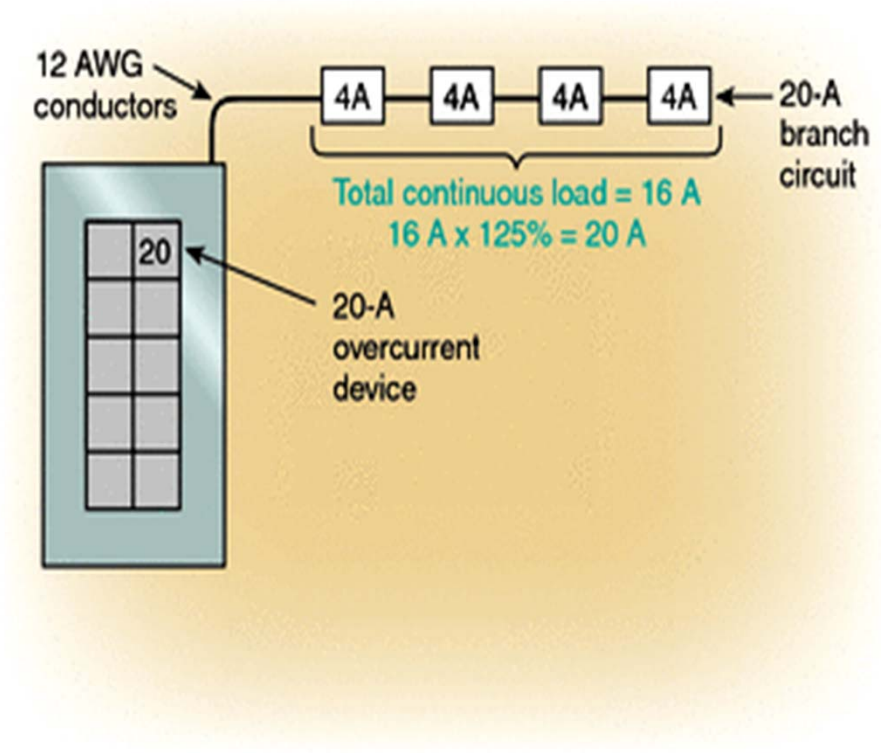


BRANCH CIRCUIT

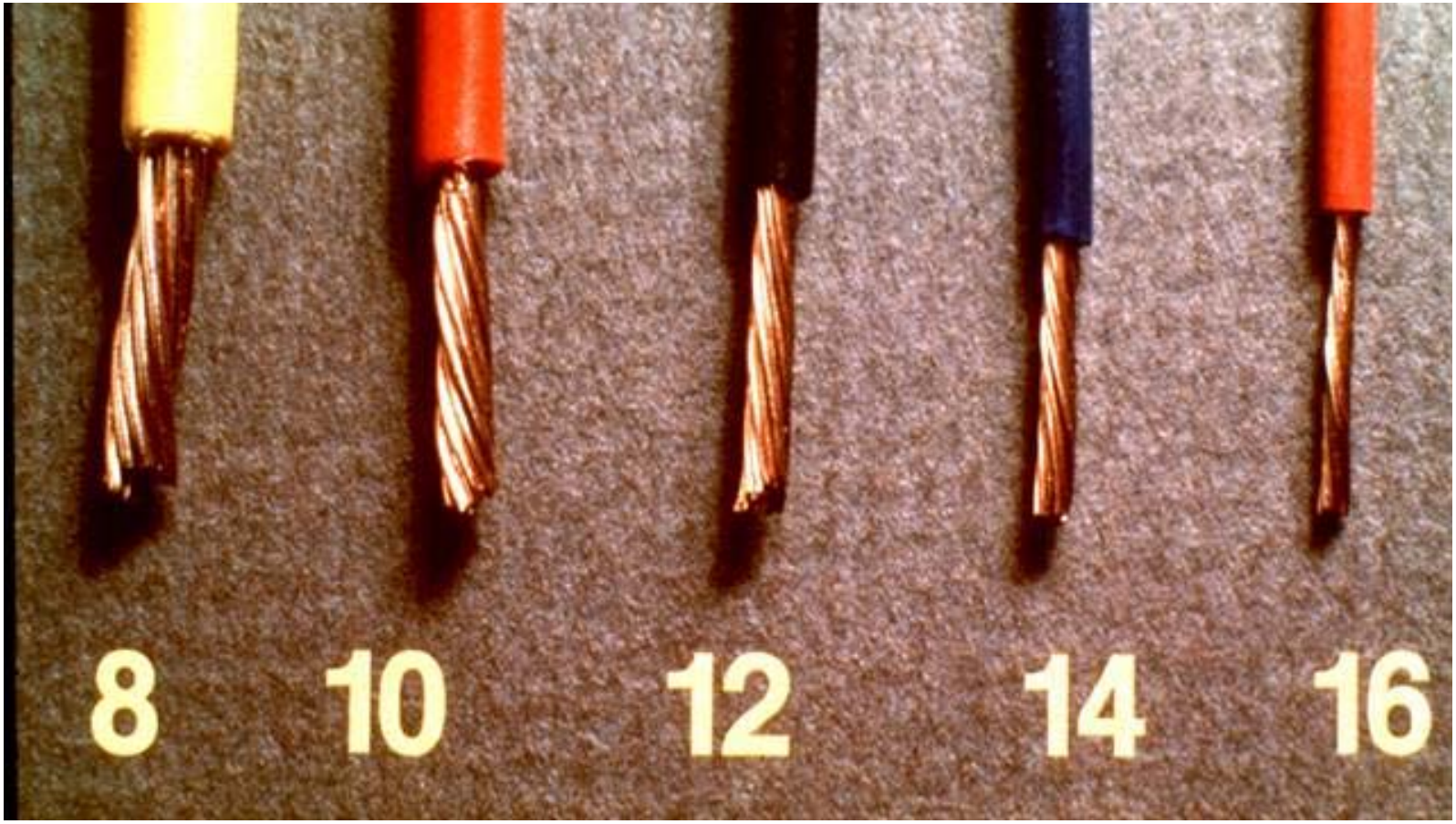
- The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s).

CONTINUOUS AND NON-CONTINUOUS LOADS

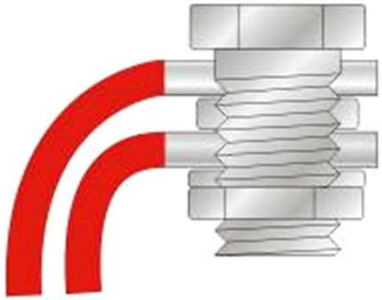
- Where a branch circuit supplies continuous loads or any combination of continuous and non-continuous loads, the rating of the overcurrent device shall not be less than the non-continuous load plus 125 percent of the continuous load.

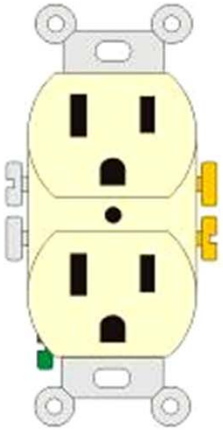


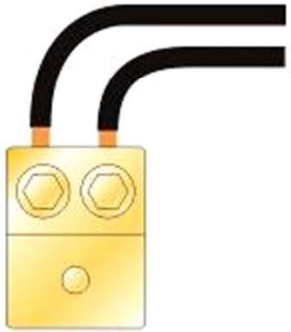
WIRING METHODS AND MATERIAL



ELECTRICAL CONNECTIONS







Pressure terminal or pressure splicing connectors and soldering lugs shall be identified for the material of the conductor

Conductors of dissimilar metals shall not be in physical contact unless the device is identified for the purpose and conditions of use

Connections are to ensure thor-oughly good connection without damaging conductor

Terminals not marked CO/ALR, copper or copper clad only

Screwless terminals for copper and CU clad solid or stranded

One wire per terminal unless marked otherwise

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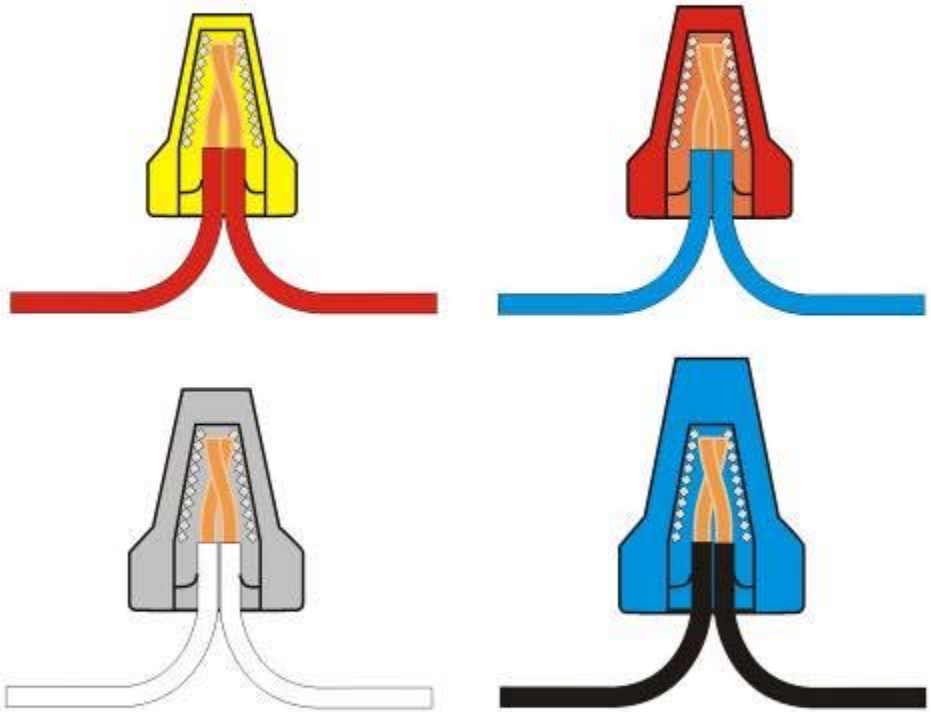
CONDUCTOR SPLICES

Twist-on Wire Connectors (typical)



Conductors are required to be spliced with devices suitable for the type of conductor material.

Conductors of dissimilar metals are not to be intermixed unless the splicing device is identified for the purpose.

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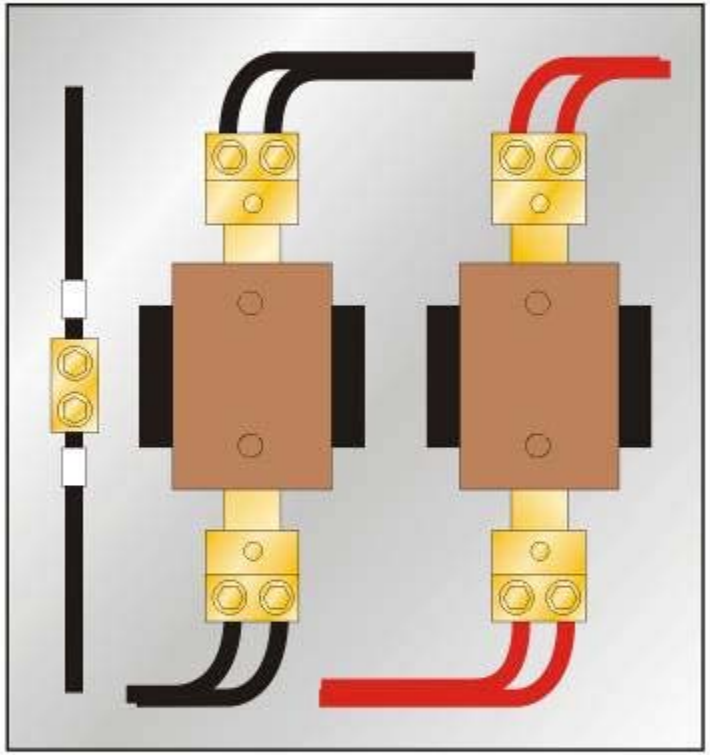
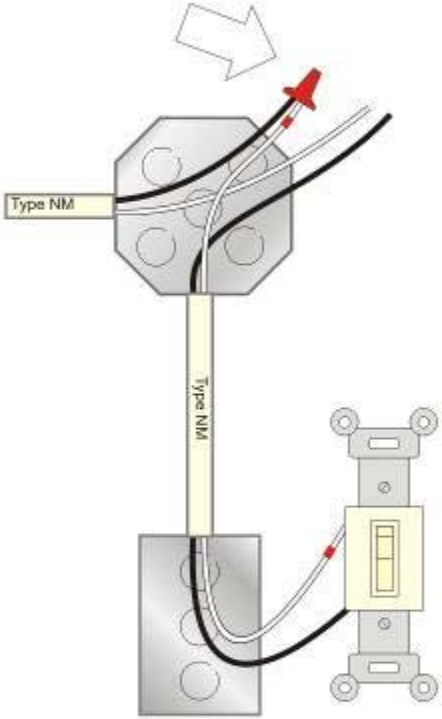
SEPARATE CONNECTOR PROVISIONS

Current transformer
or similar enclosure





Separately installed pressure connectors shall be used with conductors at the ampacities not exceeding the ampacity at the listed and identified temperature rating of the connector.

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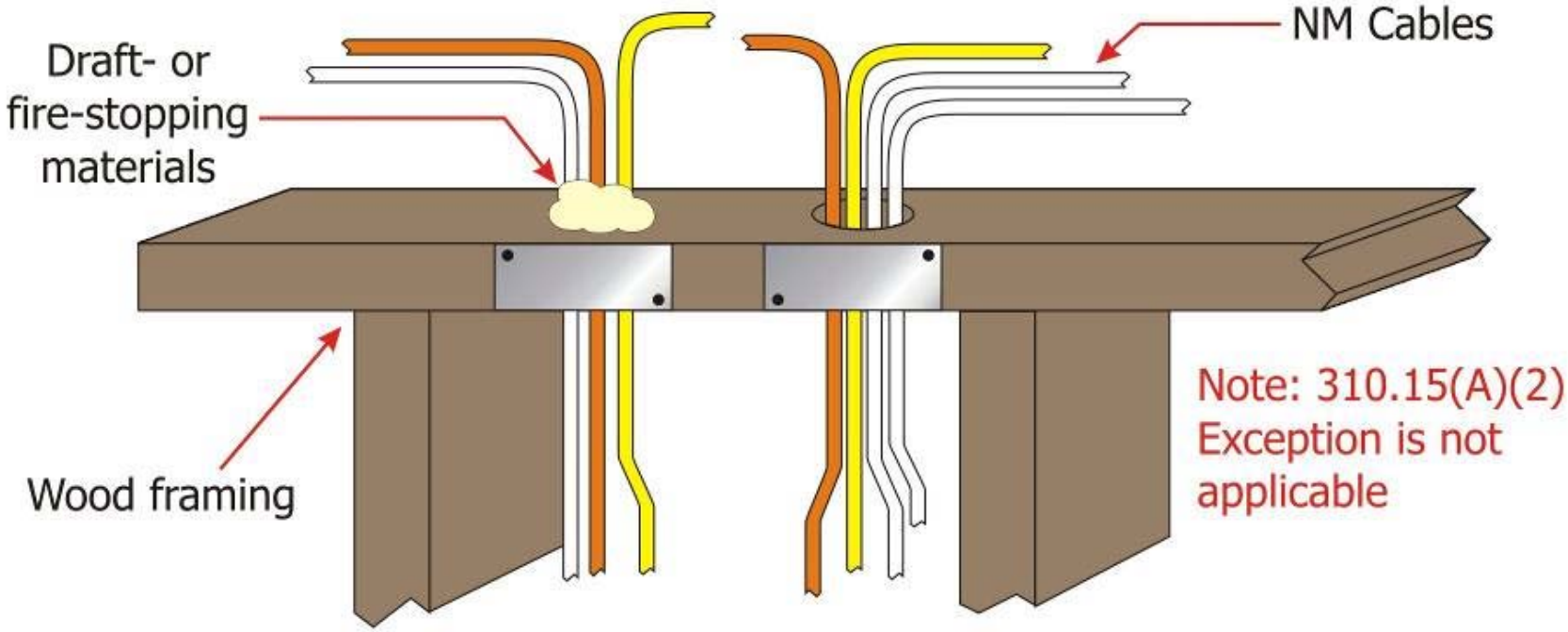
UNGROUNDED CONDUCTORS

- Where a premises wiring system is supplied by more than one nominal voltage system, each branch circuit is required to be **identified by phase and system.**
- This identification shall be used at all termination, connection, and splice points.
- The means of identification is required to be permanently posted at each branch-circuit panel board or similar branch-circuit distribution equipment.

Table B.310.1 Ampacities of Two or Three Insulated Conductors, Rated 0 Through 2000 Volts, Within an Overall Covering (Multiconductor Cable), in Raceway in Free Air Based on Ambient Air Temperature of 30°C (86°F)

Size (AWG or kcmil)	Temperature Rating of Conductor. [See Table 310.13(A).]						Size (AWG or kcmil)
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, ZW	Types THHN, THHW, THW-2, THWN-2, RHH, RWH-2, USE-2, XHHW, XHHW-2, ZW-2	Type TW	Types RHW, THHW, THW, THWN, XHHW	Types THHN, THHW, THW-2, THWN-2, RHH, RWH-2, USE-2, XHHW, XHHW-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
14	16*	18*	21*	—	—	—	14
12	20*	24*	27*	16*	18*	21*	12
10	27*	33*	36*	21*	25*	28*	10
8	36	43	48	28	33	37	8
6	48	58	65	38	45	51	6
4	66	79	89	51	61	69	4
3	76	90	102	59	70	79	3
2	88	105	119	69	83	93	2
1	102	121	137	80	95	106	1
1/0	121	145	163	94	113	127	1/0
2/0	138	166	186	108	129	146	2/0
3/0	158	189	214	124	147	167	3/0
4/0	187	223	253	147	176	197	4/0

334.80 Ampacity



Ampacity adjustment factors in Table 310.15(B)(2)(a) apply to the following:

Where more than two cables pass through wood framing without maintaining spacing and the wood framing is draft- or fire-stopped using thermal insulation, sealing foam, or caulking material

Where more than two NM cables with two or more current-carrying conductors are installed in thermal insulation without maintaining spacing between the cables

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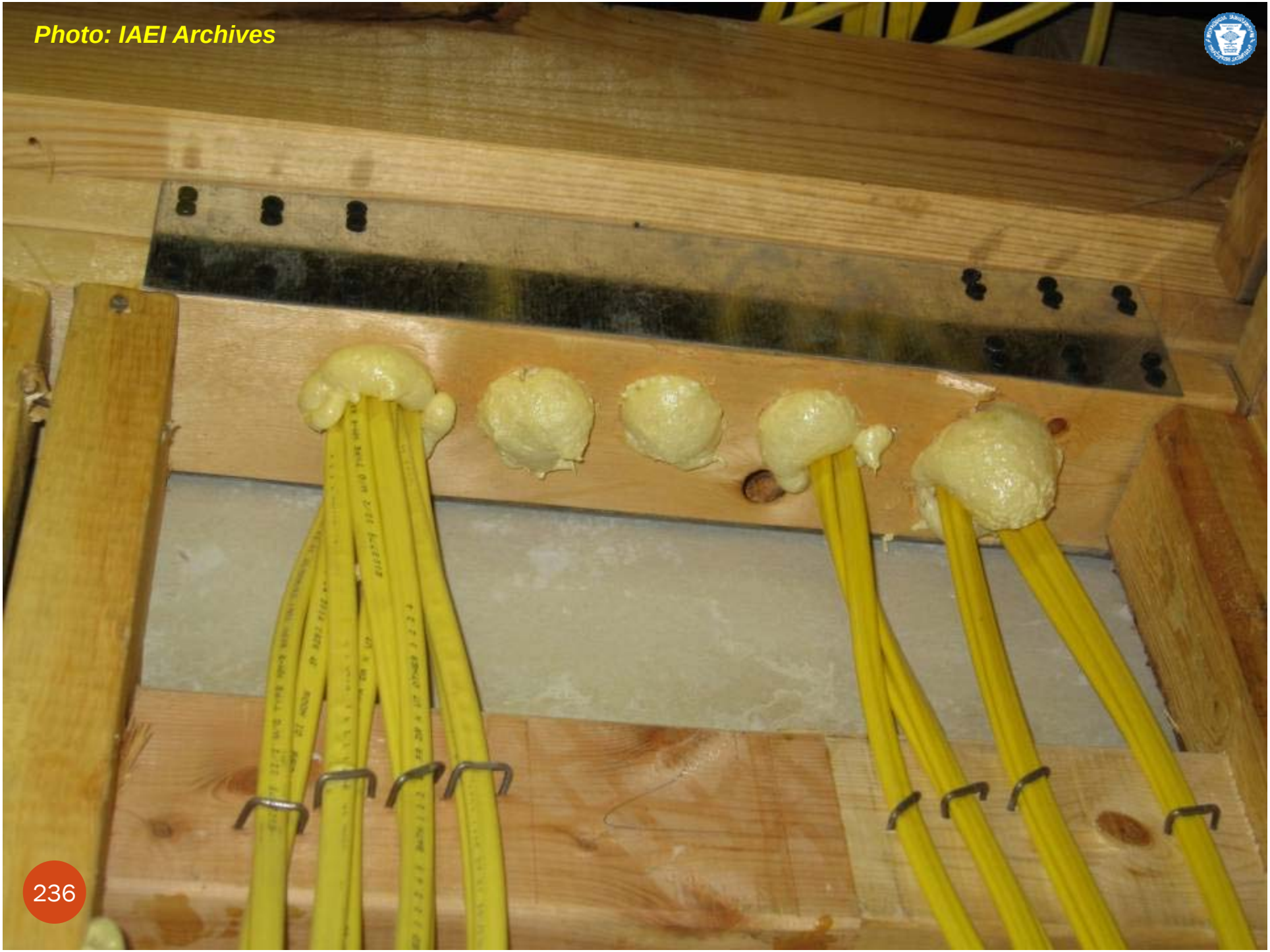


Photo: IAEI Archives

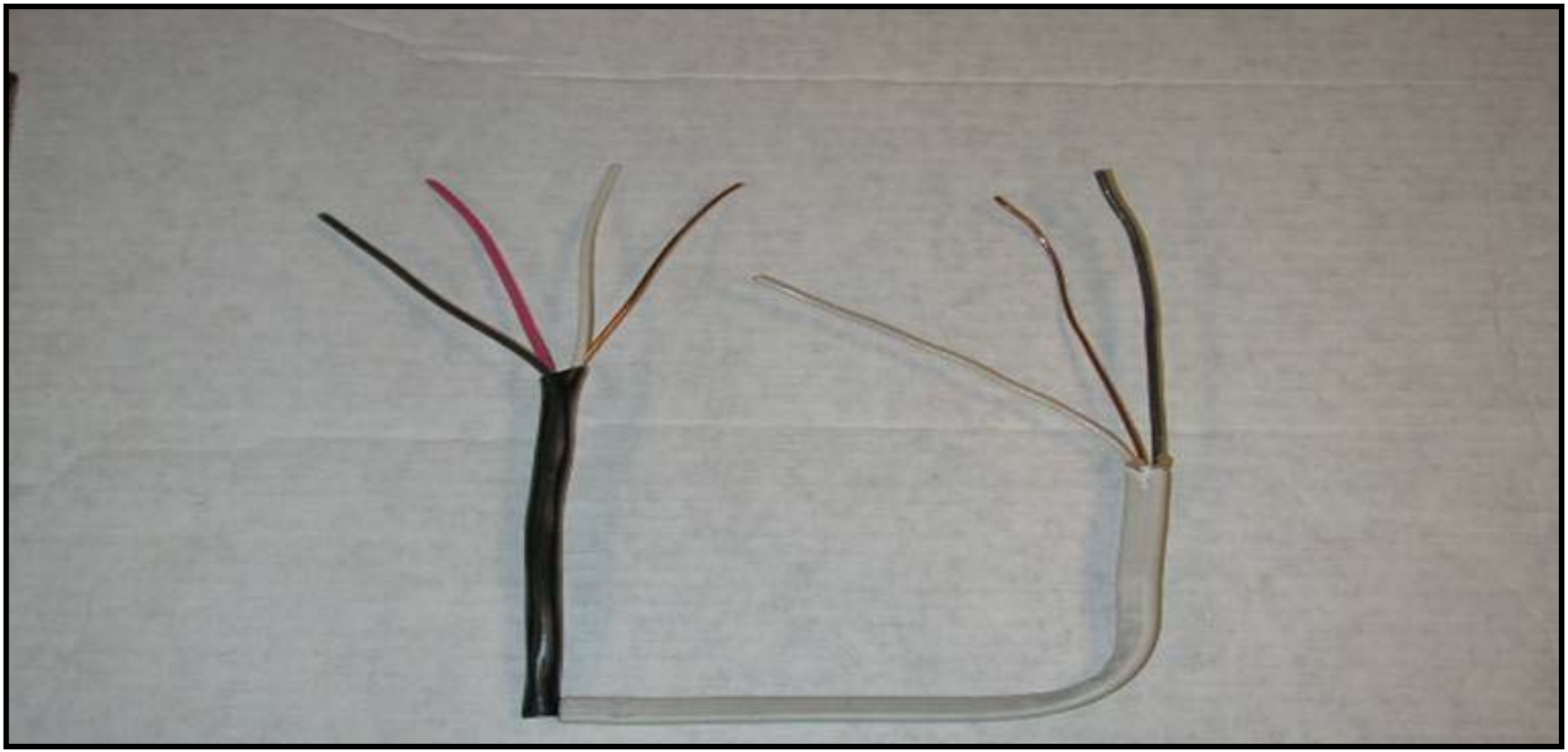
CONDUCTOR MATERIAL

- Wire connectors or the unit containers are marked with **the type of conductor** material(s) as follows:

Marking:	For Use With:
AL	Aluminum Only
CC	Copper-Clad Aluminum Only
AL-CU or CU-AL	Copper, Aluminum or Copper-Clad Aluminum
CC-CU or CU-CC	Copper or Copper-Clad Aluminum
CU, CU-CU	Copper Only or equivalent wording

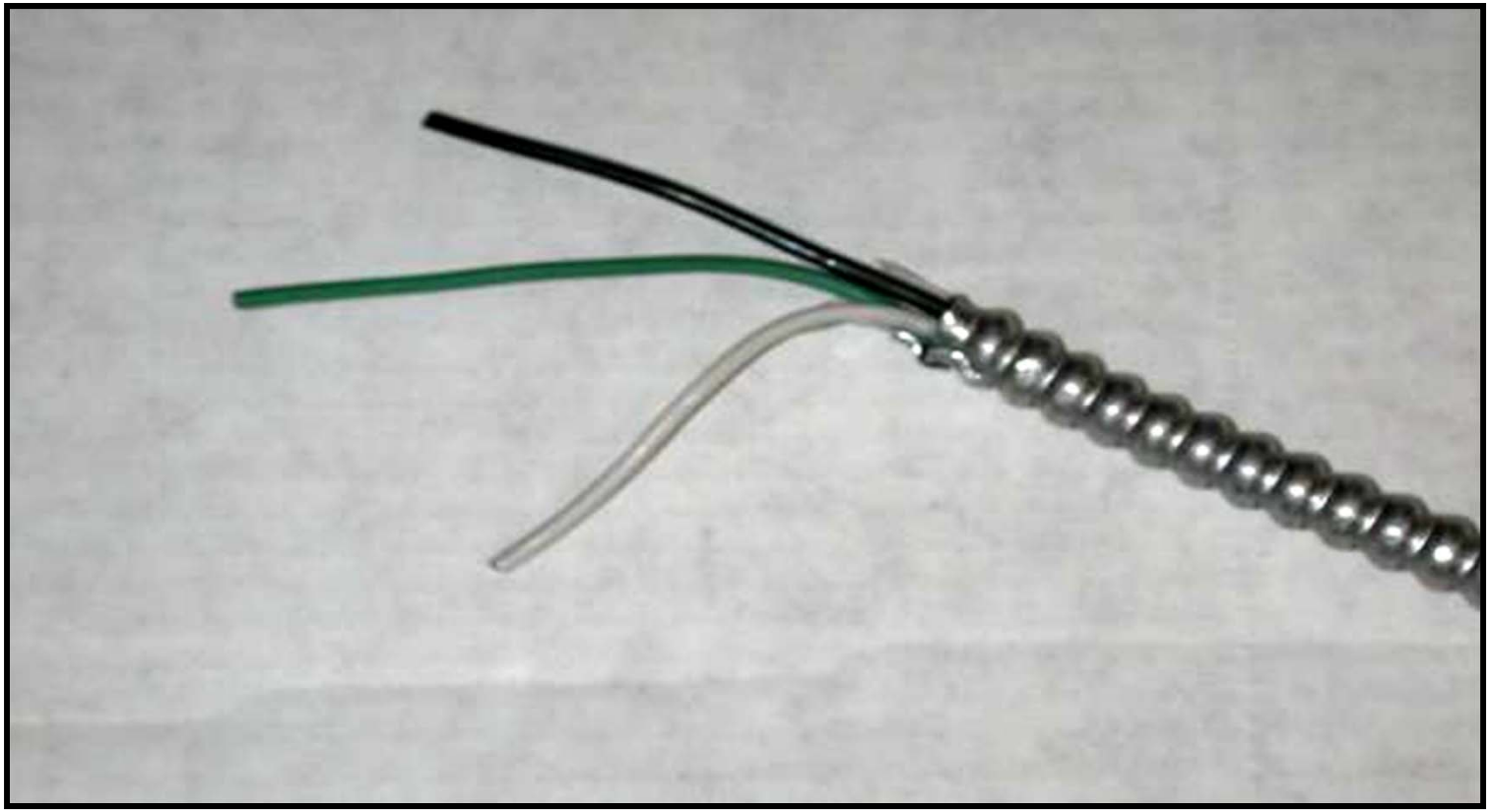
INSTALLATION
SCREW TERMINALS
TERMINAL HELICE
#14-#12
AWG
GRN OR BARE WIRE
FIL NU OU VERT
0 78477 82807 6
CU
WIRE
ONLY
For La
Temporizado
Para Lámparas y

NON-METALLIC SHEATHED CABLE



CABLE LABELING

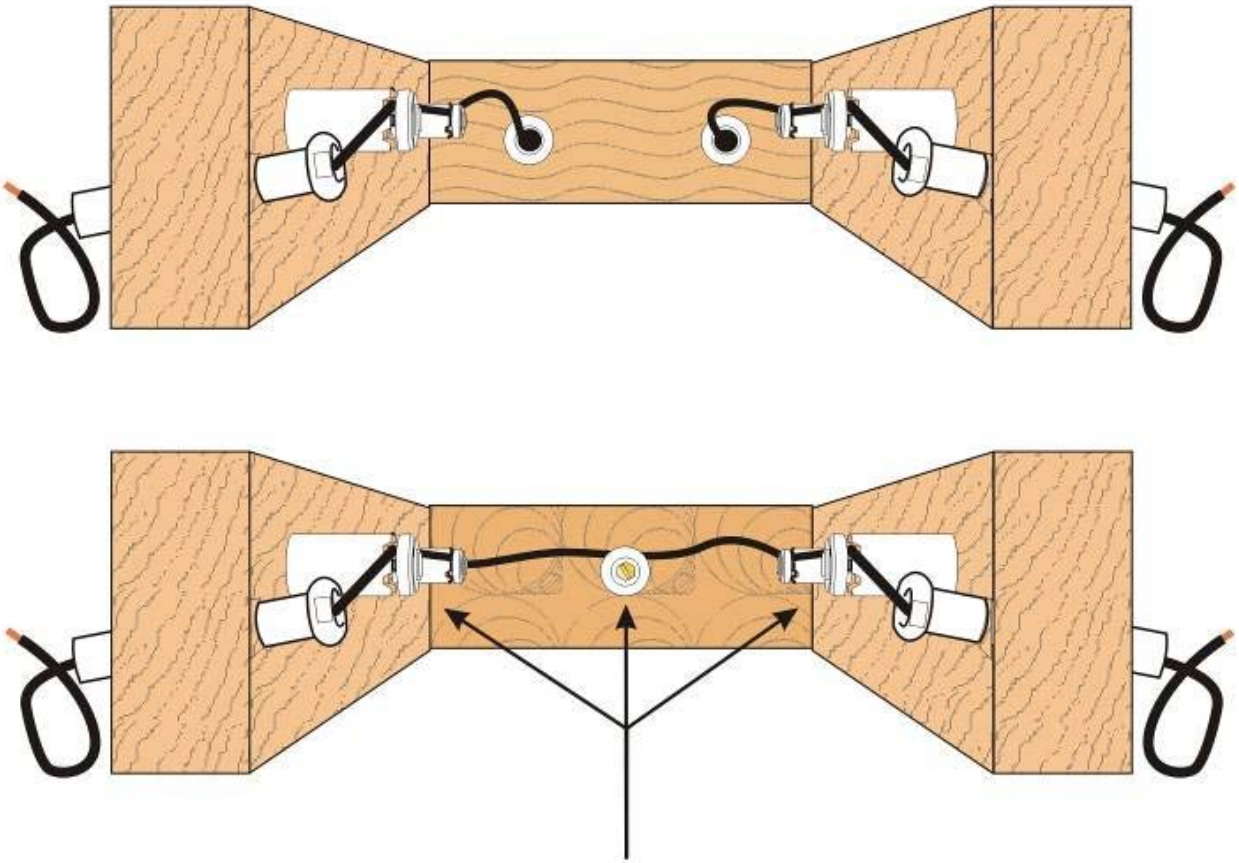
METALLIC SHEATHED CABLE



CONDUIT

Metal conduit
NEMA TC-2 SUNLIGHT RESISTANT
RIGID NONMETALLIC CONDUIT ABOVEGROUND
10/20/01
PVC conduit

SECURING KNOB-AND-TUBE WIRING



Support conductors at intervals not exceeding 1.4 m (4½ ft) and within 150 mm (6 in.) of each splice or tap.

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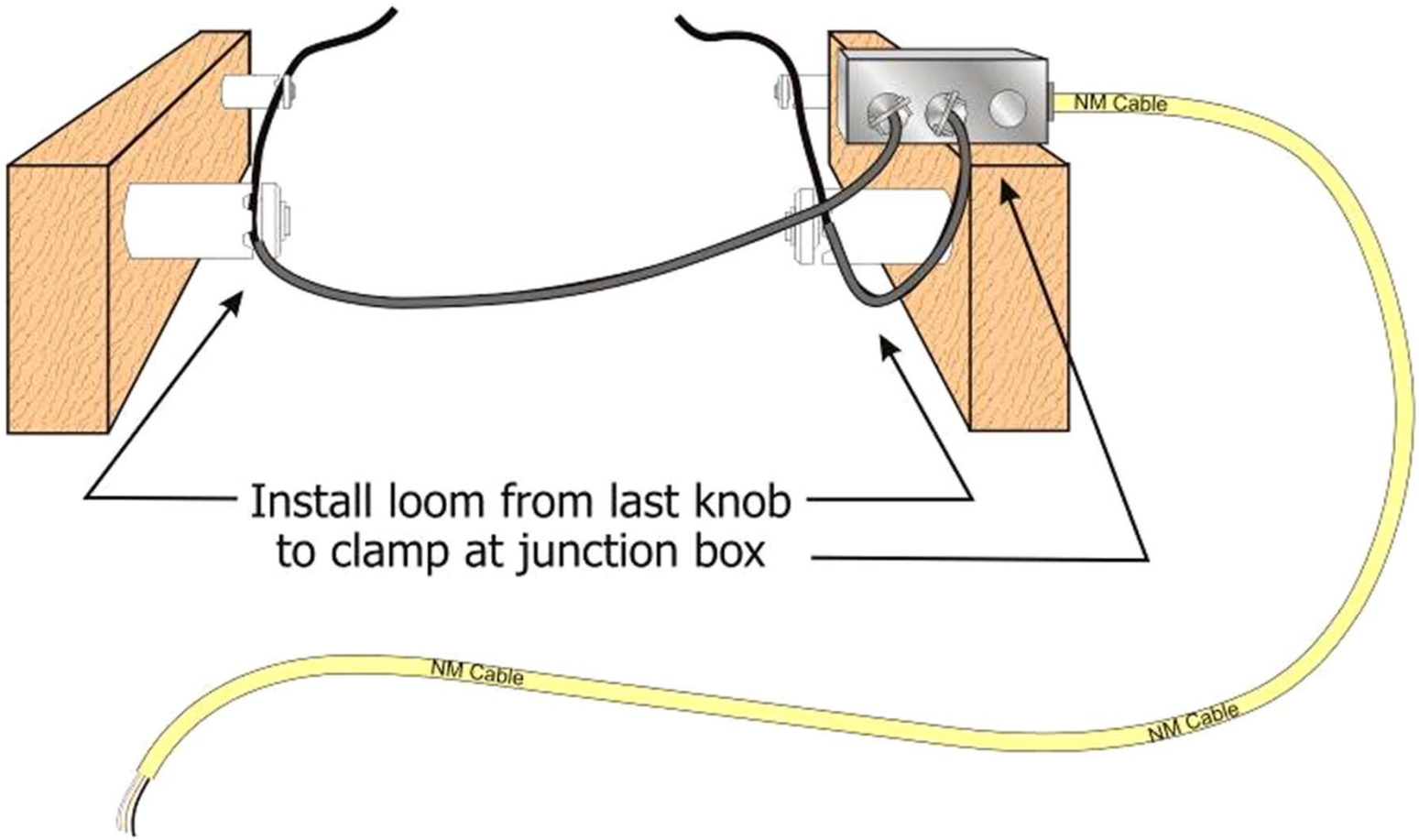
JUNCTION BOX REQUIREMENTS

Junction box for extension of branch circuit by another wiring methods

Box and splices must be accessible



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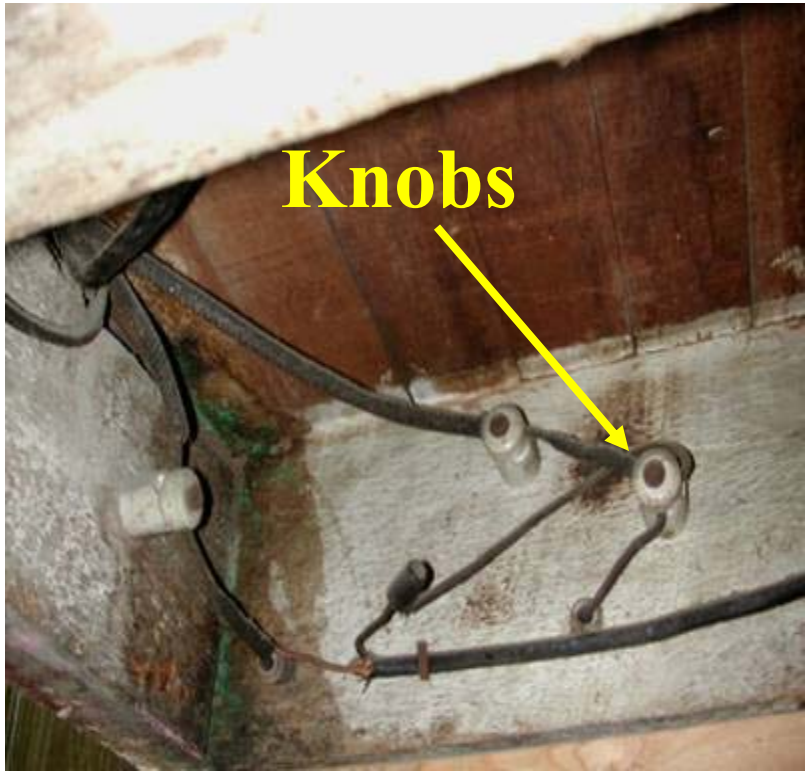
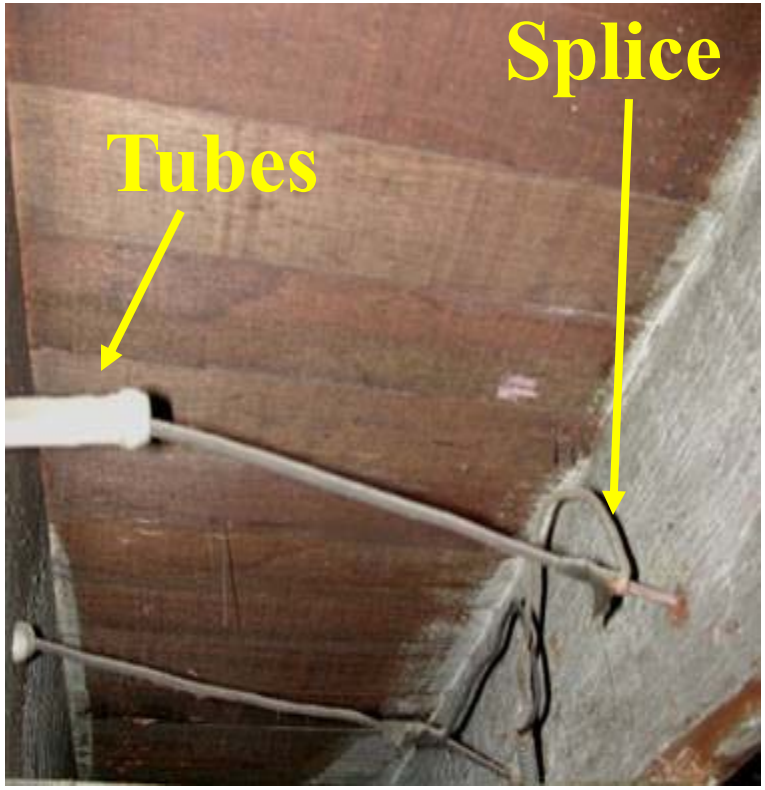
KNOB AND TUBE



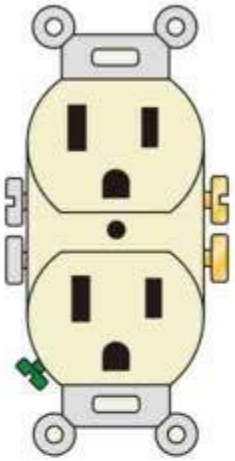


RECEPTACLE OUTLET

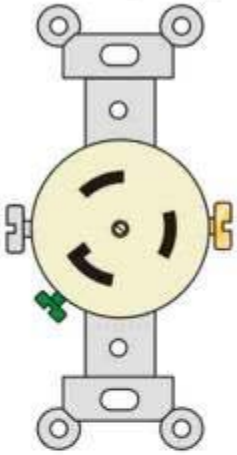
- An outlet where one or more receptacles are installed.

Article 100 Device

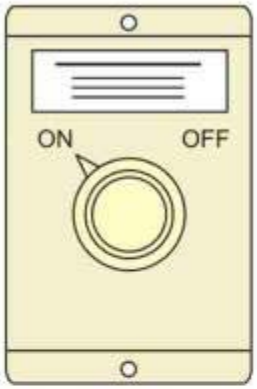
Duplex receptacle



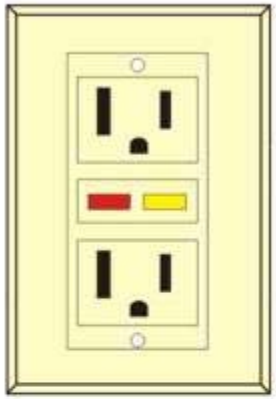
Locking type

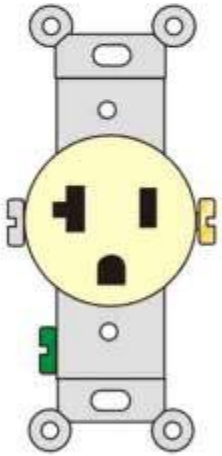


Fan control

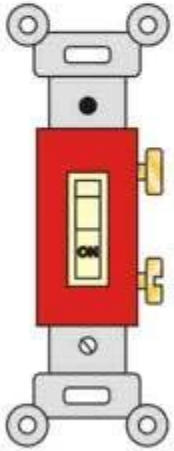


GFCI receptacle

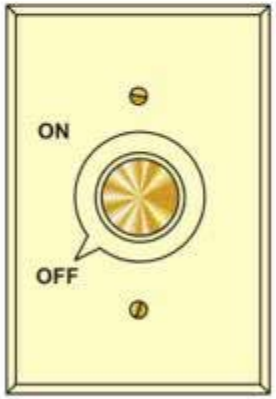




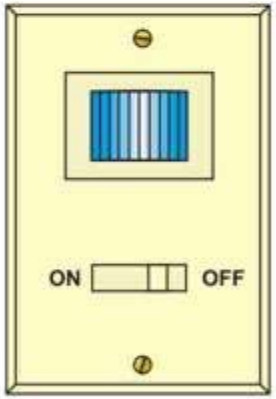
Single receptacle



Switches



Dimmers



Occupancy sensors

A device is a unit of the electrical system that carries or controls electrical energy as its principal function.

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TABLE 210.24
SUMMARY OF BRANCH-CIRCUIT REQUIREMENTS

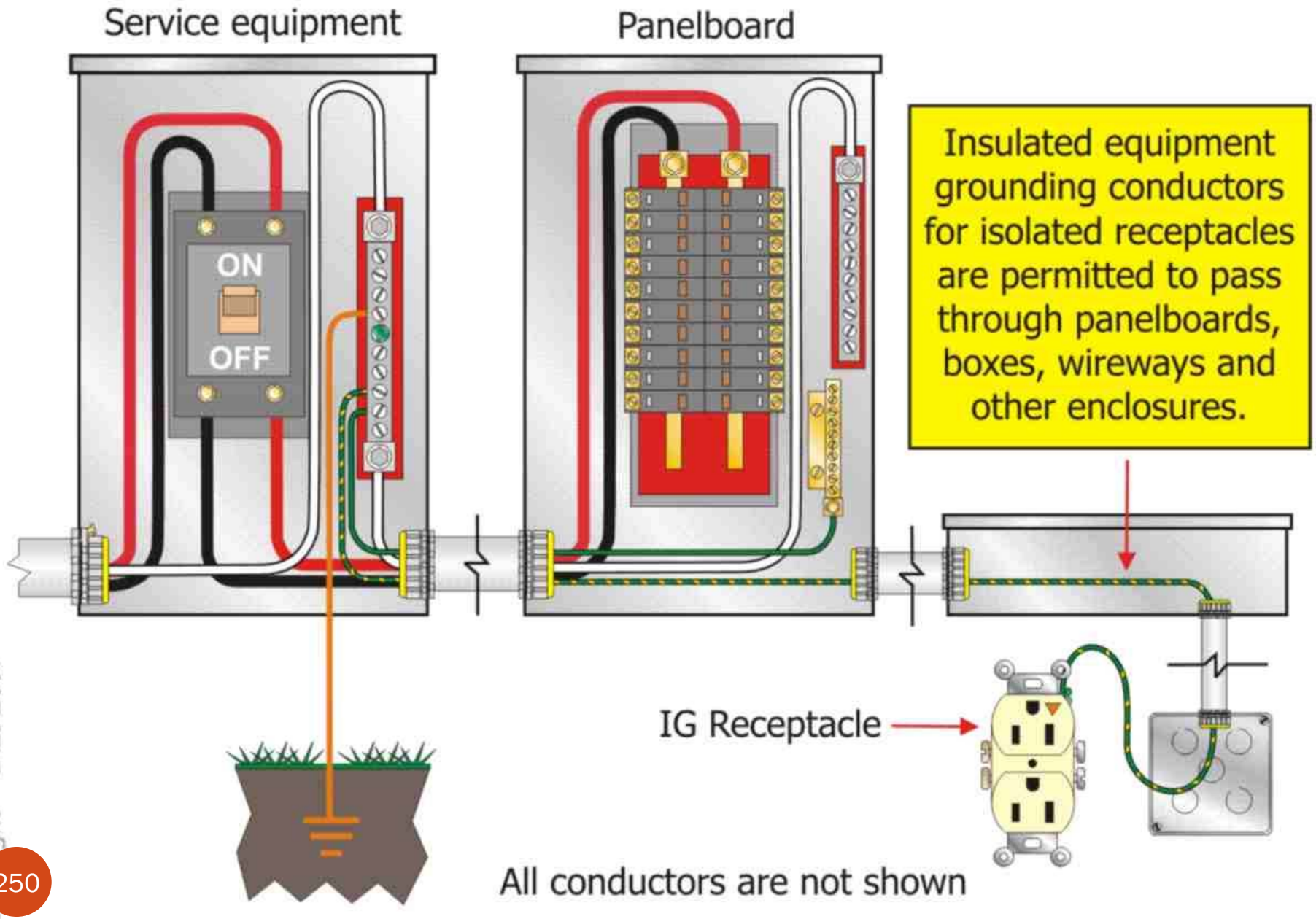
Table 210.24 Summary of Branch-Circuit Requirements

Circuit Rating	15 A	20 A	30 A	40 A	50 A
Conductors (min. size):					
Circuit wires[1]	14	12	10	8	6
Taps	14	14	14	12	12
Fixture wires and cords — see 240.5					
Overcurrent Protection	**15 A**	**20 A**	**30 A**	**40 A**	**50 A**
Outlet devices:					
Lampholders permitted	Any type	Any type	Heavy duty	Heavy duty	Heavy duty
Receptacle rating[2]	15 max. A	15 or 20 A	30 A	40 or 50 A	50 A
Maximum Load	**15 A**	**20 A**	**30 A**	**40 A**	**50 A**
Permissible load	See 210.23(A)	See 210.23(A)	See 210.23(B)	See 210.23(C)	See 210.23(C)

[1]These gauges are for copper conductors.

[2]For receptacle rating of cord-connected electric-discharge luminaires, see 410.62.

250.146(D) Isolated Receptacles



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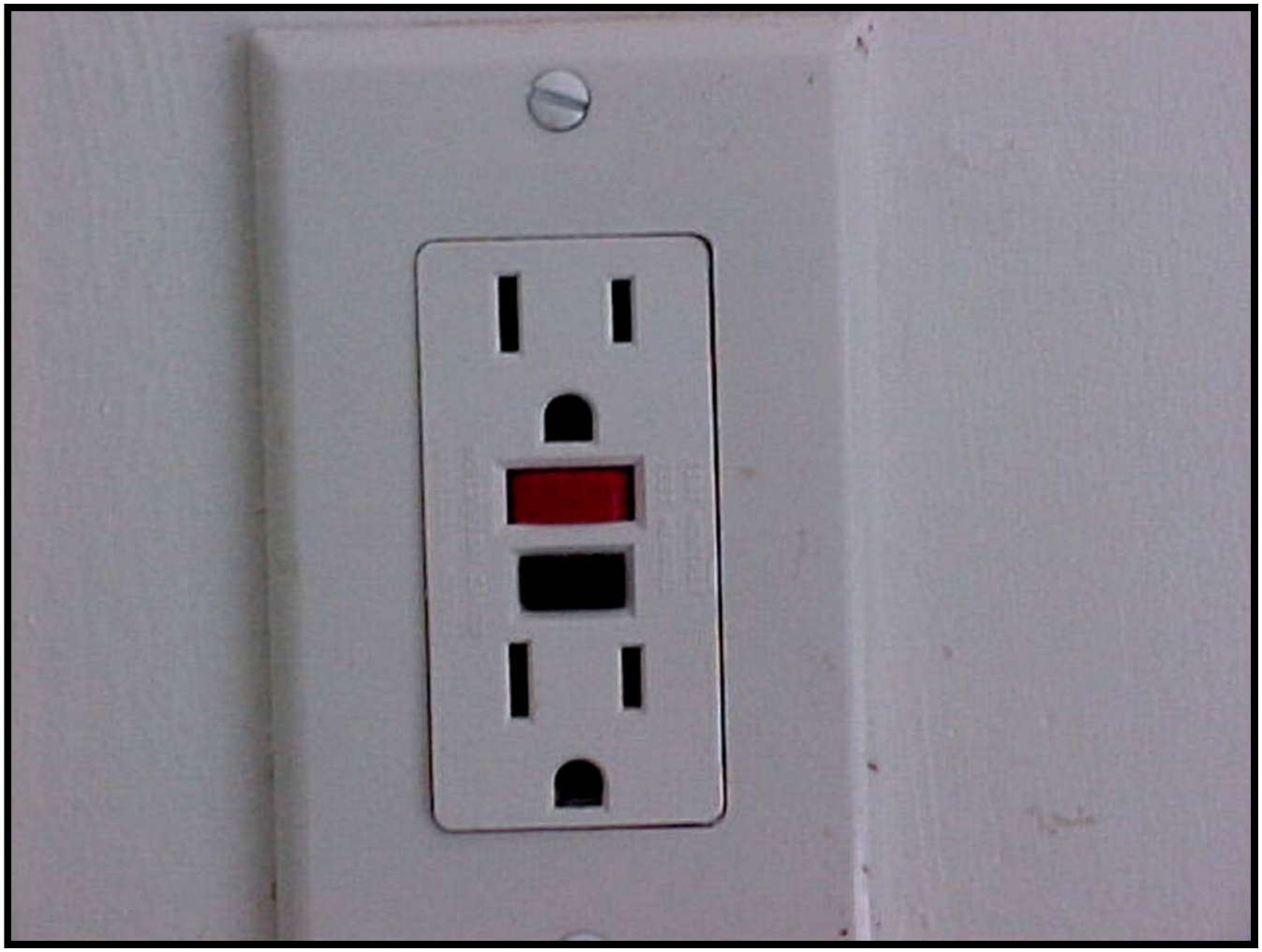
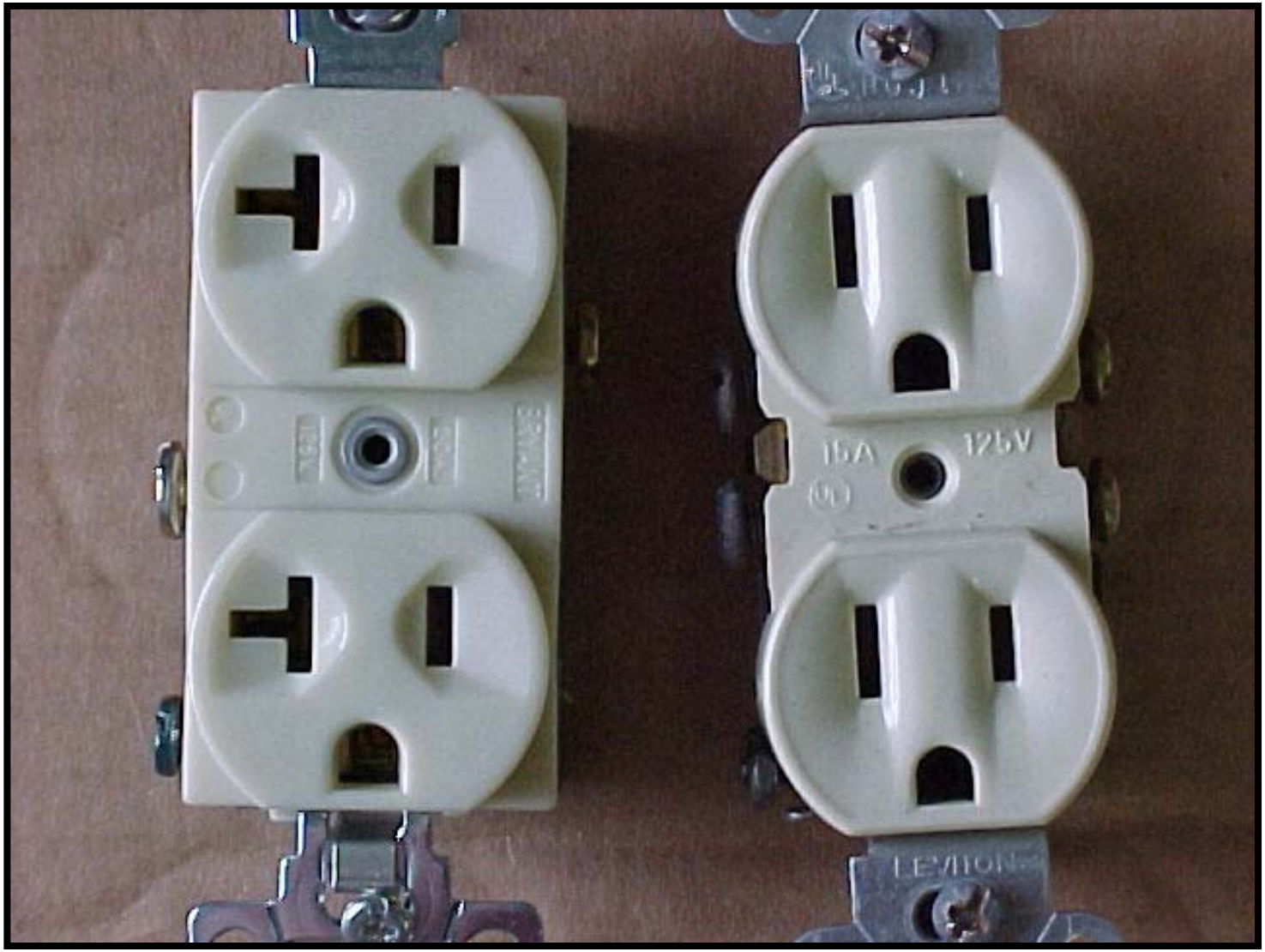
15 AMP GFI RECEPTACLE



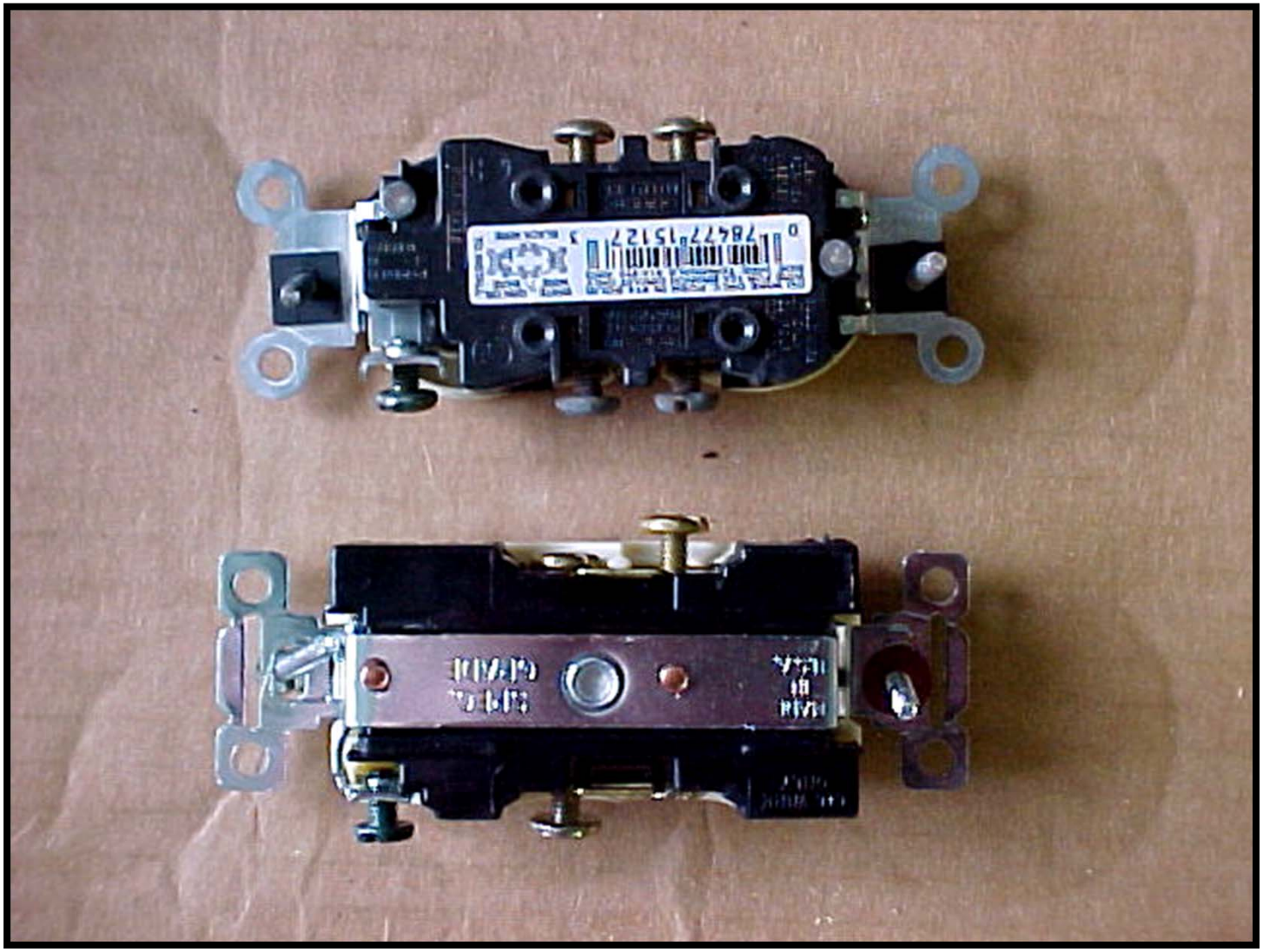
GFCI RECEPTACLE

- The line conductors are passed through a sensor and are connected to a shunt-trip device. As long as the current in the conductors is equal, the device remains in a closed position. If one of the conductors comes in contact with a grounded object, either directly or through a person's body, some of the current returns by an alternative path, resulting in an unbalanced current.
- The toroidal coil senses the unbalanced current, and a circuit is established to the shunt-trip mechanism that reacts and opens the circuit. Note that the circuit design does not require the presence of an equipment grounding conductor
- GFCIs operate on currents of 5 mA.

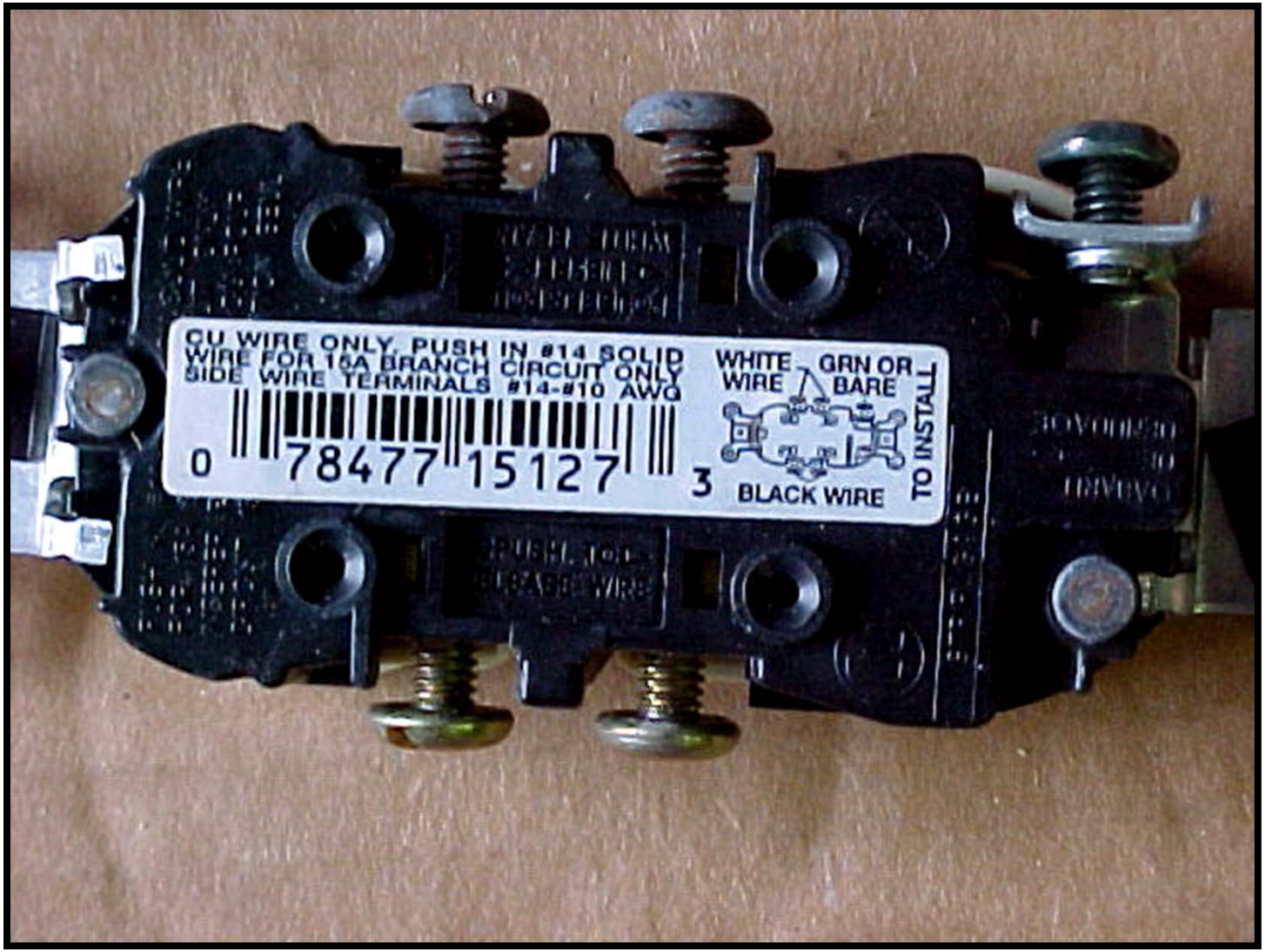
RECEPTACLES



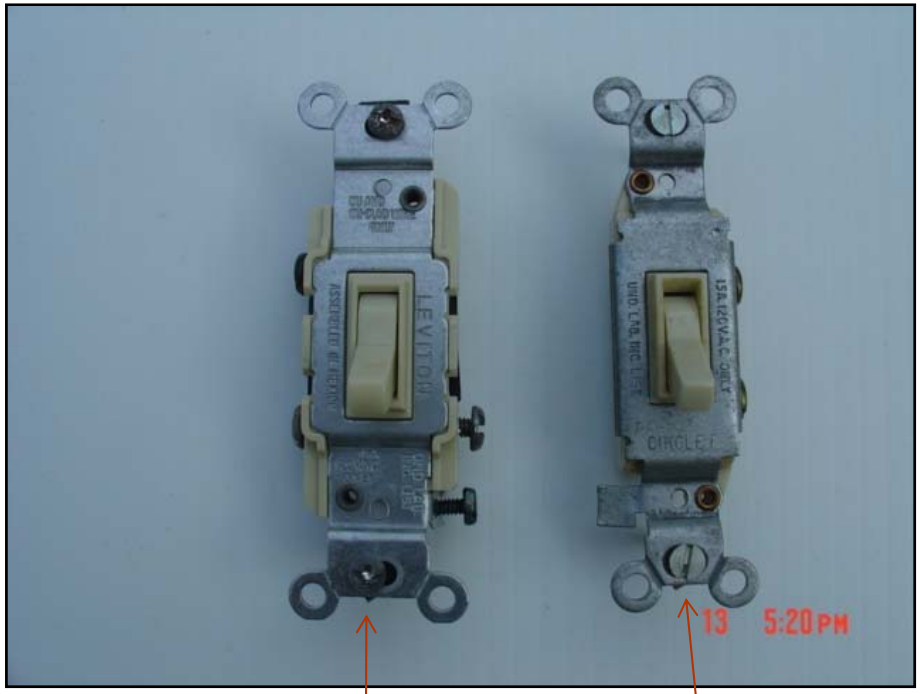
15 AMP & 20 AMP RECEPTACLE



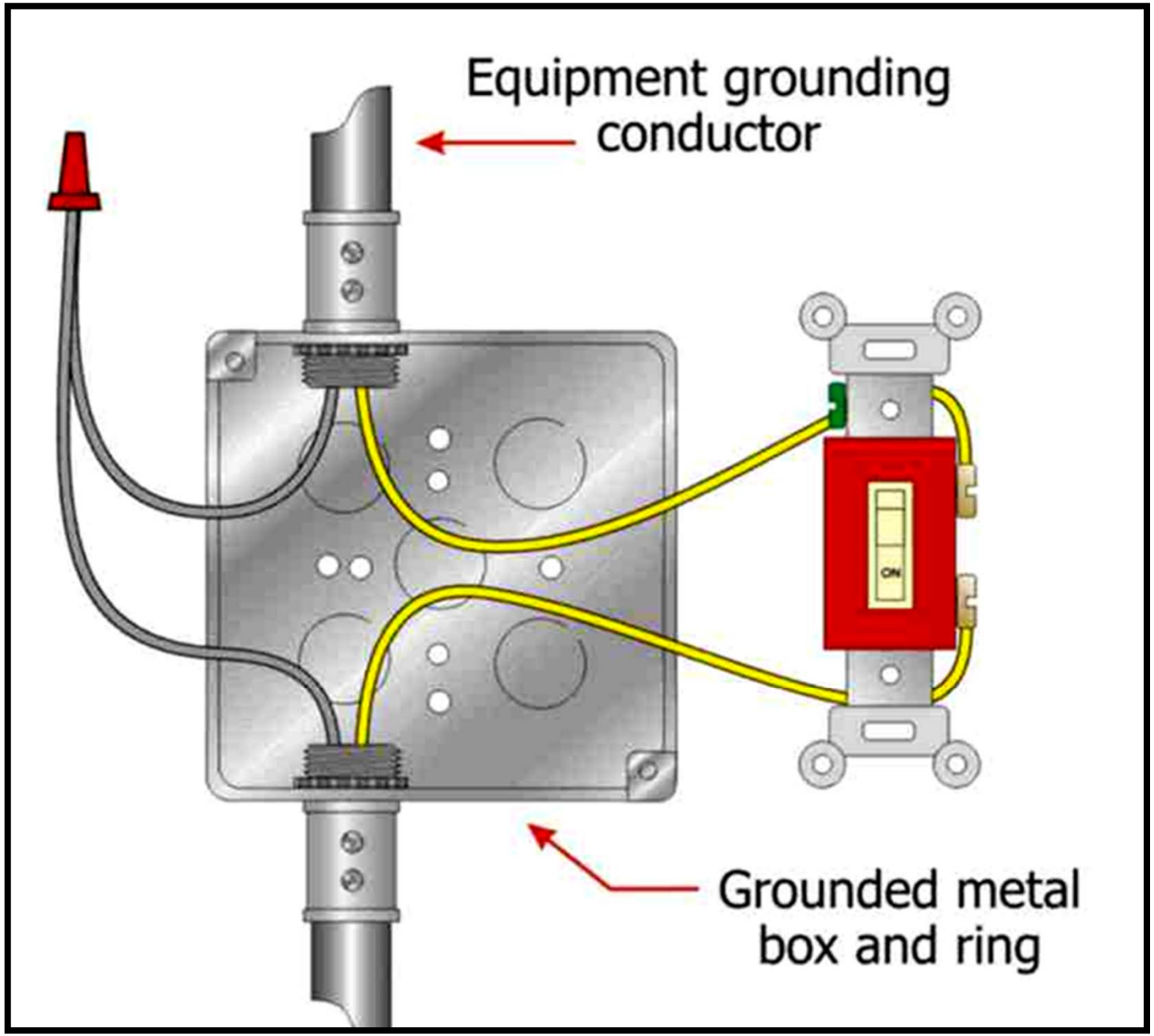
REAR OF 15 AMP RECEPTACLE



TOGGLE SWITCHES



3 WAY SP


Equipment grounding conductor
Grounded metal box and ring

RECESSED LIGHT FIXTURES

Two fixture types:

IC – Insulation Contact

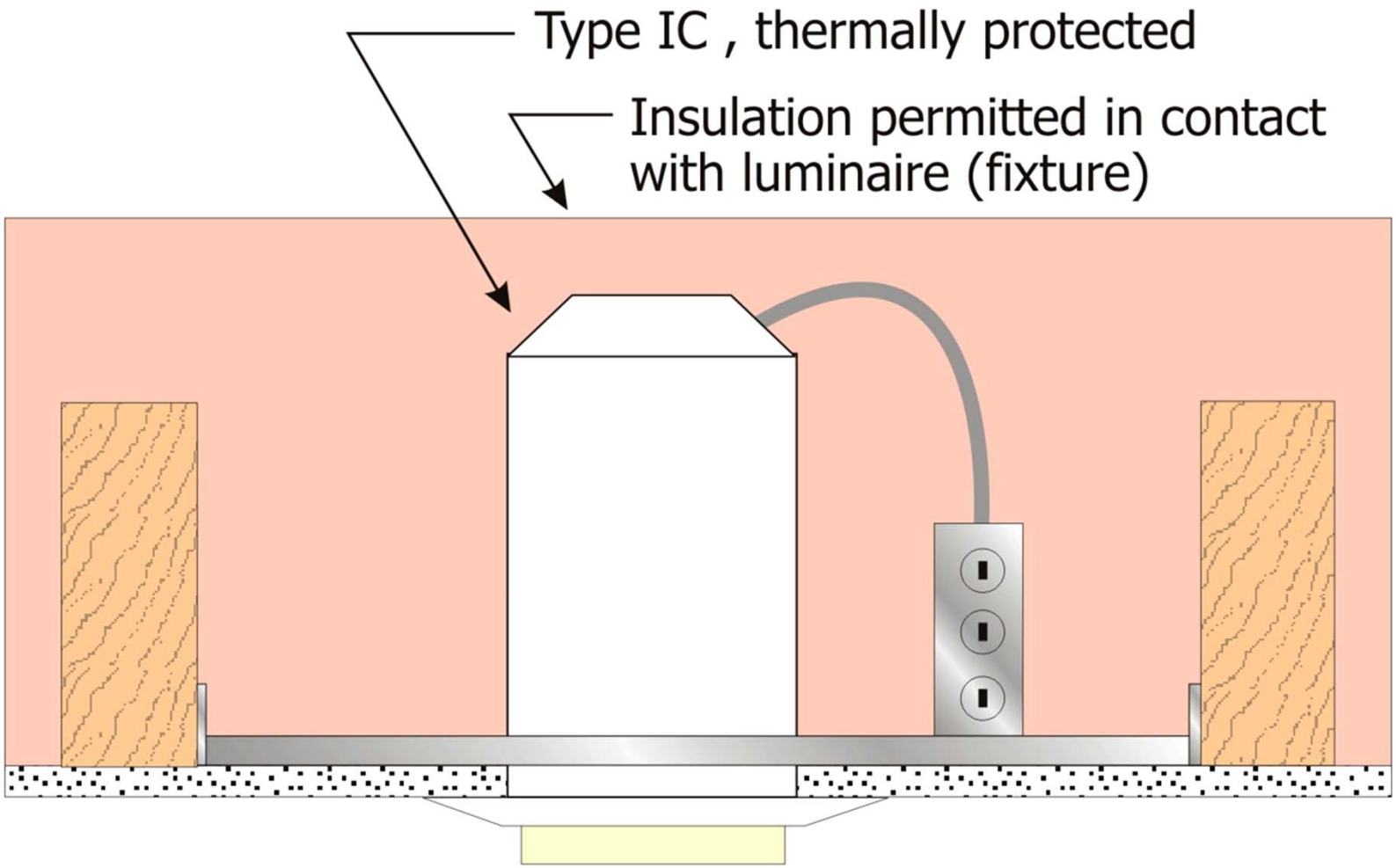
Non-IC – Non Insulation Contact

Both may be listed as combination of styles, such as IC-AT, T-AT, etc. "AT" refers to "Air-tight" meaning the fixture assembly is designed to prevent the movement of air through it, for energy conservation purposes.

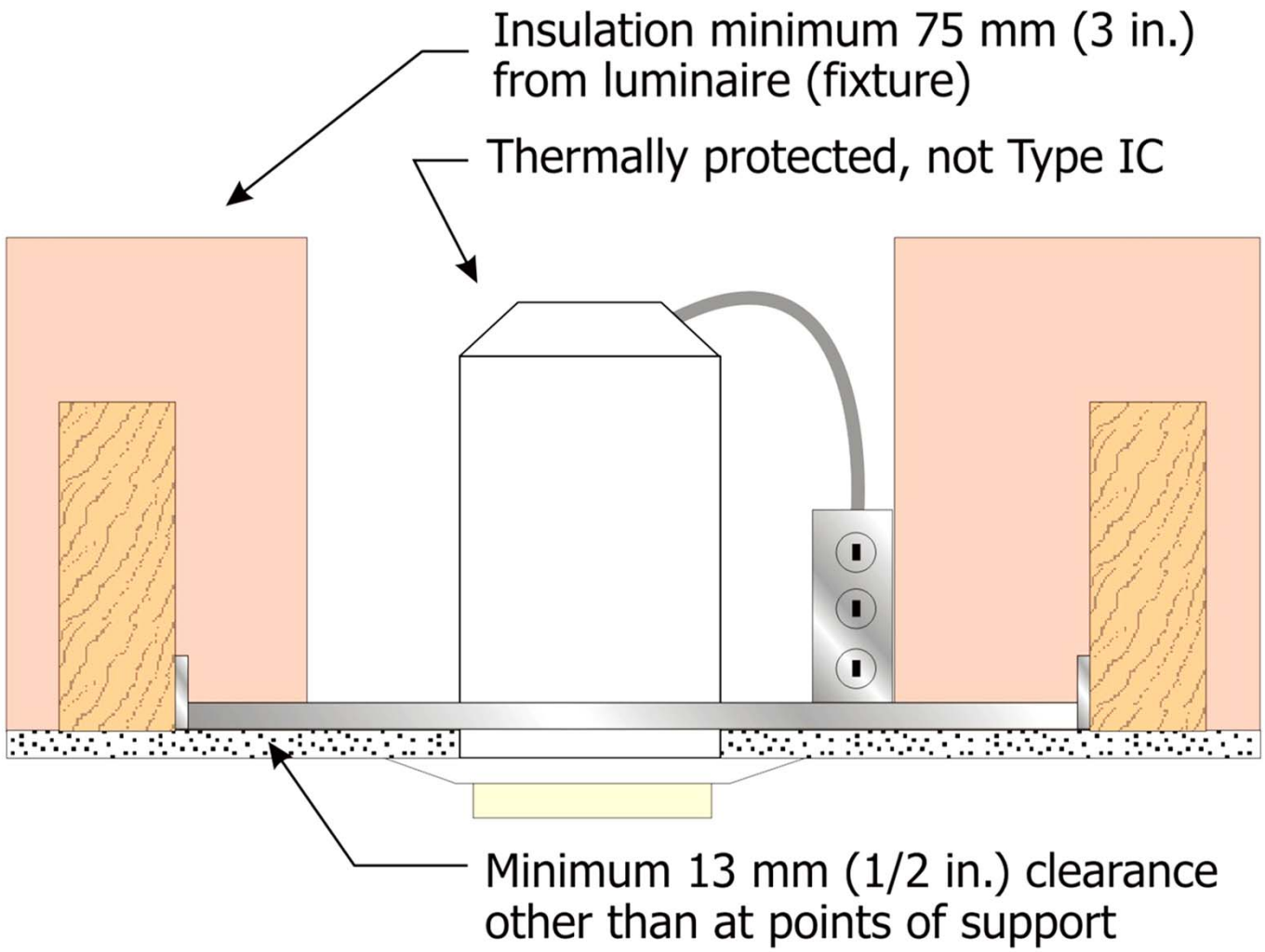
Maximum wattage of bulb is dependent on bulb style, trim type, fixture type (IC vs. Non-IC).

A wattage/trim chart is usually affixed to inside of fixture/can, but usually falls off or is removed due to poor adhesion of label such as a square label on a round surface. This chart shows what the maximum wattage bulb that can be used with a bulb/trim combination is.

IC TYPE INSTALLATION



NON-IC TYPE INSTALLATION



RECESSED LIGHT FIXTURES

All recessed lights manufactured after 1982 are required to have a thermal cutoff in the circuit that interrupts power if temperature inside the housing exceeds 90°C / 194°F.

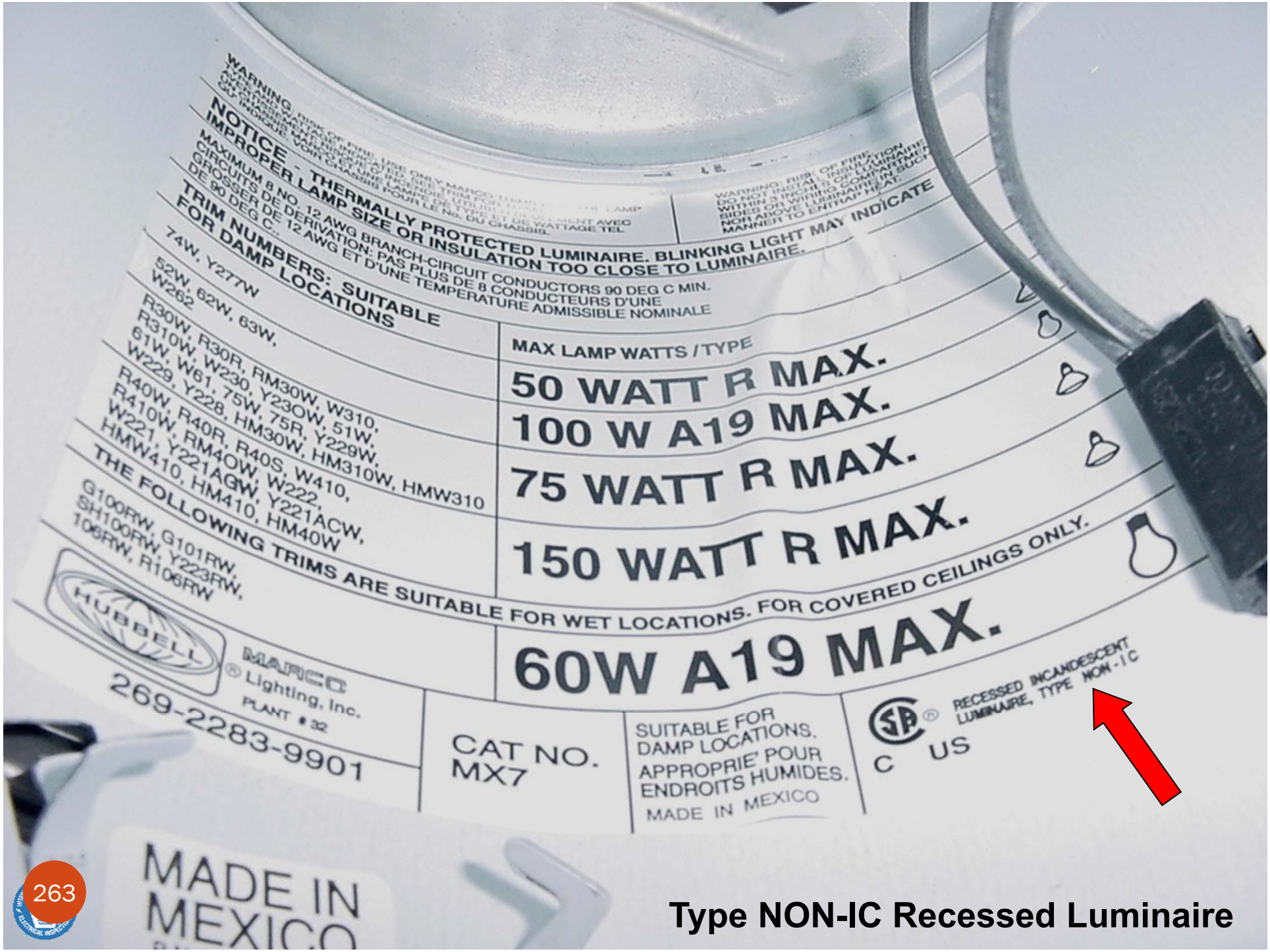
The thermal cutoff helps to protect wiring from degradation from excess heat.

RECESSED LIGHT FIXTURES

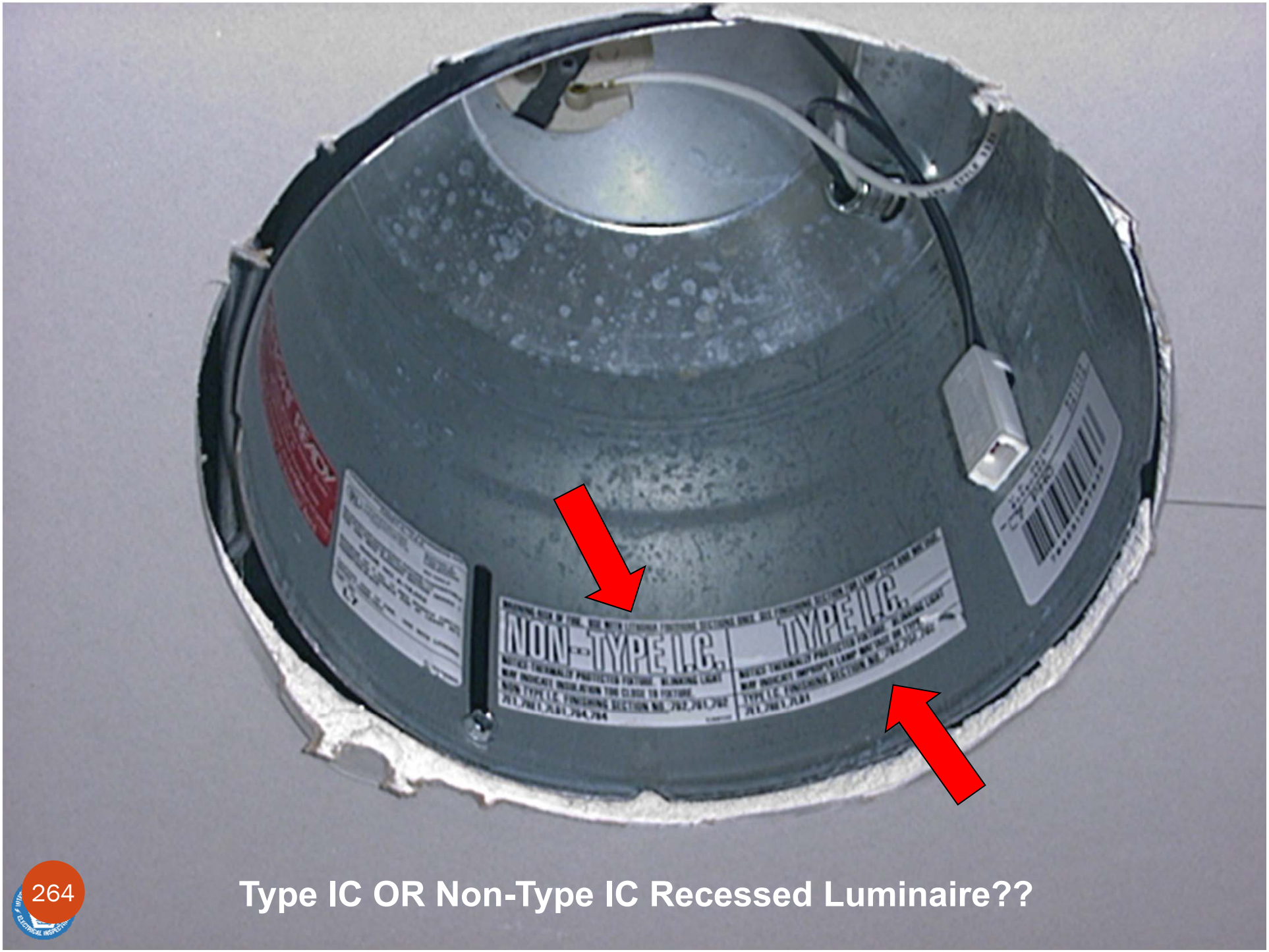
Signs of excess heat, which is usually caused too high of a wattage bulb for the trim/bulb combination, or a non-IC fixture surrounded with insulation:

- Thermal cutoff cycles the light on & off continuously
- Bulbs burn out prematurely / low life span
- Degradation/discoloring/deformation of trim pieces from excess heat

If LED or compact fluorescent bulbs (CFL) are used in place of standard incandescent bulbs, do not confuse "equivalent wattage" ratings used to compare lumen levels to incandescent bulbs with the actual electrical wattage used. The bulb itself will have a wattage listed on it - usually 1/3rd to 1/8th of the "equivalent wattage" rating.



Type NON-IC Recessed Luminaire



Type IC OR Non-Type IC Recessed Luminaire??

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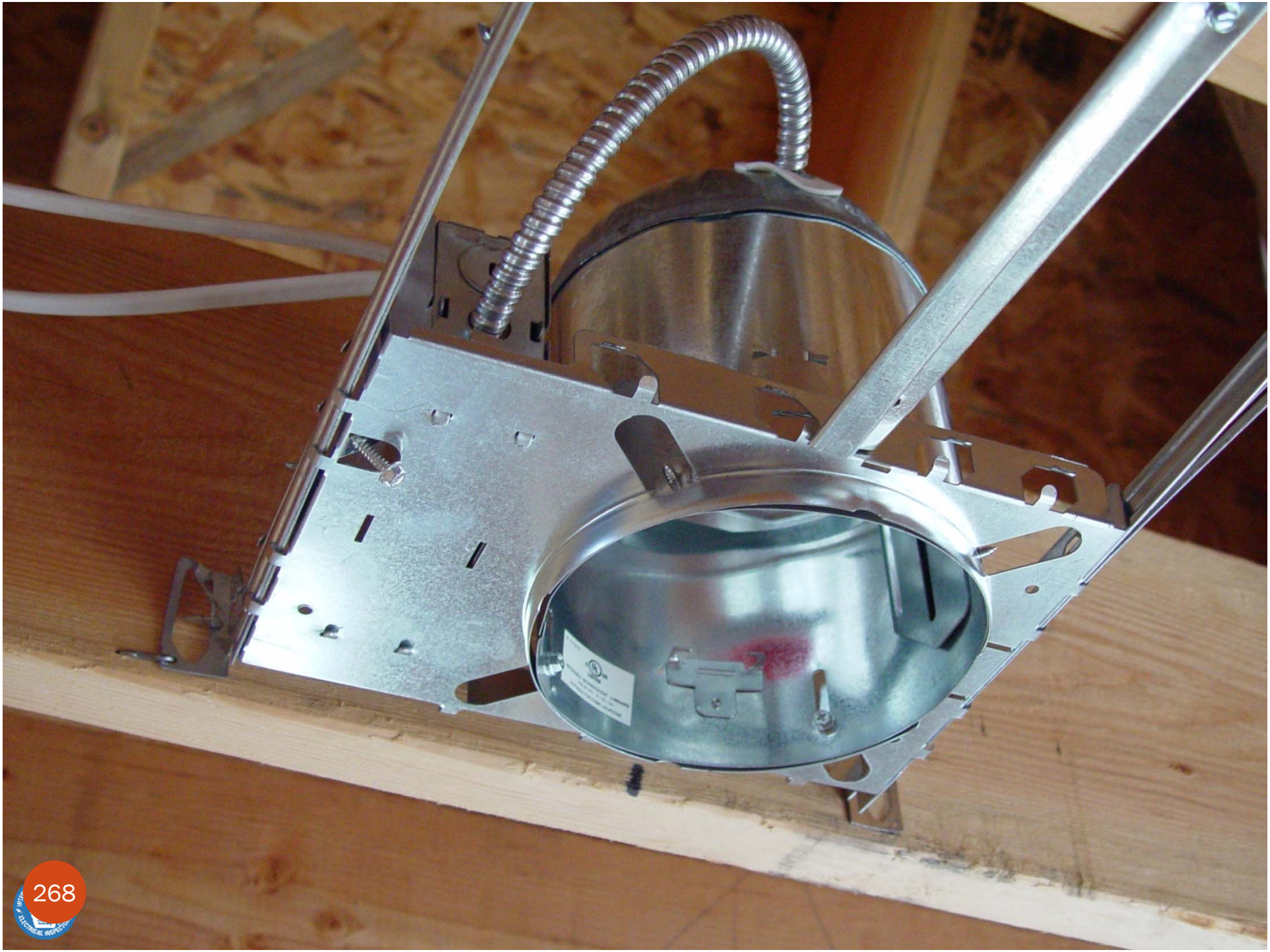
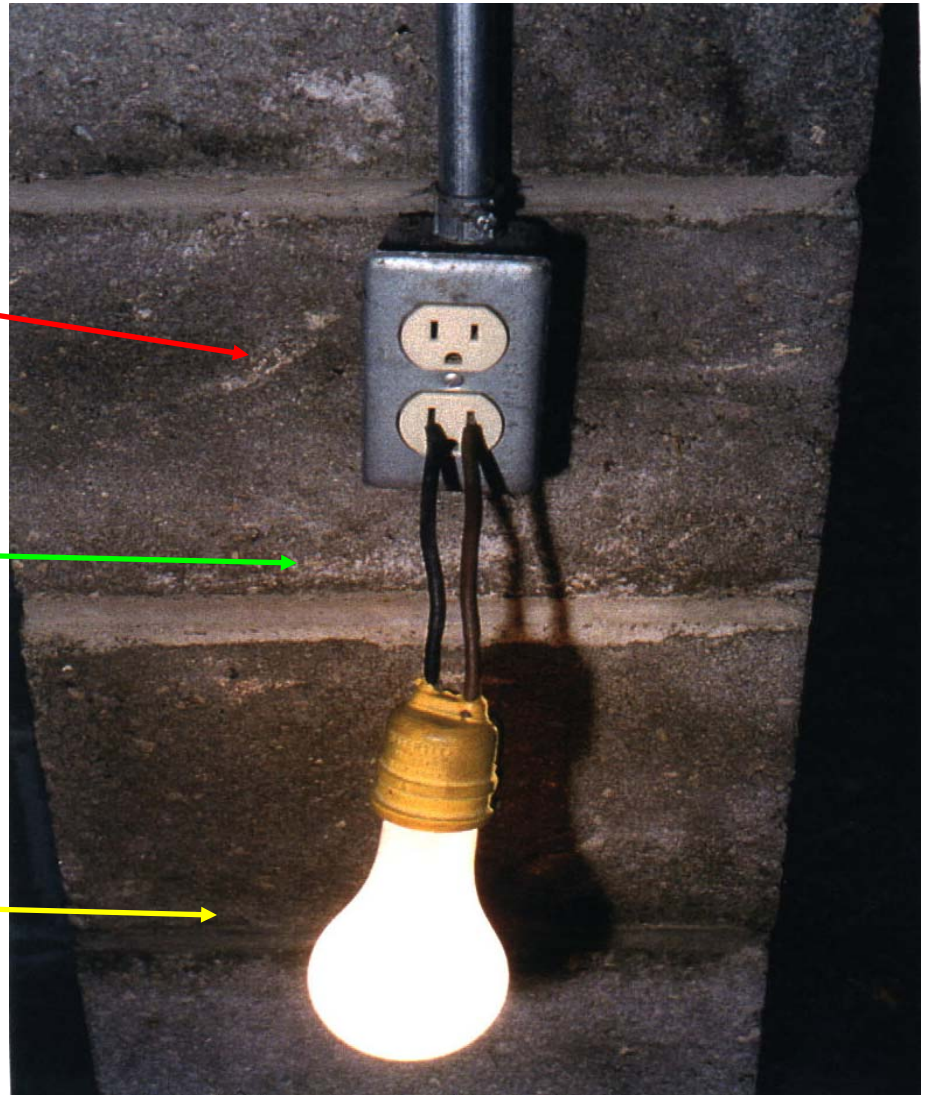


WHAT IS AN ELECTRICAL CIRCUIT?

Source

Path

Load



EXAMINING FIRES OF ELECTRICAL ORIGIN

EXAMINING FIRES OF ELECTRICAL ORIGIN

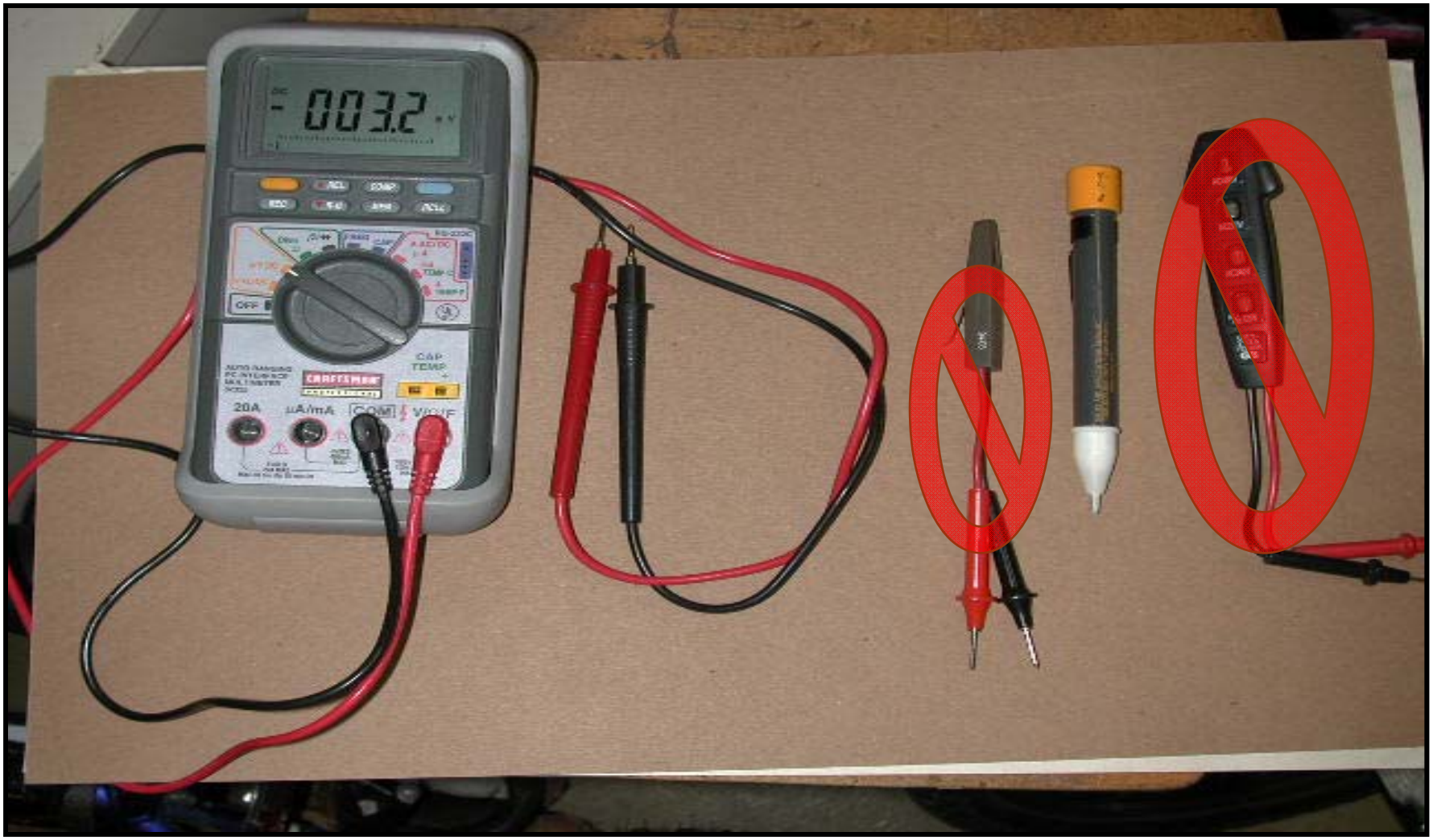
- SAFETY is the number one concern.
- Make sure circuit or system is de-energized.
- CHECK with a metering device before touching anything.
- Lockout/Tagout if applicable.

TESTING & EQUIPMENT

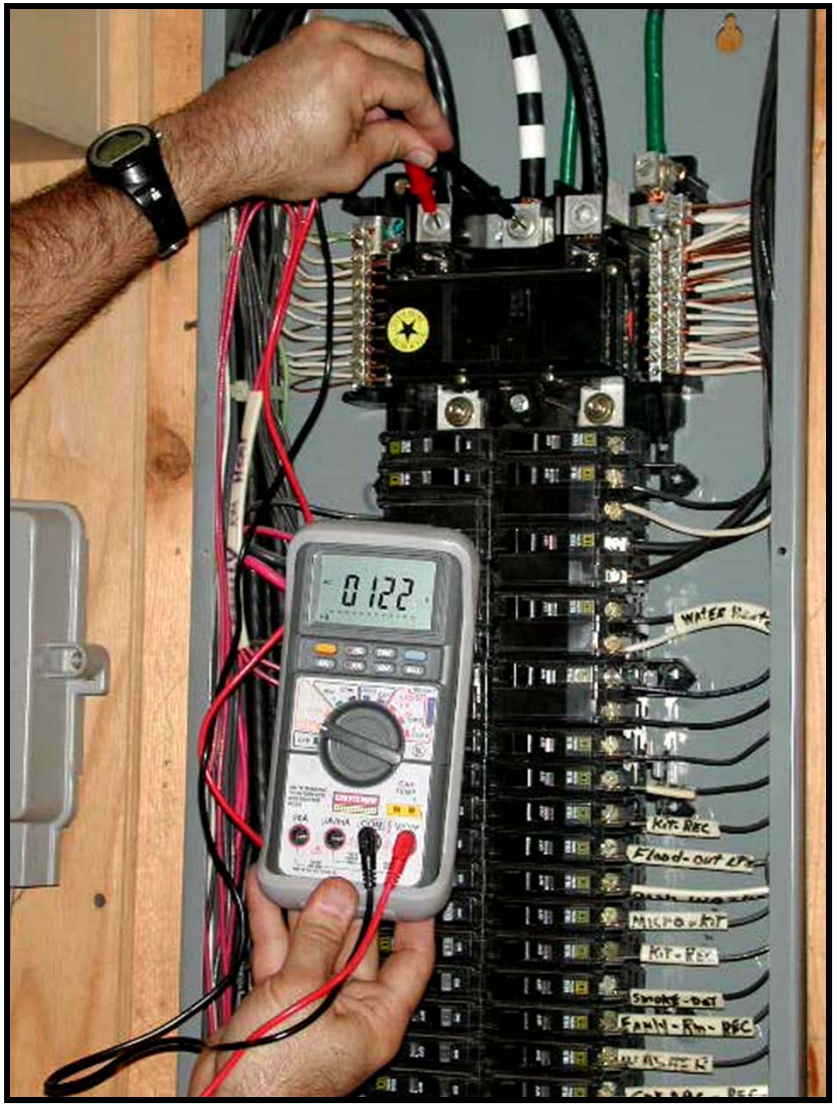
- Ensure the circuit is de-energized.
- Take proper precautions if the circuit cannot be de-energized
- Meters
  - Analog (needle & scale)
  - Digital (numeric LCD display)
- Neon Testers – **NO!!**
- Non-contact Voltage Testers

SAFETY EQUIPMENT

SAFETY EQUIPMENT

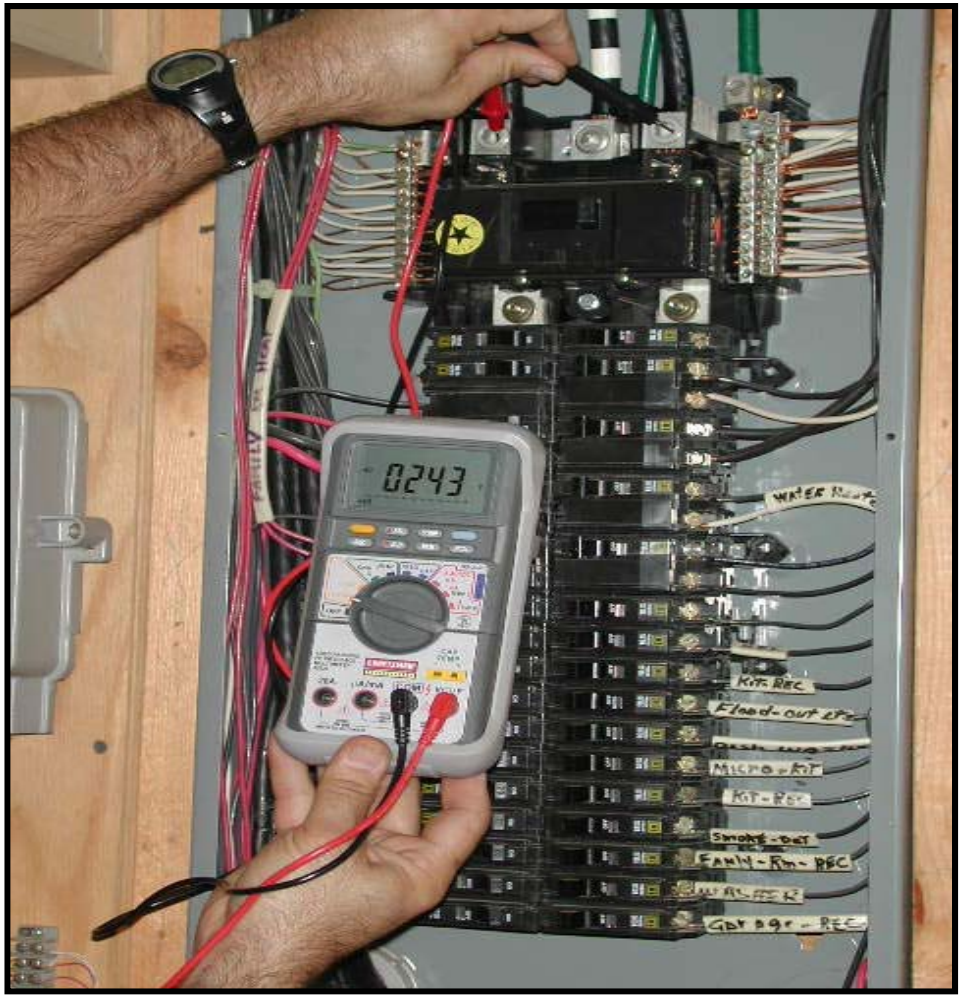


DIGITAL METER



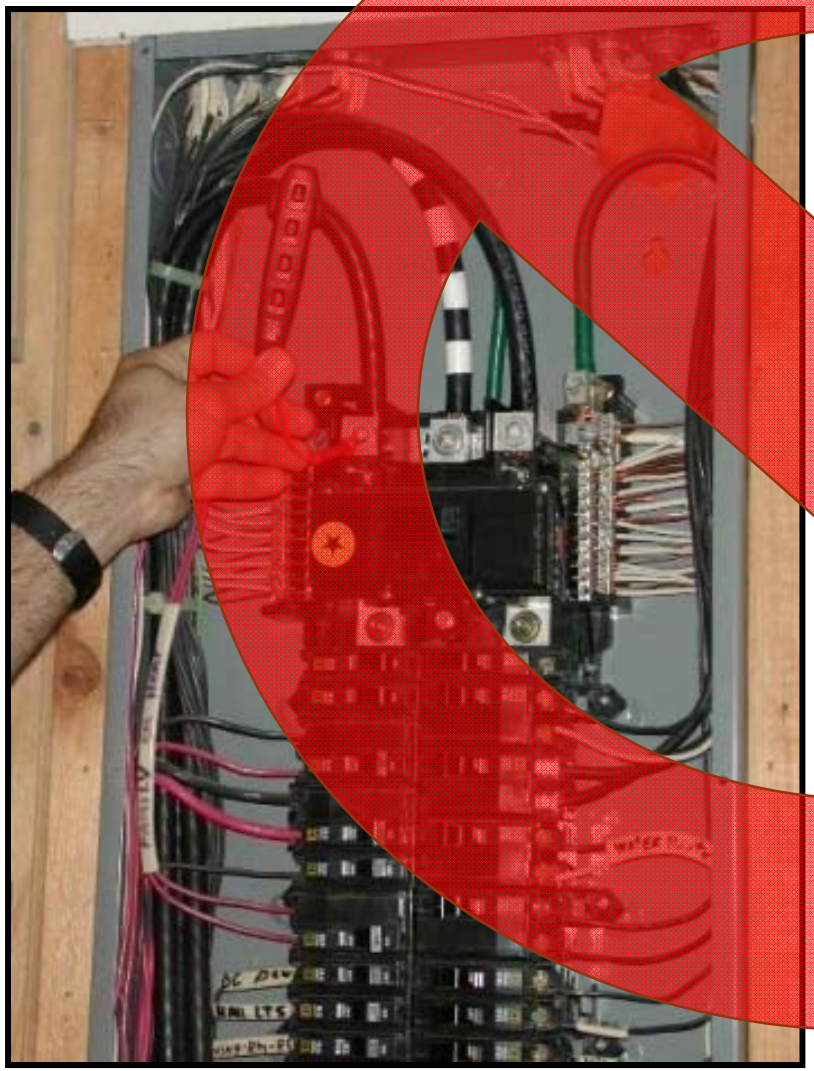
- Checking the Main service entrance conductors.
- One lead on the "hot" conductor the other to the Neutral Conductor
- 120 Volts

DIGITAL METER



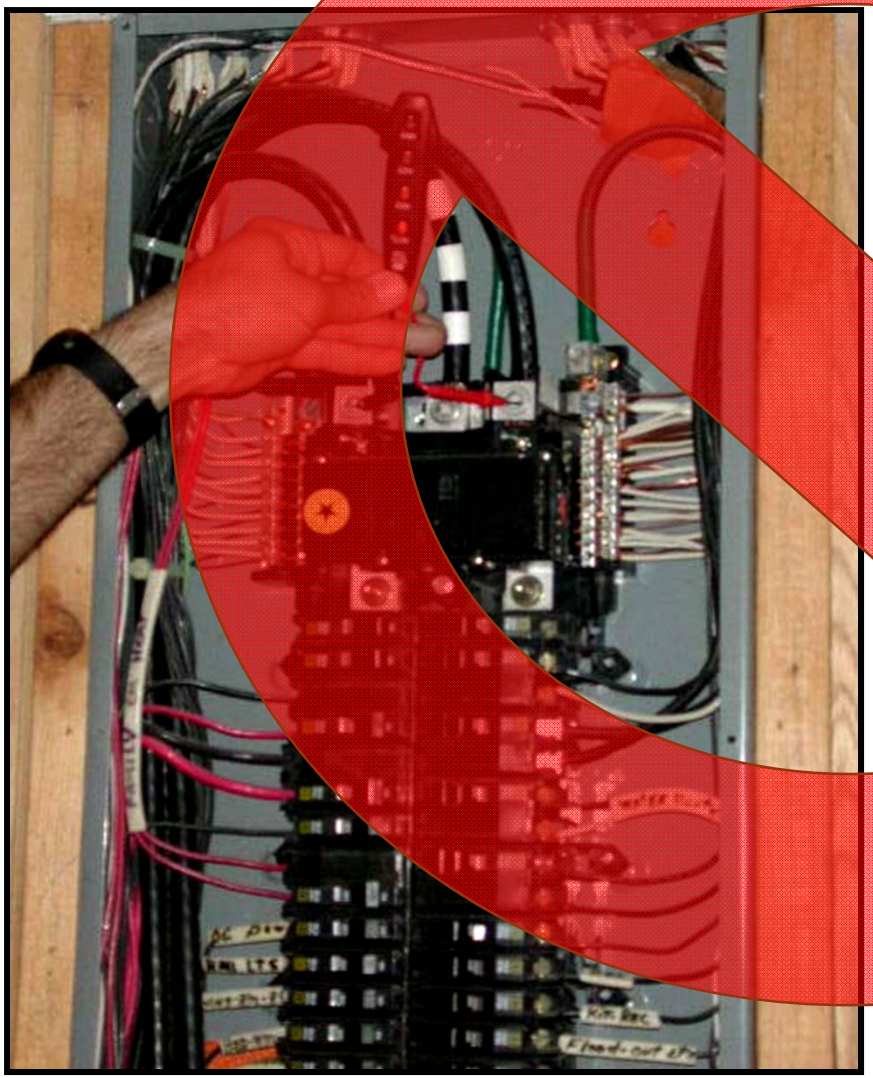
- Meter leads across both “Hot” conductors at the panel box.
- 240 volts

NEON TESTER



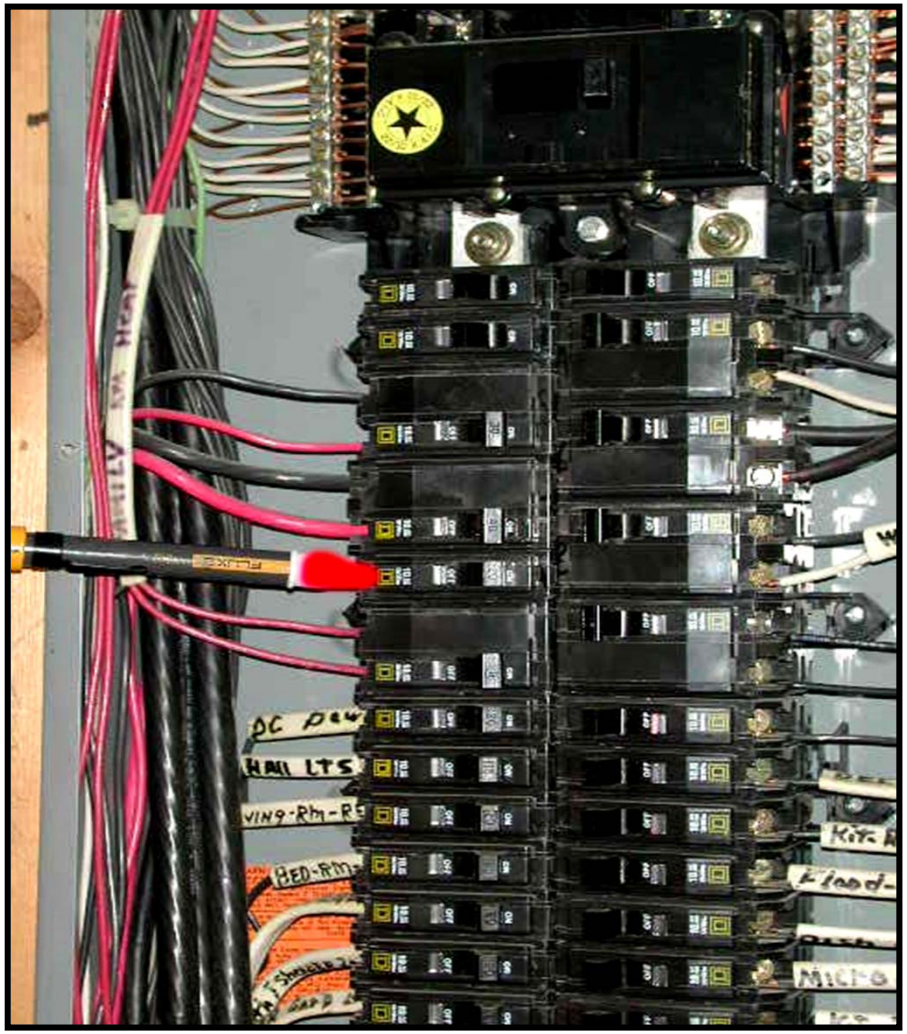
- Neon tester used to check voltage at the main service panel.
- One side of tester on the "hot" conductor.
- The other side of a grounded source.
- Leads can be reversed.

NEON TESTER



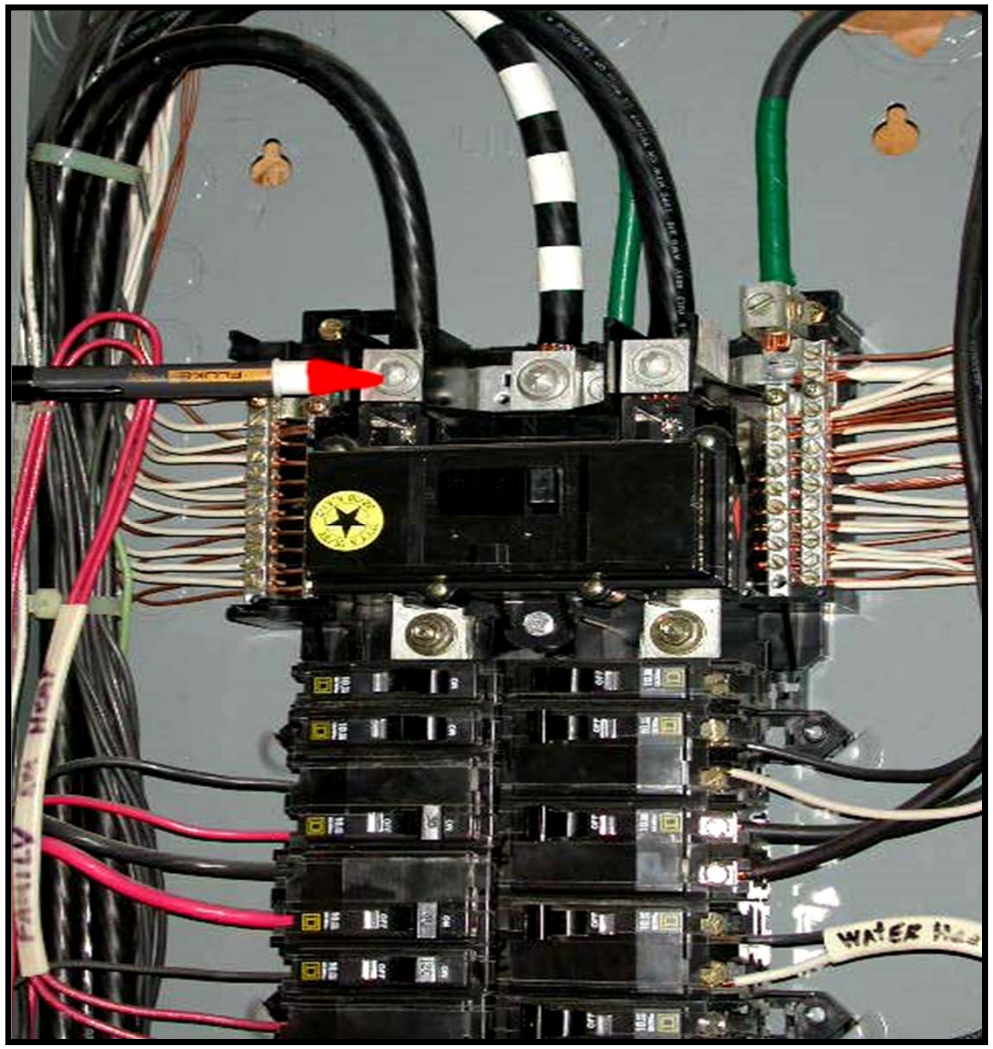
- Leads attached to both "hot" conductors.
- 240 Volt reading on tester or an increased brightness on tester lamp.
- One hand operation

NON-CONTACT VOLTAGE TESTER



- Luminary voltage tester.
- Tip either lights up or some models add a buzz or beep sound.
- Inexpensive and reliable.
- **TEST ON A KNOWN GOOD CIRCUIT BEFORE EVERY USE!**

NON-CONTACT VOLTAGE TESTER



- Can be used to check any type of energized circuit.
- NO voltage amount given, just confirms the presence of a voltage.

SAFETY

- REMEMBER YOU CANNOT SEE ELECTRICITY
- ONLY ITS EFFECTS

- **TEST BEFORE YOU TOUCH !!!**

DOCUMENT THE DISTRIBUTION SYSTEM USE THE SCIENTIFIC METHOD!

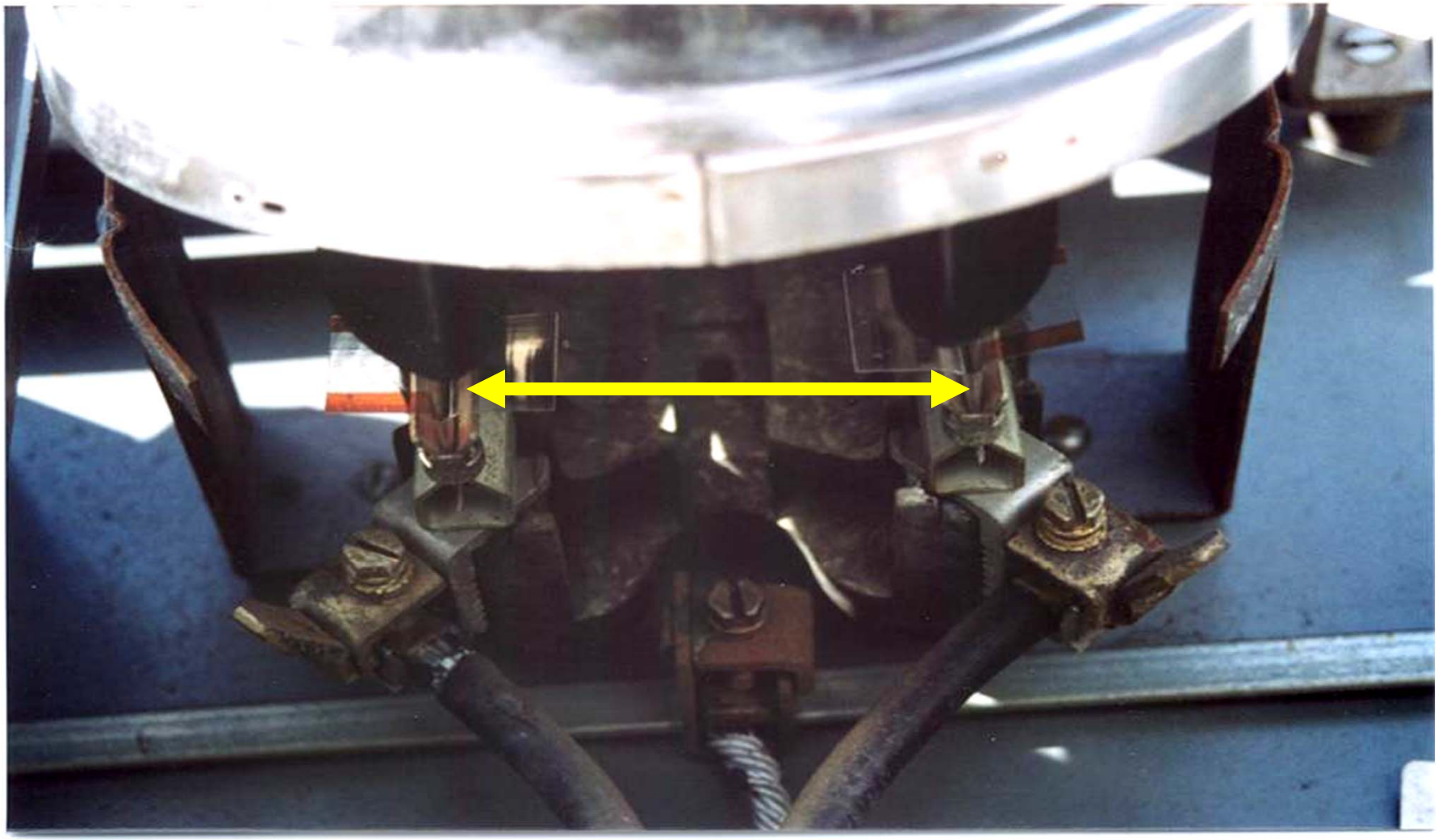
- **Utility transformer(s)**
  - **Document their physical location and appearance.**
  - **When and how was the utility power de-energized (test to see if it is off)?**
  - **How many transformers service the structure?**
  - **Are the transformers pole or pad mounted?**
  - **Has the transformer been replaced since the fire?**
  - **Did the transformer serve more than one structure?**
  - **Are the primary fuses open?**
  - **Did anyone hear the fuses blow?**
- **Service conductors**
  - **What type (drop or lateral)?**
  - **Condition of conductors (attached, broken, arced).**
  - **Connections at transformer and meter base.**
  - **Presence of tree limbs, building members, etc.**
- **Meter base**
  - **Present or absent.**
  - **Condition of conductors and connections.**
  - **Arc damage.**

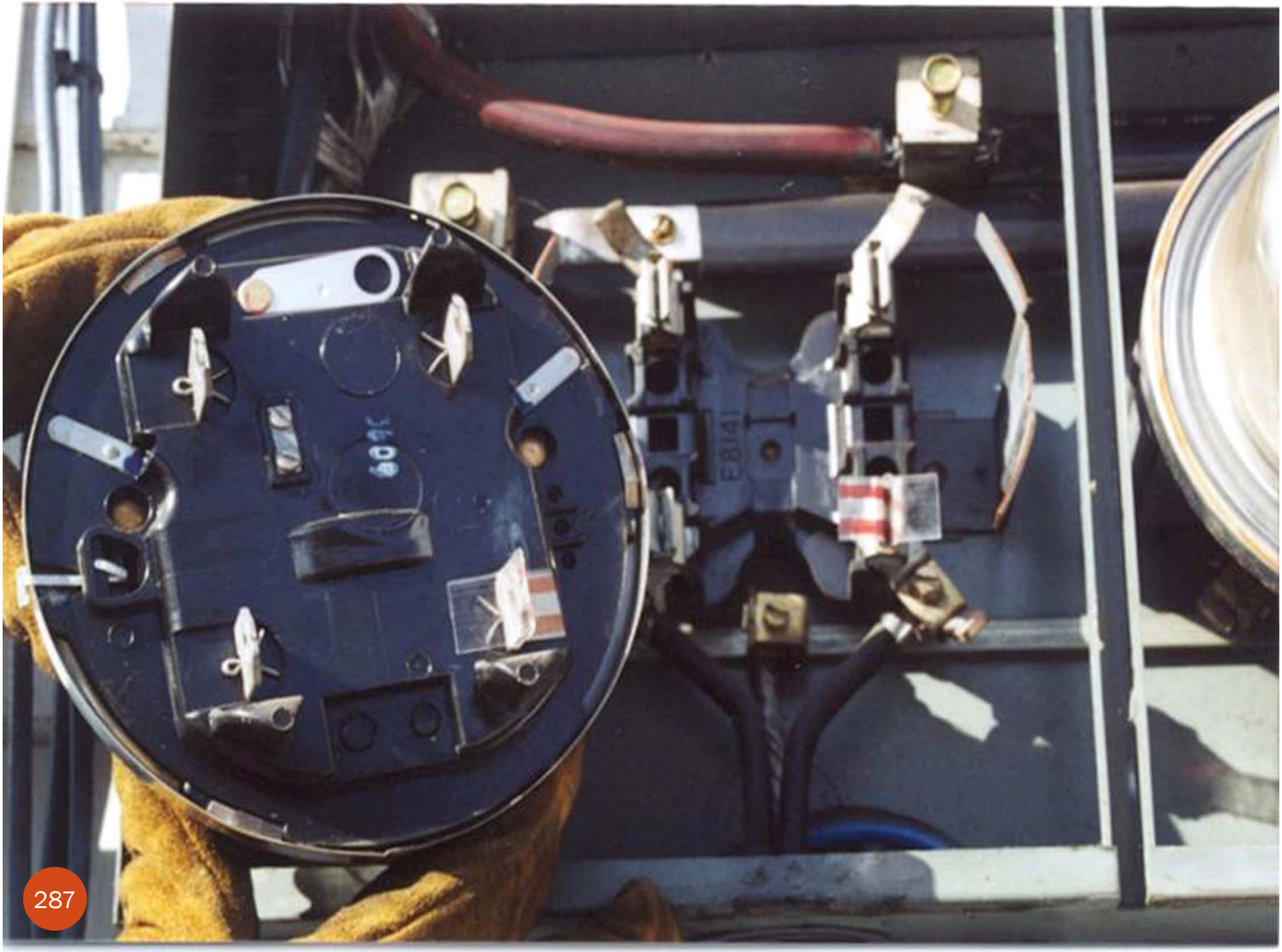
DOCUMENT THE PANELBOARD

- **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!**

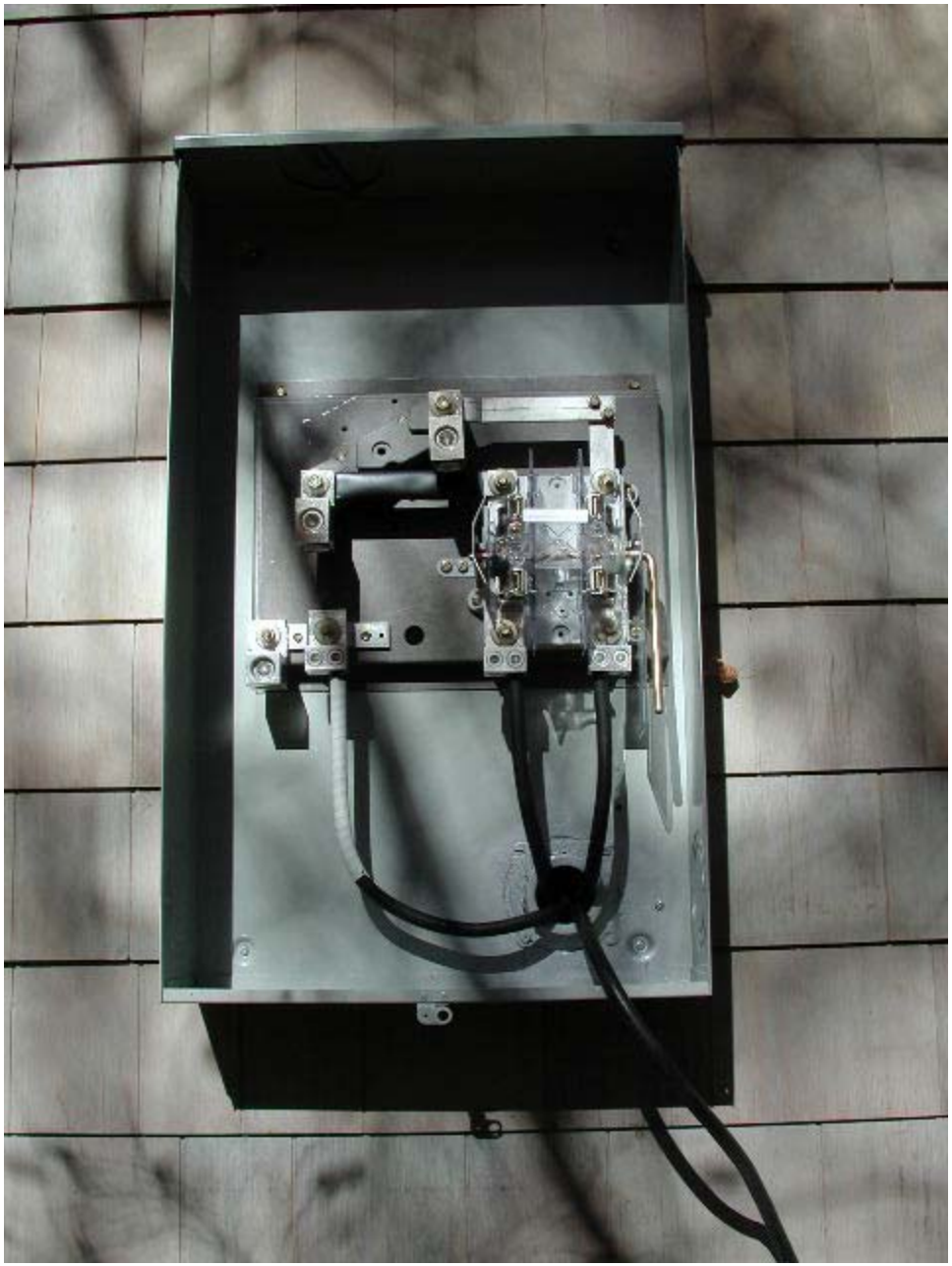
KILOWATTHOURS
LANDIS & GYR
38 385 571
PPEL
APT-1
1ST FLOOR

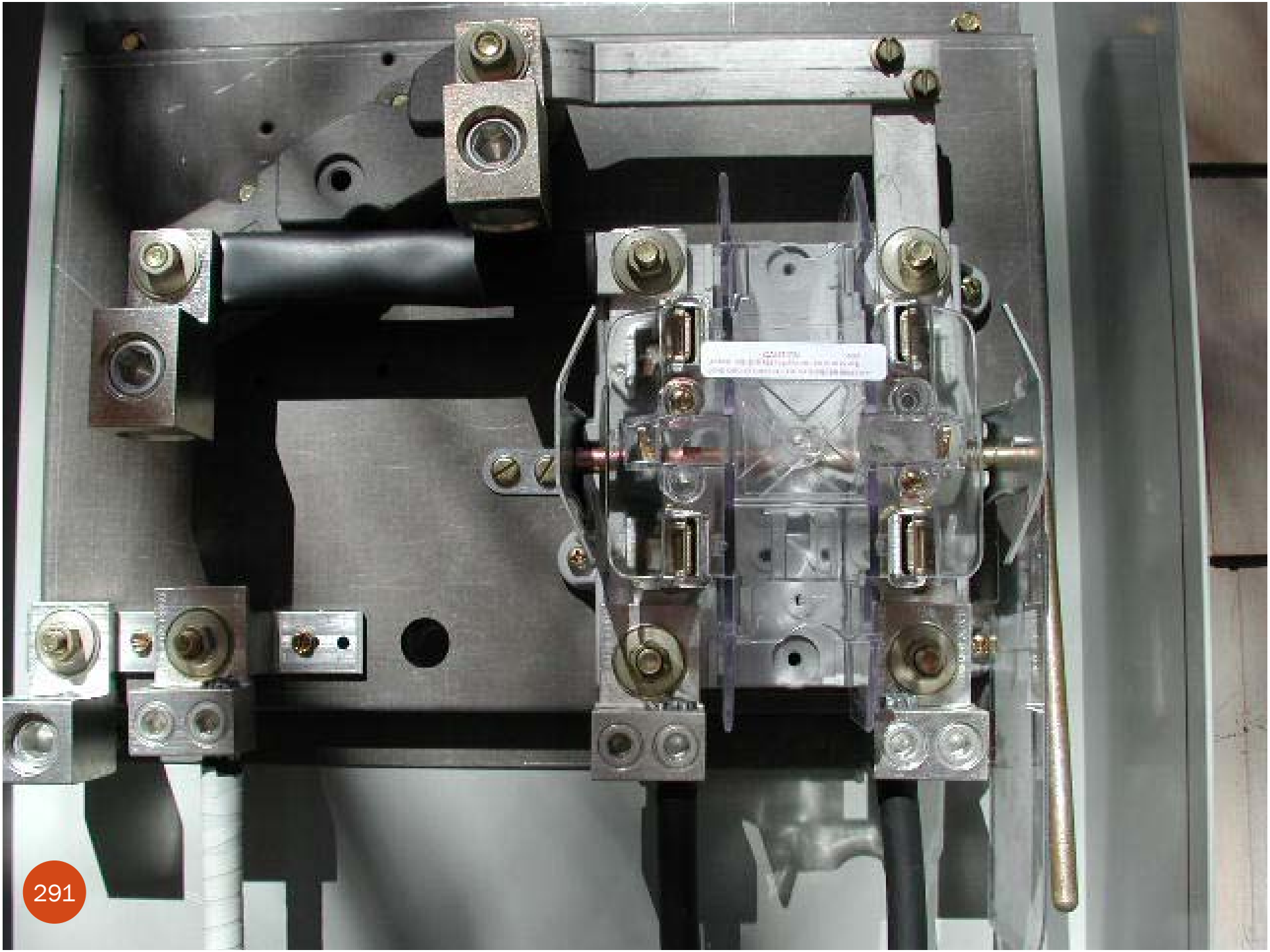
“BOOTED” METER

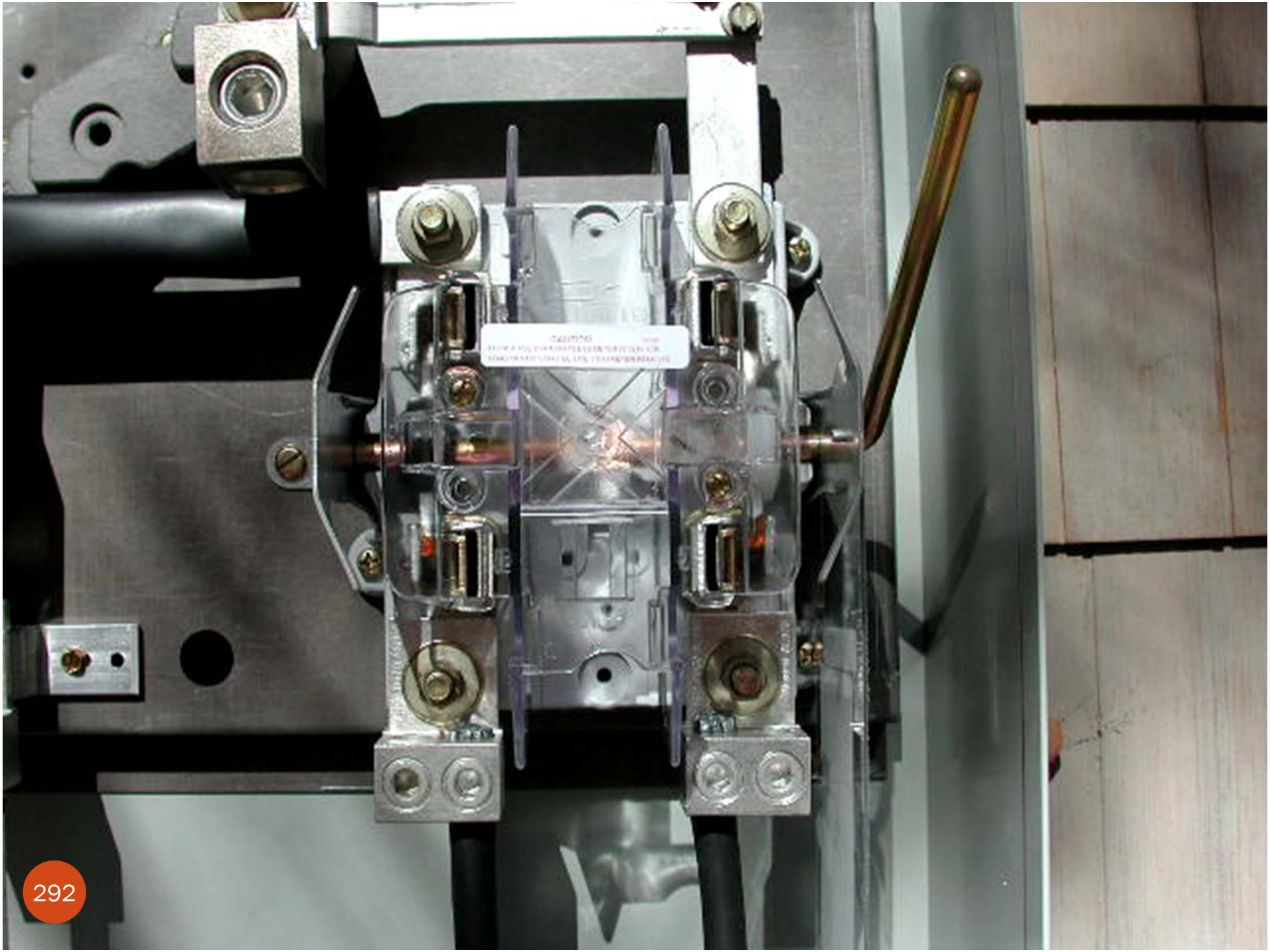



E8141

22,000 AIR
200
MAIN
PRINCIPAL
ON
OFF







GALVANIZED
RAINPROOF

GALVANIZED
RAINPROOF

SQUARE D
ENCLOSED
CIRCUIT BREAKER
INTERRUPTOR
AUTOMATICO EN GABINETE
DISJONCTEUR
SOUS COFFRET
Automatic trip is indicated by handle position midway between ON and OFF. Reset breaker by moving handle to OFF then ON position.
El disparo automático se indica cuando la palanca se encuentra a la mitad de las posiciones de CERRADO y ABIERTO. Restablezca el interruptor moviendo la palanca a la posición de ABIERTO y luego a la posición CERRADO.
La position de la manette à mi-course entre ARRET et MARCHE indique un déclenchement automatique. Réinitialiser le disjoncteur en déplaçant la manette sur ARRET puis sur MARCHE.
40274-522-02

CL 480
P P & L
AXD54
55 975 997

Alternative Power Source

EVALUATE THE COMPONENTS

Once the source is established, the path is determined, and the load is identified…

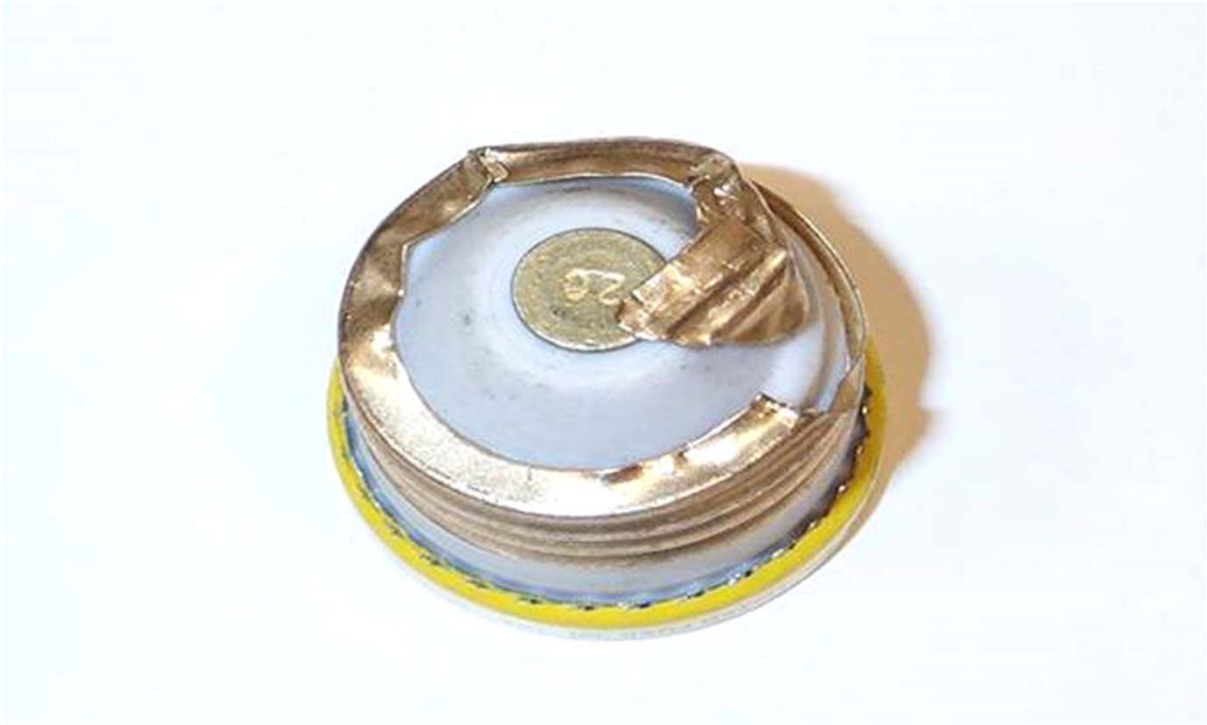
Was it an electrical event or not is the next question.

EVIDENCE OF TAMPERING

EVIDENCE OF TAMPERING

EVIDENCE OF TAMPERING

EVIDENCE OF TAMPERING

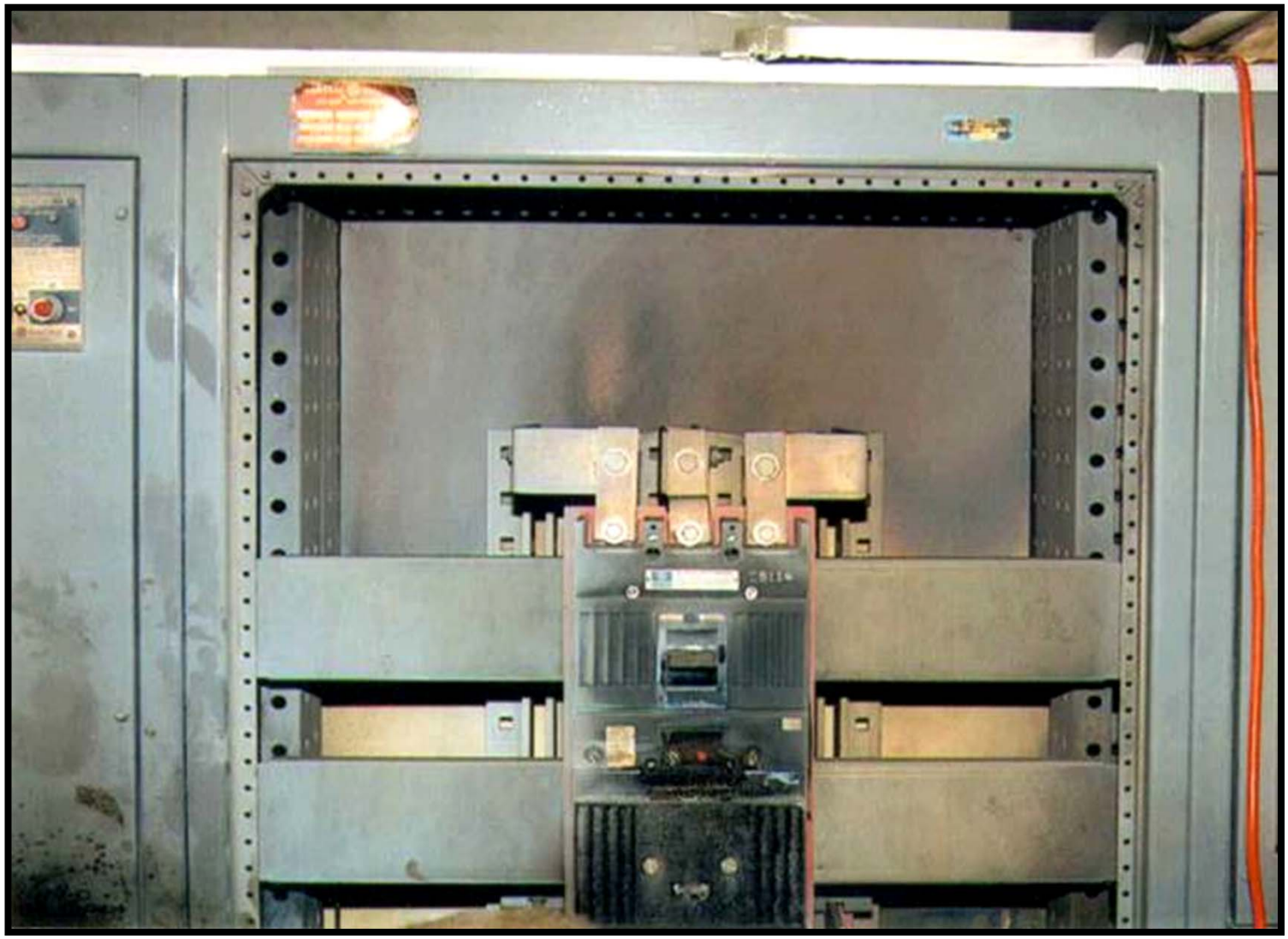


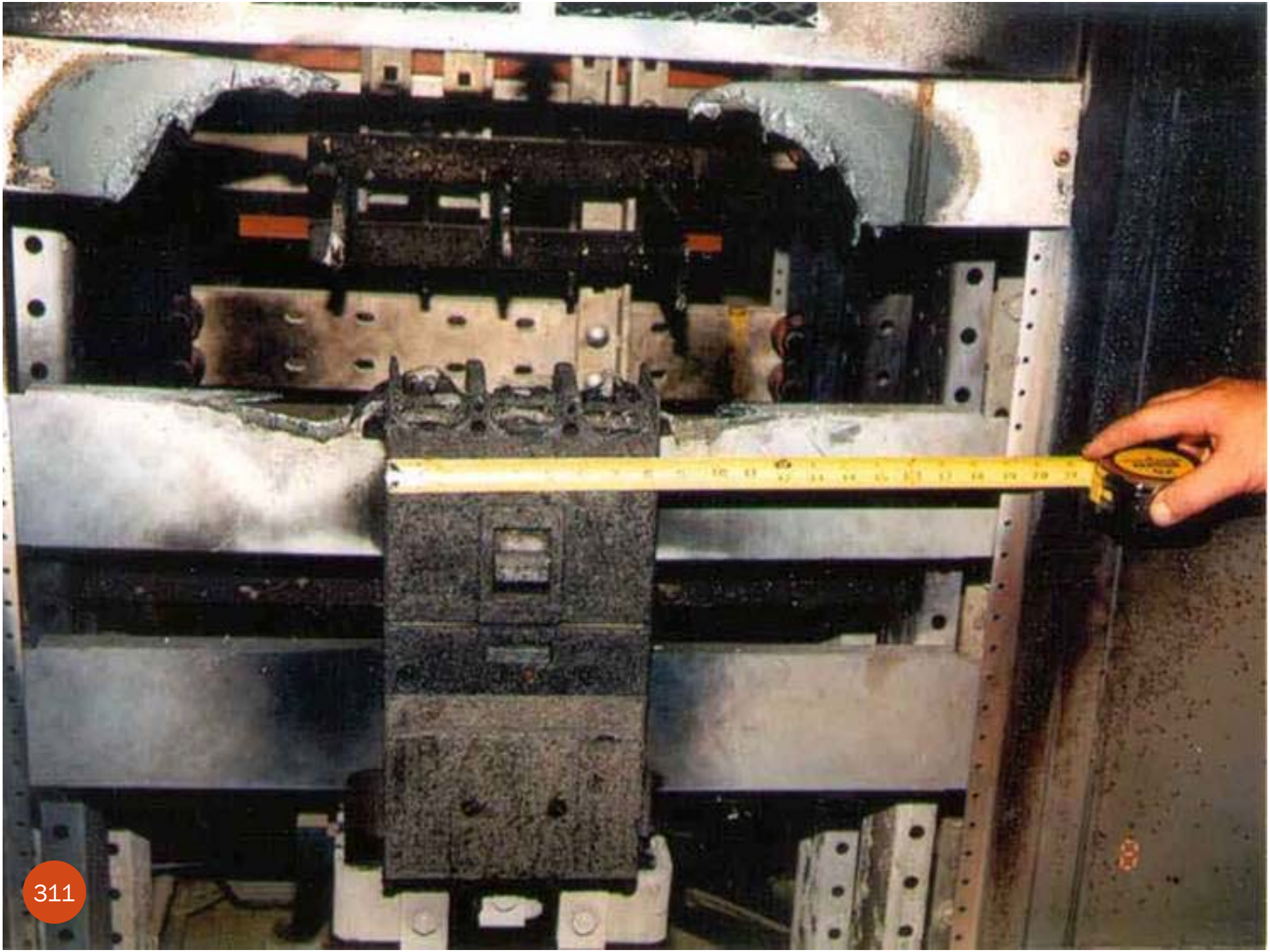
DO THE BURN PATTERNS SUPPORT THE CAUSE DETERMINATION?

Fire at the service panel or service panel impacted by fire ????

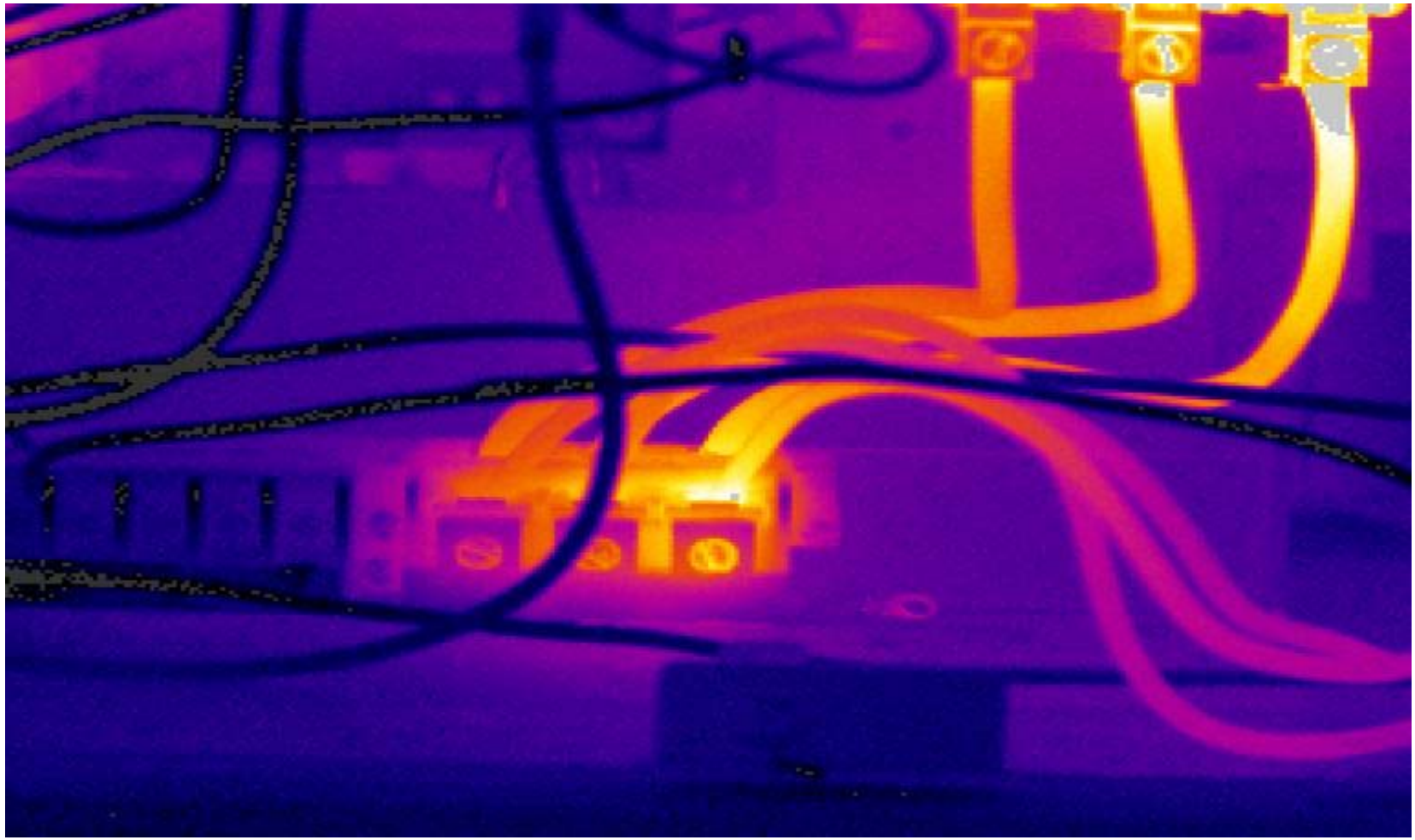
EXAMINATION

EXAMINATION





PROBABLE CAUSE....OVERHEATING



Thermogram 1/18/2007

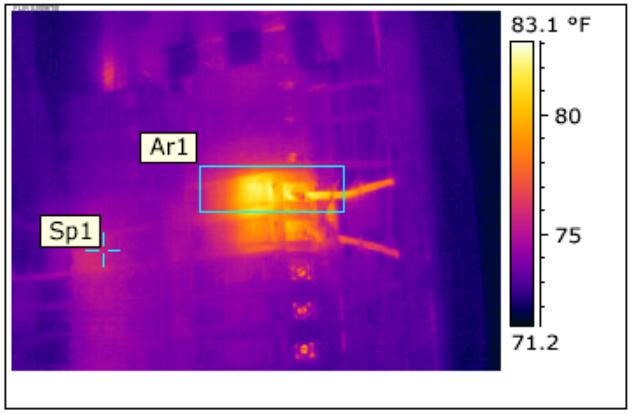
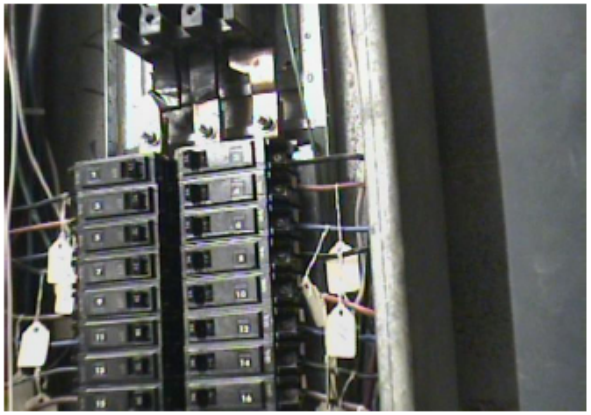


Photo and Identification



IR Text Comment	Value
Location	Ground Floor West Electric Closet
Equipment	Panel PGIA-R
Type	Breaker #8
Nom load	20A
Actual load	9A
Fault	Minor
Recommendation	No action required.
Label	**Value**
IR: File Name	Montgomery General Hospital 011.jpg

Label	Value
Sp1	75.4 °F
Ar1: Max	82.4 °F

Analysis & Recommended action:

Breaker #8 in Ar1 above is revealing a minor fault of 7 degrees while pulling a moderate load. No action required at this time. Continue to monitor as part of your electrical PM program.

Thermogram 1/18/2007

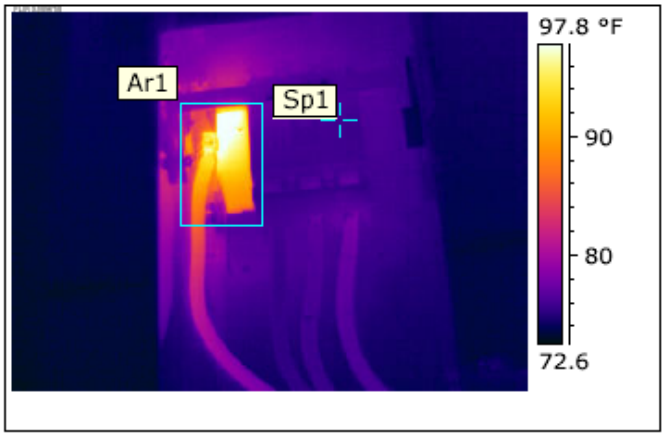
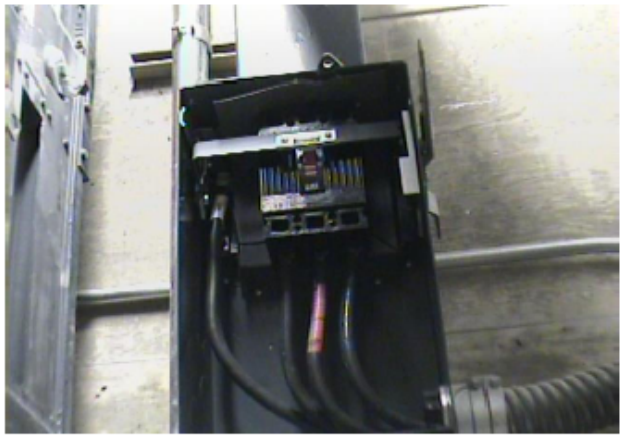


Photo and Identification



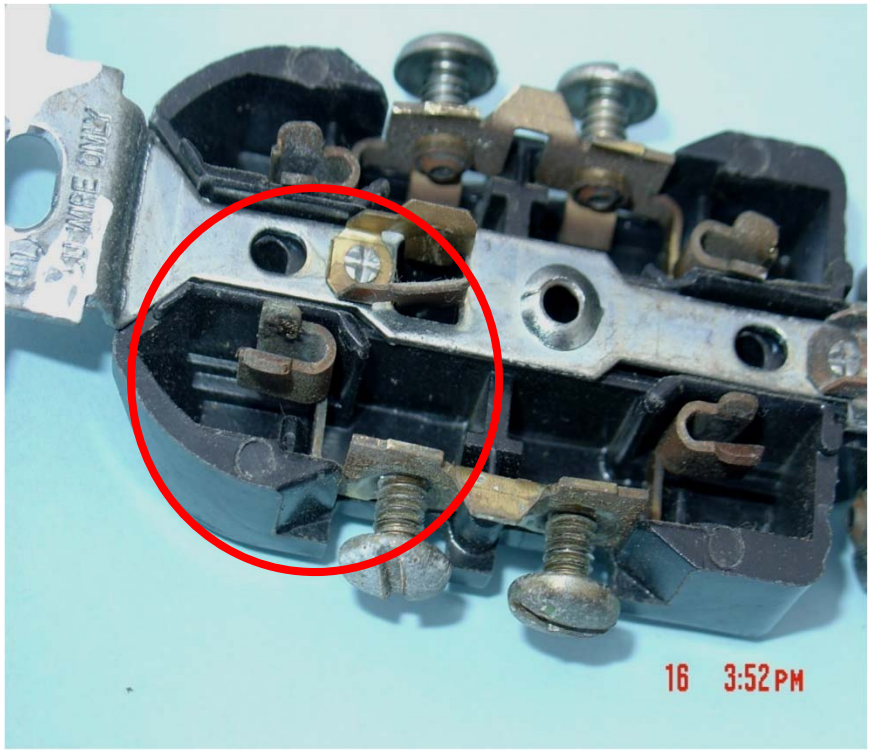
IR Text Comment	Value
Location	Ground Floor West
Equipment	Emergency Riser
Type	Disconnect - Neutral
Nom load	100A
Actual load	14A
Fault	Intermediate
Recommendation	Repair
Label	**Value**
IR: File Name	Montgomery General Hospital 005.jpg

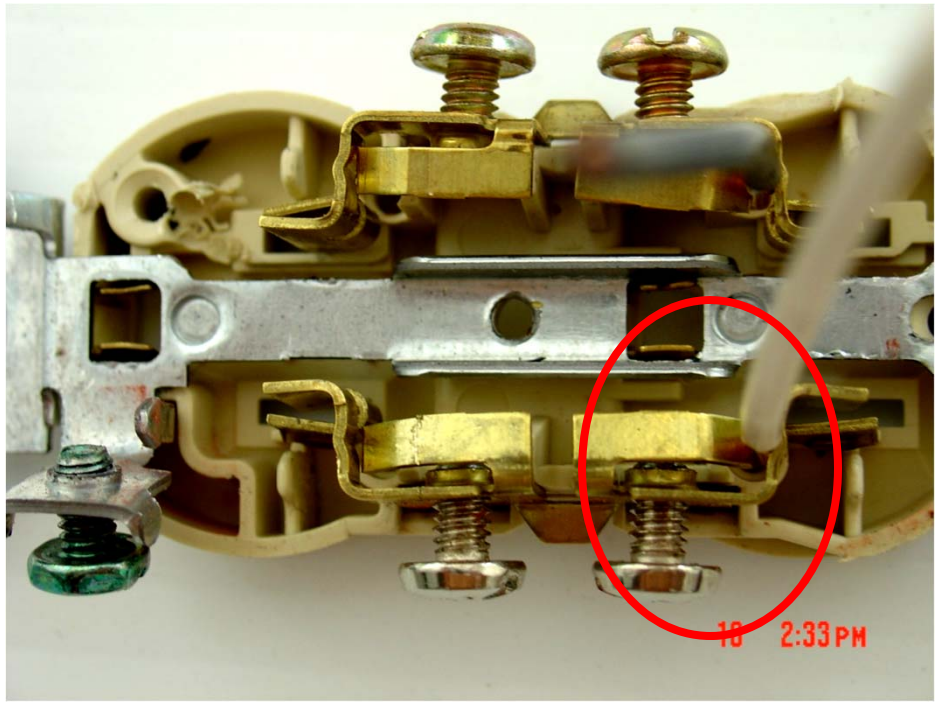
Label	Value
Sp1	76.0 °F
Ar1: Max	99.8 °F

Analysis & Recommended action:

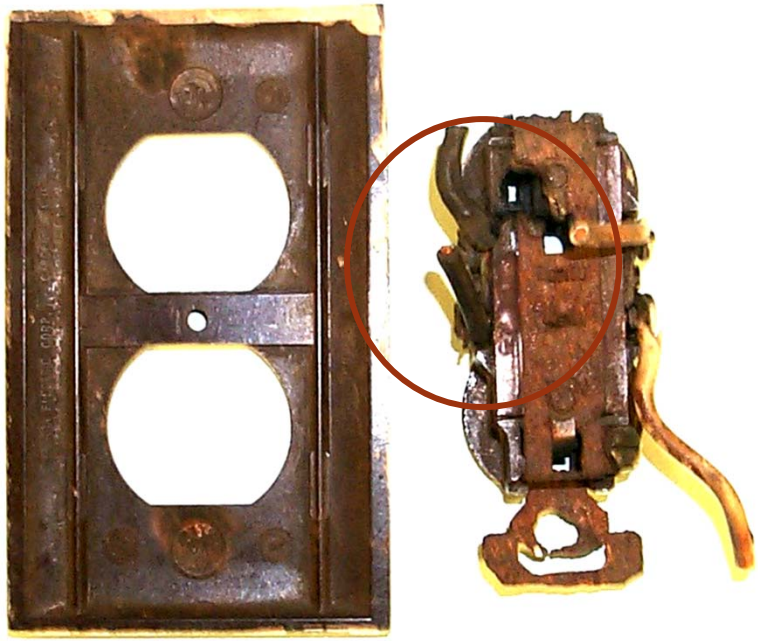
The neutral connection in Ar1 above is revealing an intermediate level fault of 23.8 degrees when compared to the C phase connection which is pulling 17.1 amps. The neutral connection at the time of the scan was measuring 14 amps. Refer to the electrician for review.

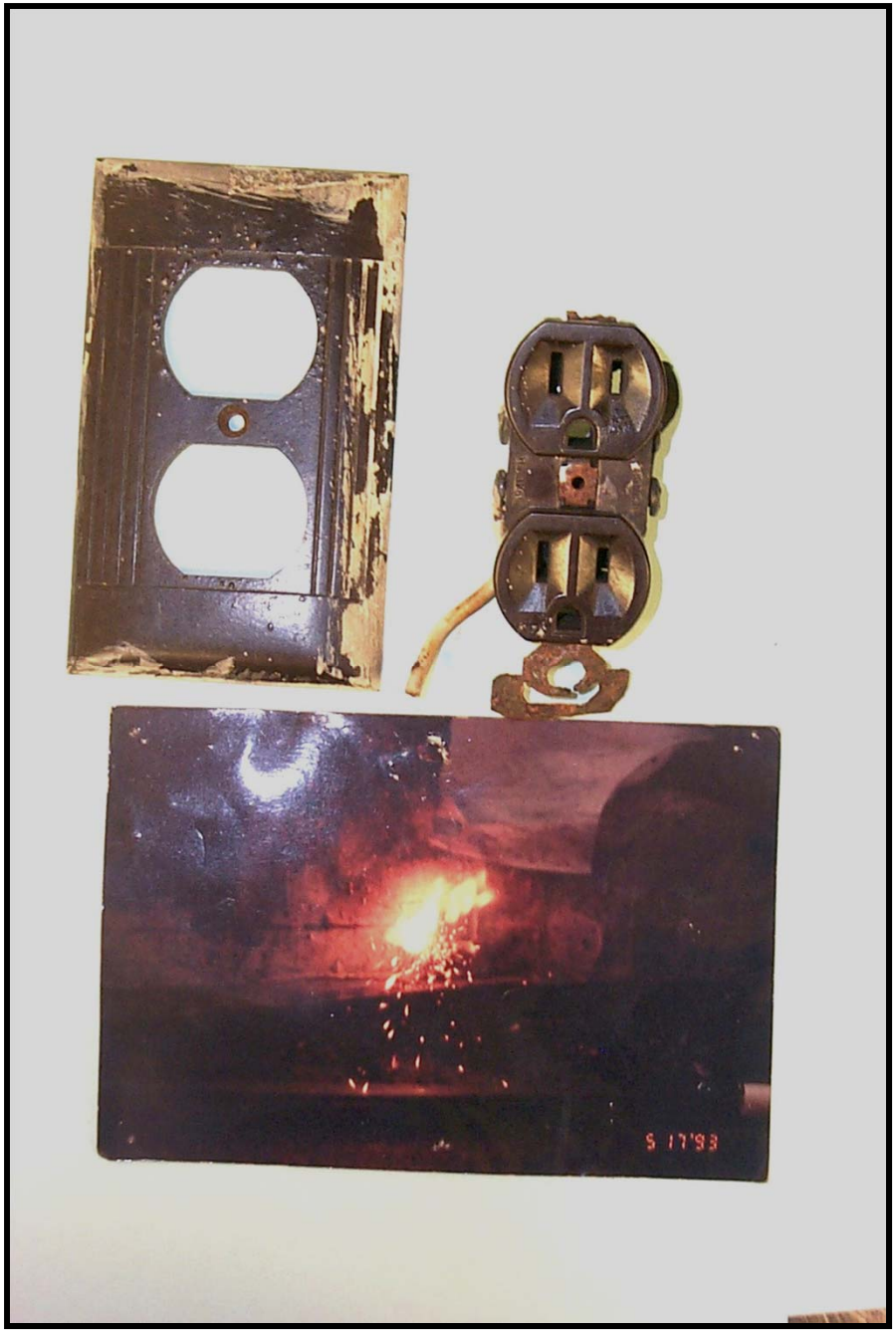
HIGH RESISTANCE CONNECTIONS





INVESTIGATE!

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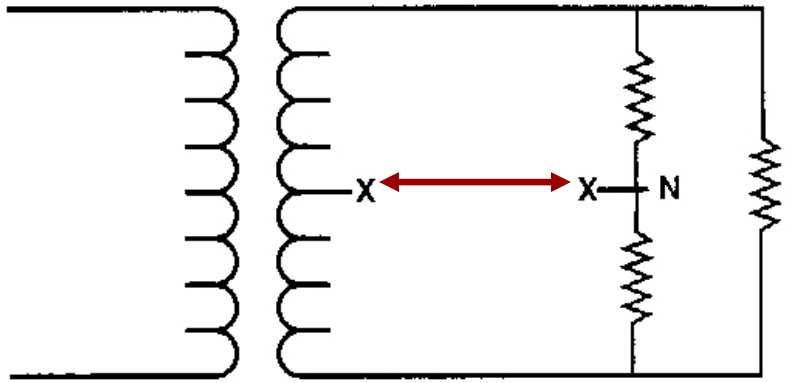
OPEN NEUTRAL FAILURE



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.

"OPEN NEUTRAL" WILL BE DEMONSTRATED DURING PRACTICAL EXERCISE

Photo: IAEI Archives

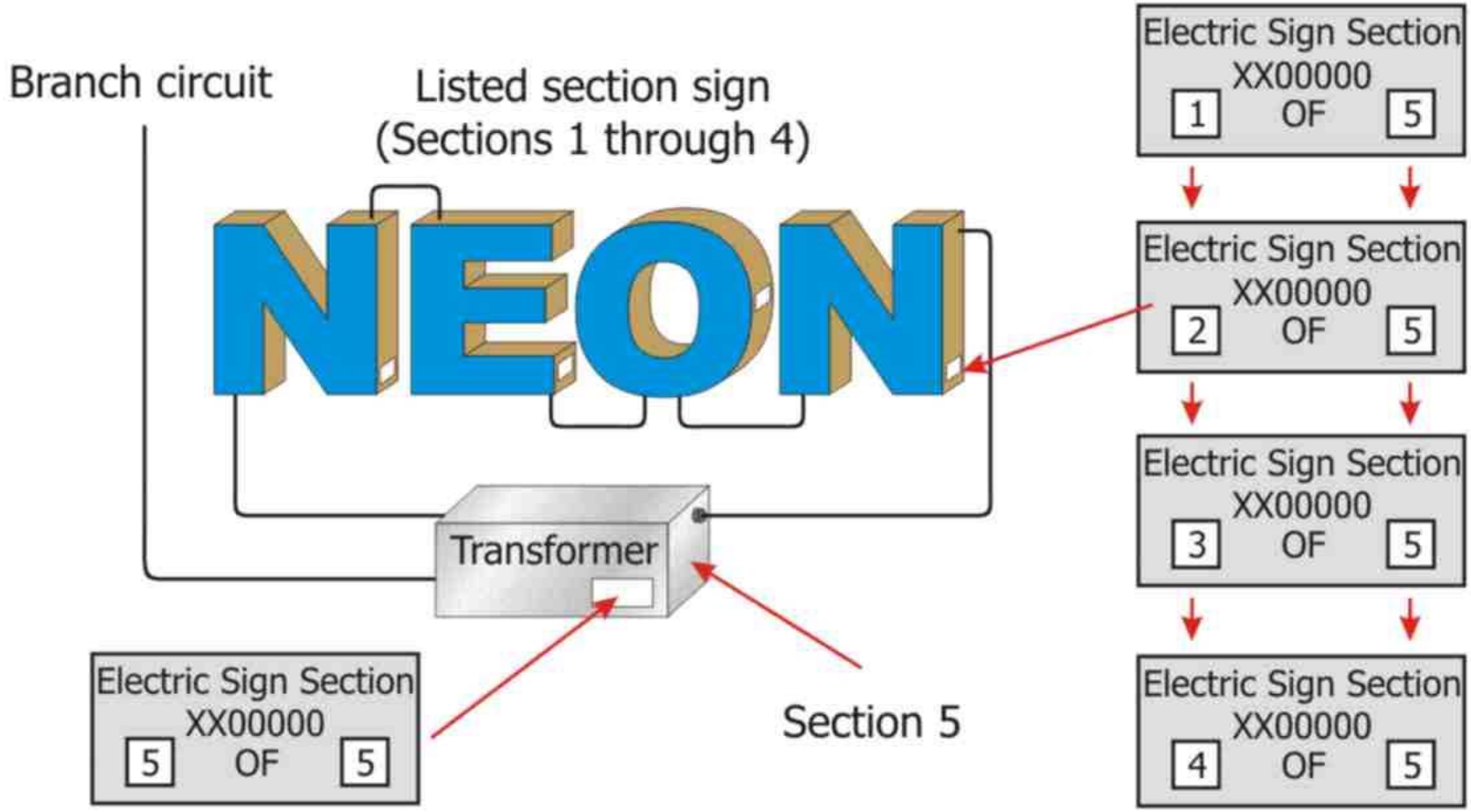
COMMON STRUCTURAL WIRING

- Pure aluminum wire melts at 1,220°F (660°C).
- Pure copper wire melts at 1,981°F (1,082°C).

WIRING MALFUNCTIONS

- Arcing or beading marks on the conductor.
  - Attempt to identify how they were formed.
  - Beading on a conductor is NOT a sole indicator the fire was electrical in nature.
- Electrical beading indicates that the circuit was energized.

600.4(C) Section Signs



Section signs are required to be marked to indicate that field-wiring and installation instructions are required [600.4(C)].

Listed equipment is required to be installed in accordance with installation instructions included in the listing [110.3(B)].

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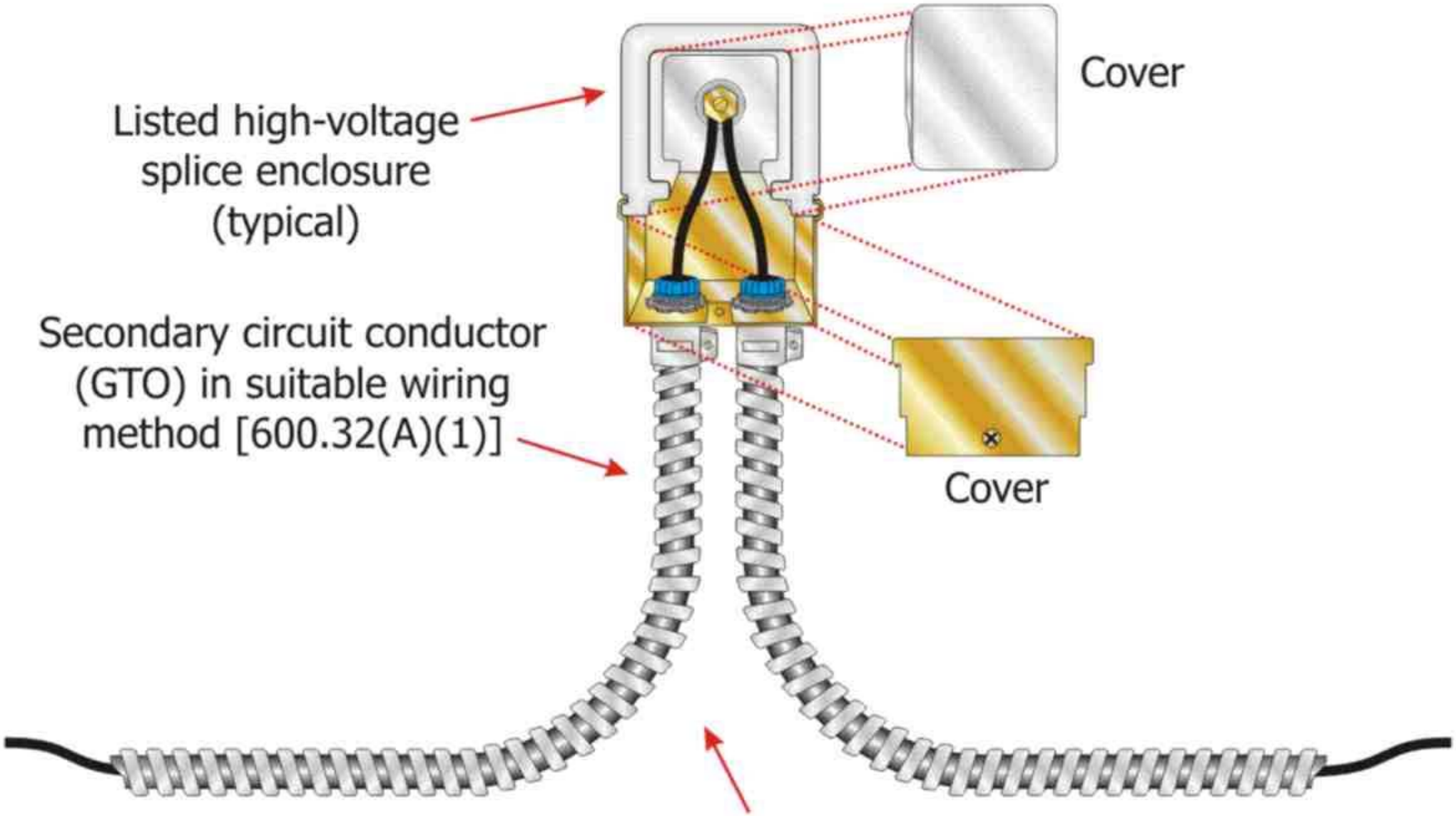
600.32(K) Splices



- Splices in high-voltage secondary circuit conductors shall be made in listed enclosures rated over 1000 volts.
- Splice enclosures shall be accessible after installation and be listed for the location where they are installed.

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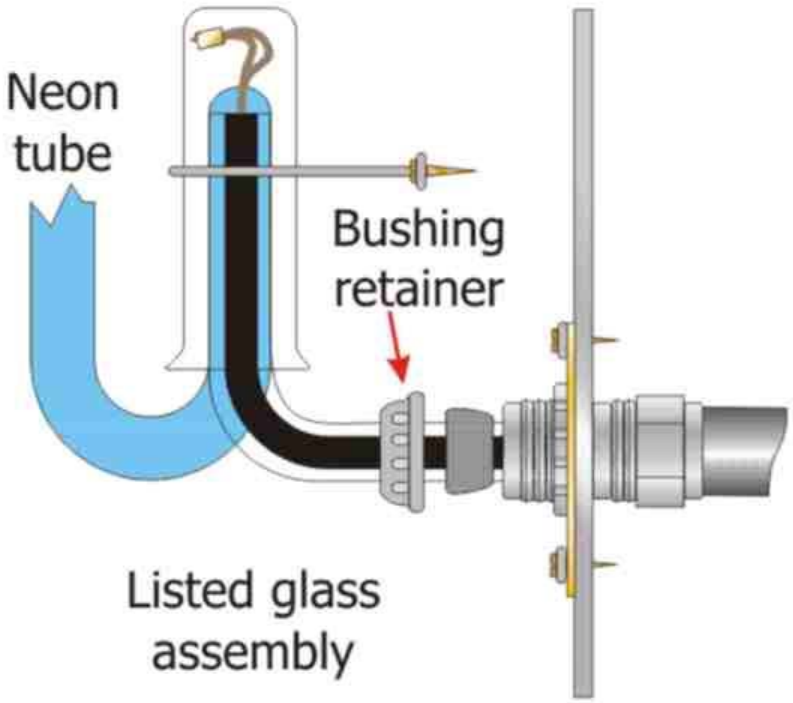
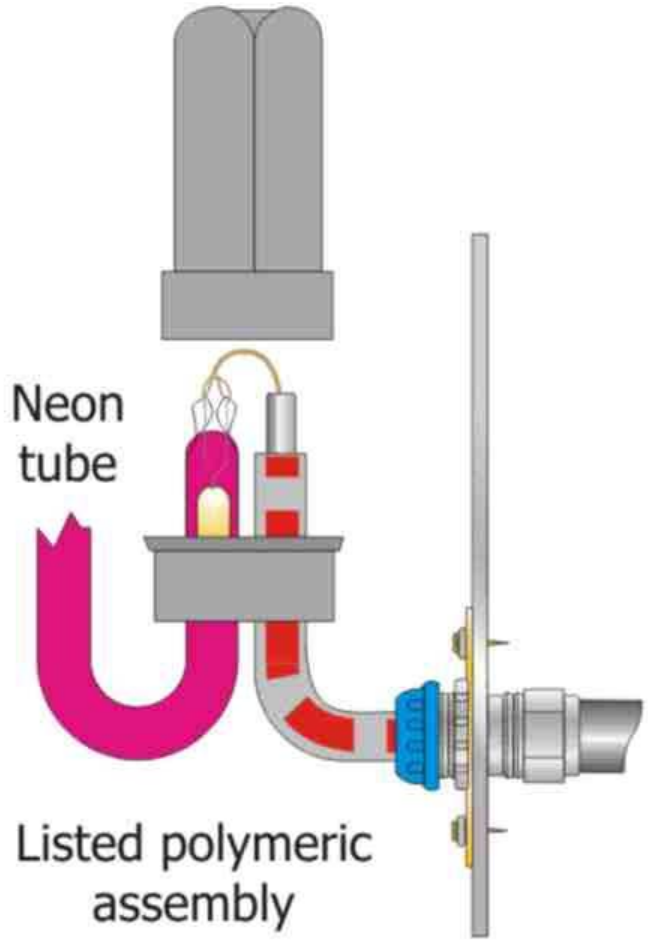
600.42(A) Points of Transition

Listed assemblies are required at points of transition between neon high-voltage secondary conductors and the electrode connections at the tubing.





Listed assemblies are required to be suitable for the location where they are installed [110.3(B)]

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Photo: IAEI Archives

Photo: IAEI Archives

ARC MELTING OF CONDUCTORS

VS

THERMAL MELTING OF CONDUCTORS

WHAT HAPPENS TO ENERGIZED WIRES THAT BURN?

This type of damage is called arcing through char. Arcing through char occurs as fire attacks an energized conductor. As the insulation begins to burn and char it forms carbon, which is a semiconductor. The presence of carbon between the energized conductor and grounded or grounding conductors creates a current limited fault path. The resultant arc is of sufficient magnitude to melt and sever the copper conductor. This type of melting is often the result of an external attack by fire, not fire causation.

BALLS AND BEADS

- So what do balls and beads tell us. They tell us where fire attacked energized conductors.
- Arc fault location tracking can be very useful in pinpointing the area of origin.
- The arc faulting of a conductor at a location furthest from the distribution panel is closer to the area of origin than an arc fault occurring closer to the panel (taking construction and fuel loads into consideration).

BALLS AND BEADS

- As arc faults occur and breakers trip the circuit is de-energized.
- Once de-energized no additional arc faulting can occur.
- Drawing a floor plan and inserting all locations of arc faulting can help show the area of origin and progression of the fire.

ARC FAULT MAPPING

- NFPA 921(2014) - Section 18.4.5 *Arc Surveys or Arc Mapping*
  - Investigative tool for large-scale and small-scale incidents
  - Identification and documentation of electrical arc damage found in circuit wiring, conduits, load centers, cords, appliances, etc.
  - Location of arc damage may provide evidence by identifying circuits that were energized at the time they were compromised by the fire.

ARC FAULT MAPPING

- Arc mapping requires careful examination of the electrical system to identify arcing that may have occurred.
- Once the arc is identified, plotting or mapping those points can, under certain circumstances, establish an area of origin, or show the fires progression through the structure.
- It will also help identify an area that may need additional examination.

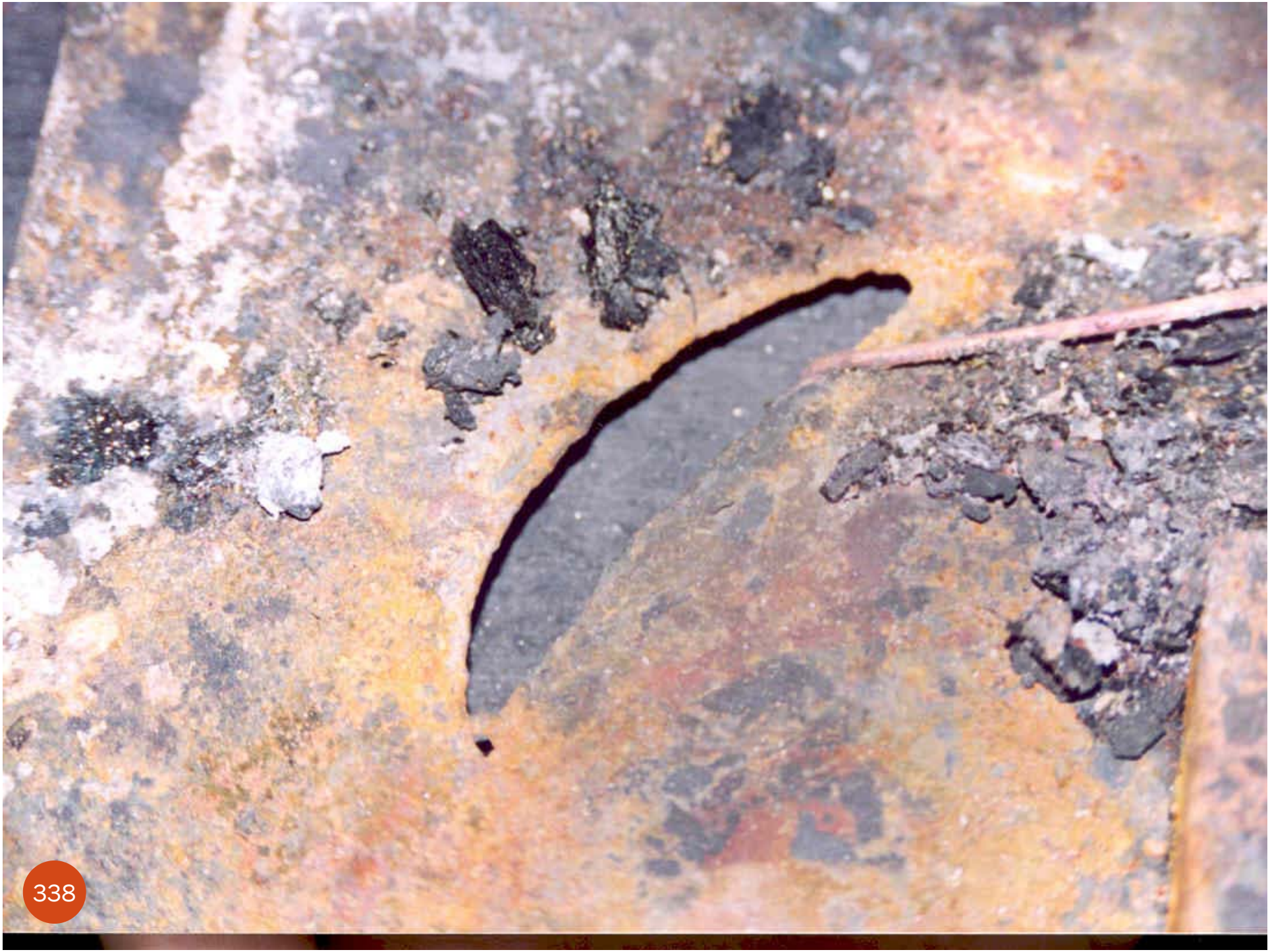
ARC FAULT MAPPING

- The "theory" behind *Arc Fault Mapping* is that when the fire, including hot gases, impinge on an **energized** electrical circuit, it will compromise the insulation and cause an electrical fault at the first point that it reaches on the circuit.

- Factors that may affect the location where arcs are discovered and when they were produced--
  - Physical protection-concealed areas
  - Walls, ceilings, insulation, etc

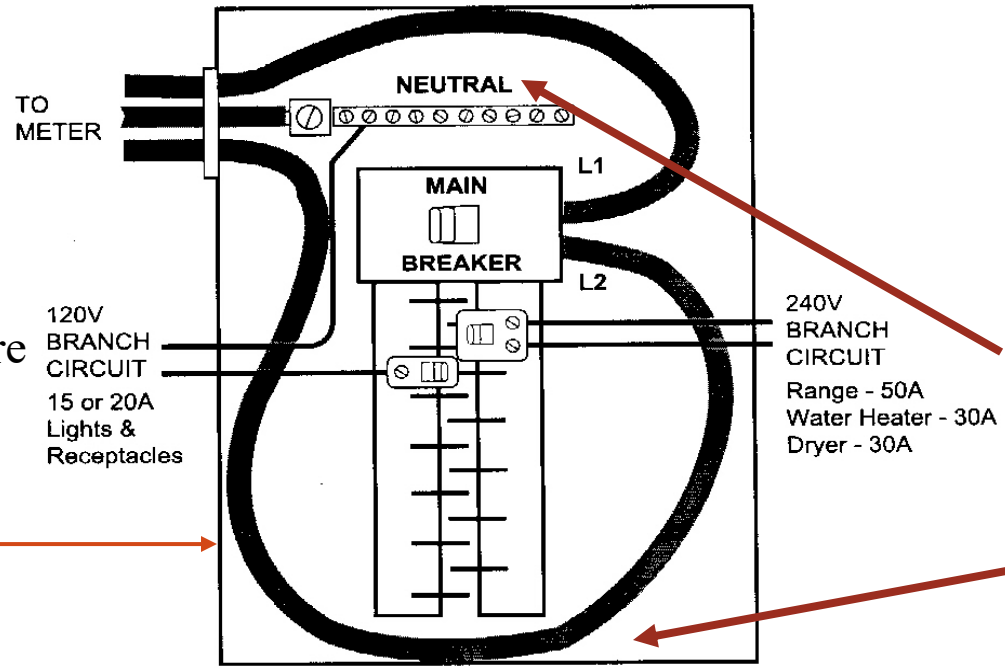
ARC FAULT MAPPING

- Differentiating between thermal and electrical damage is often the challenge.
  - Additional Forensic examination either at the scene, EE or in a laboratory setting may be needed.
- Some arcs damage is very obvious while others are not, this can become a very labor intensive undertaking, depending on the involved structure.
- What does the damage actually look like?



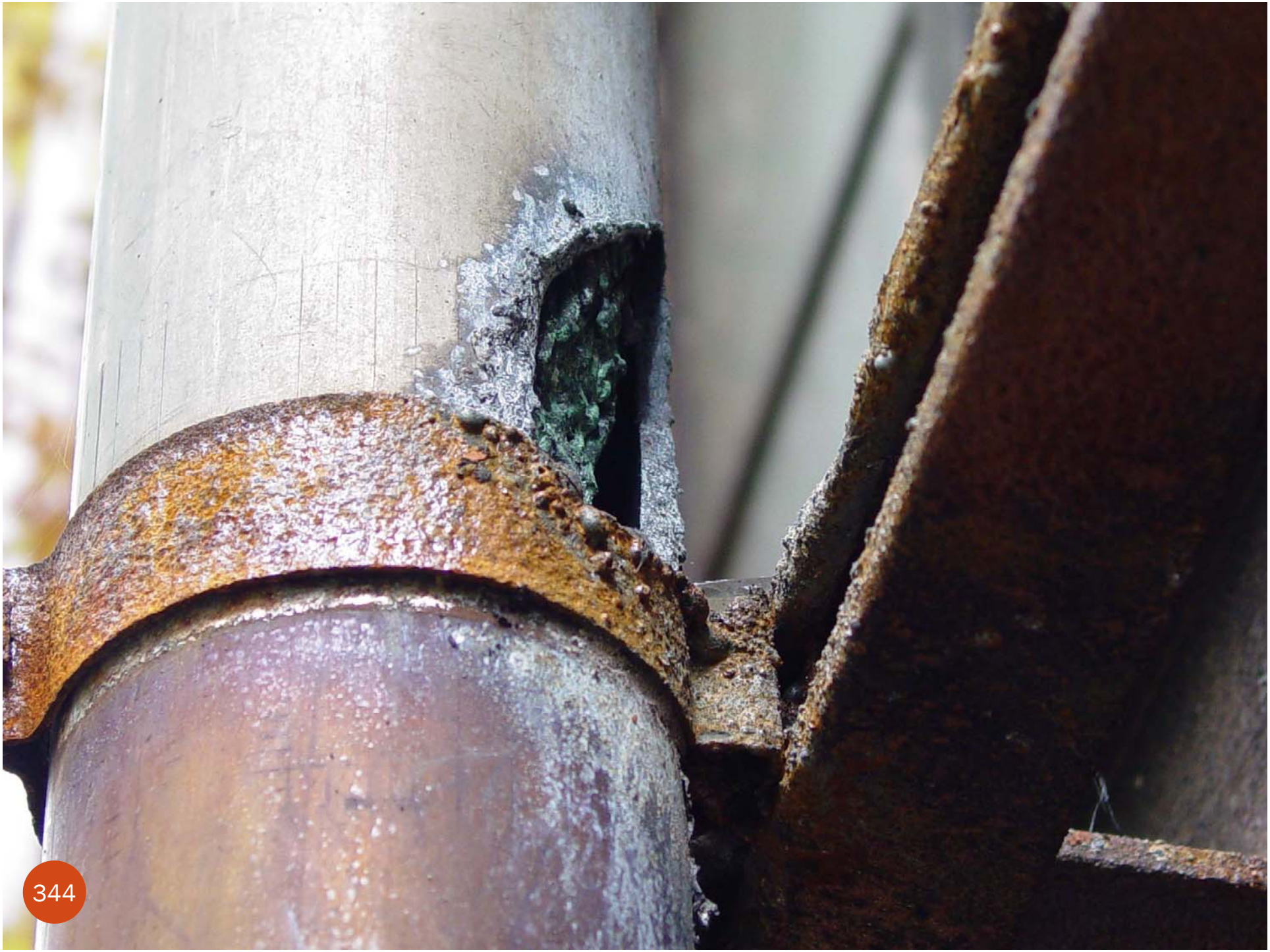
ARC FAULT DAMAGE-FLAME IMPINGEMENT

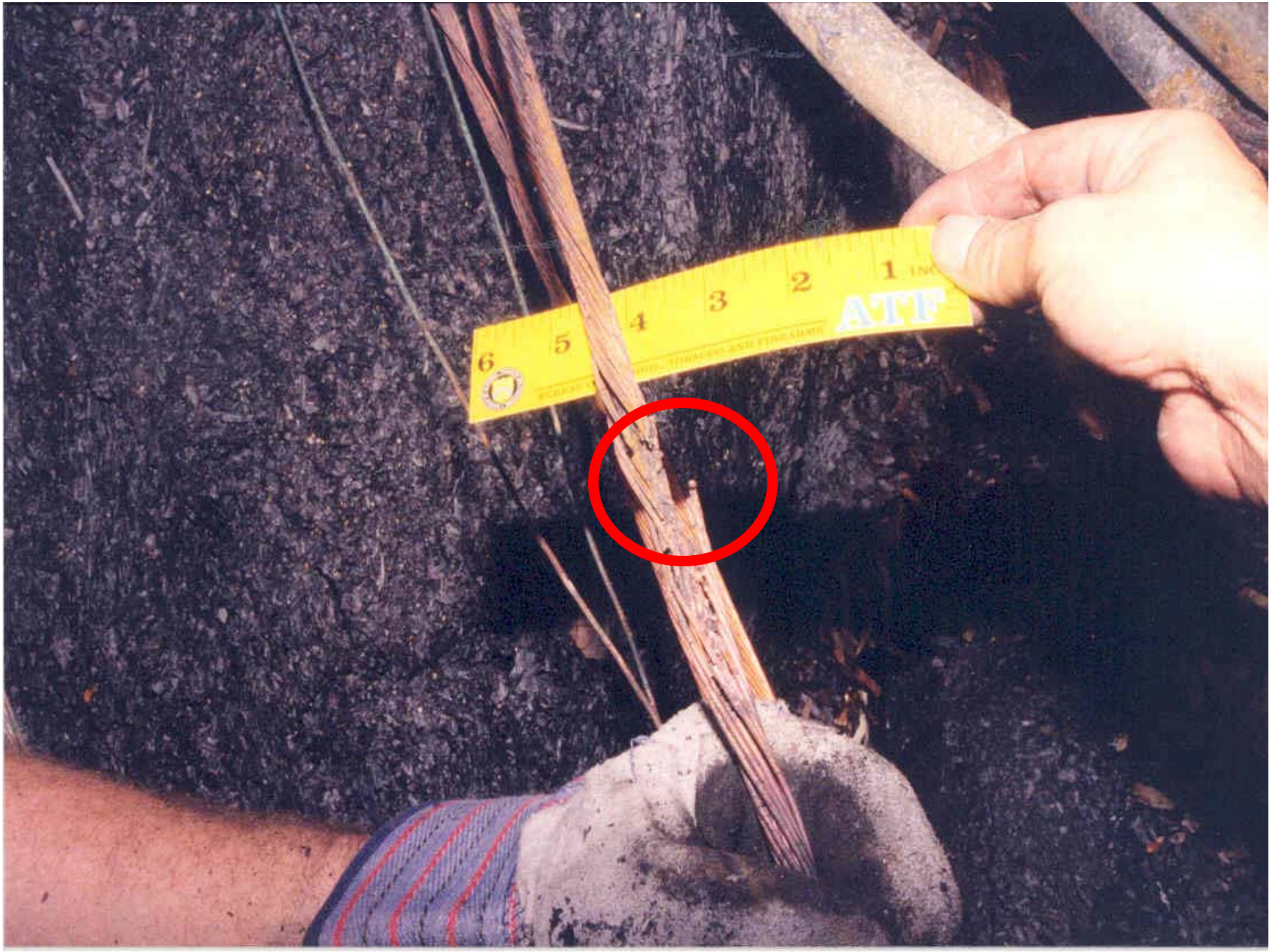
Remember between the transformer and the service panel there is no overcurrent protection



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.

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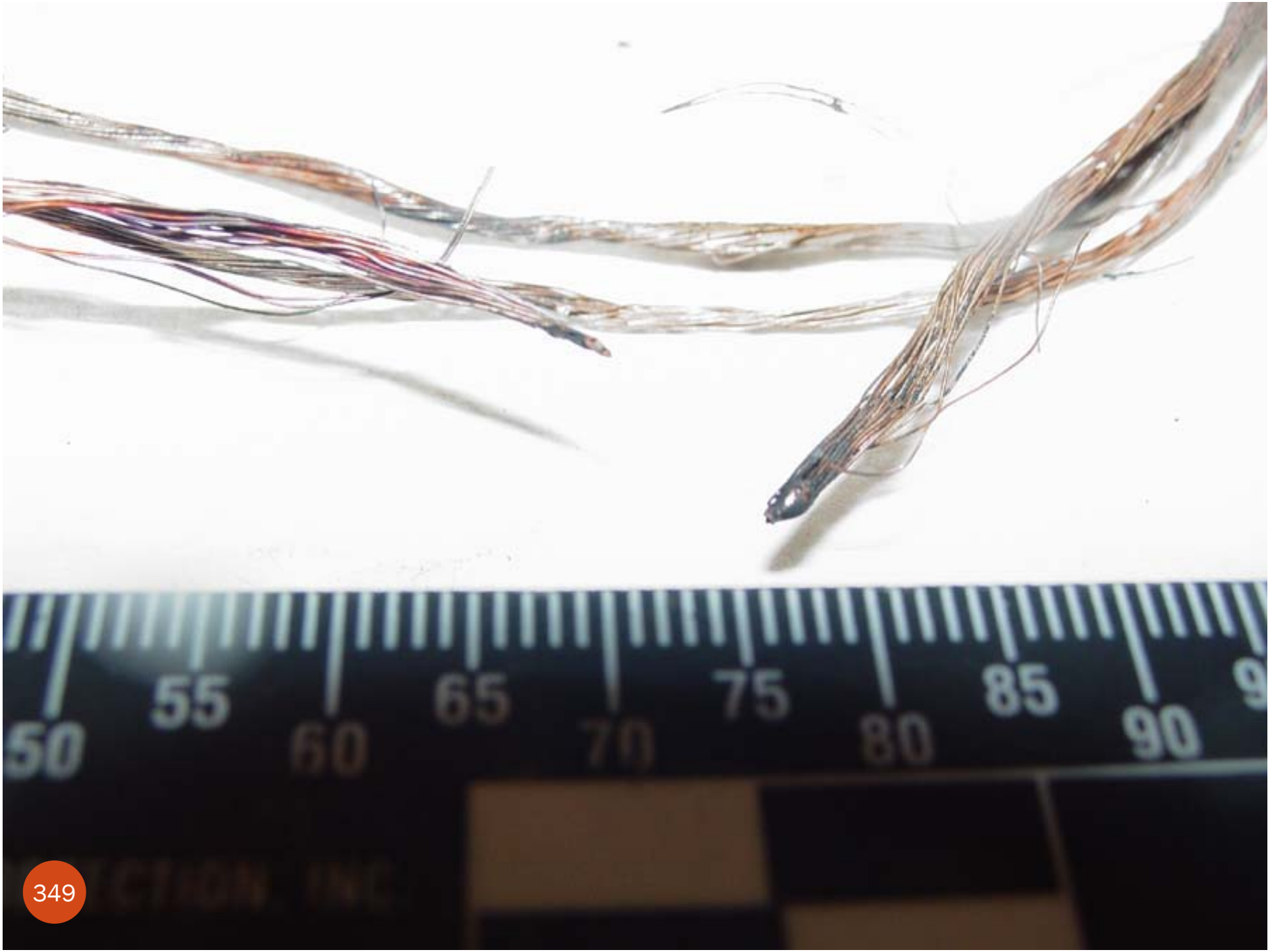
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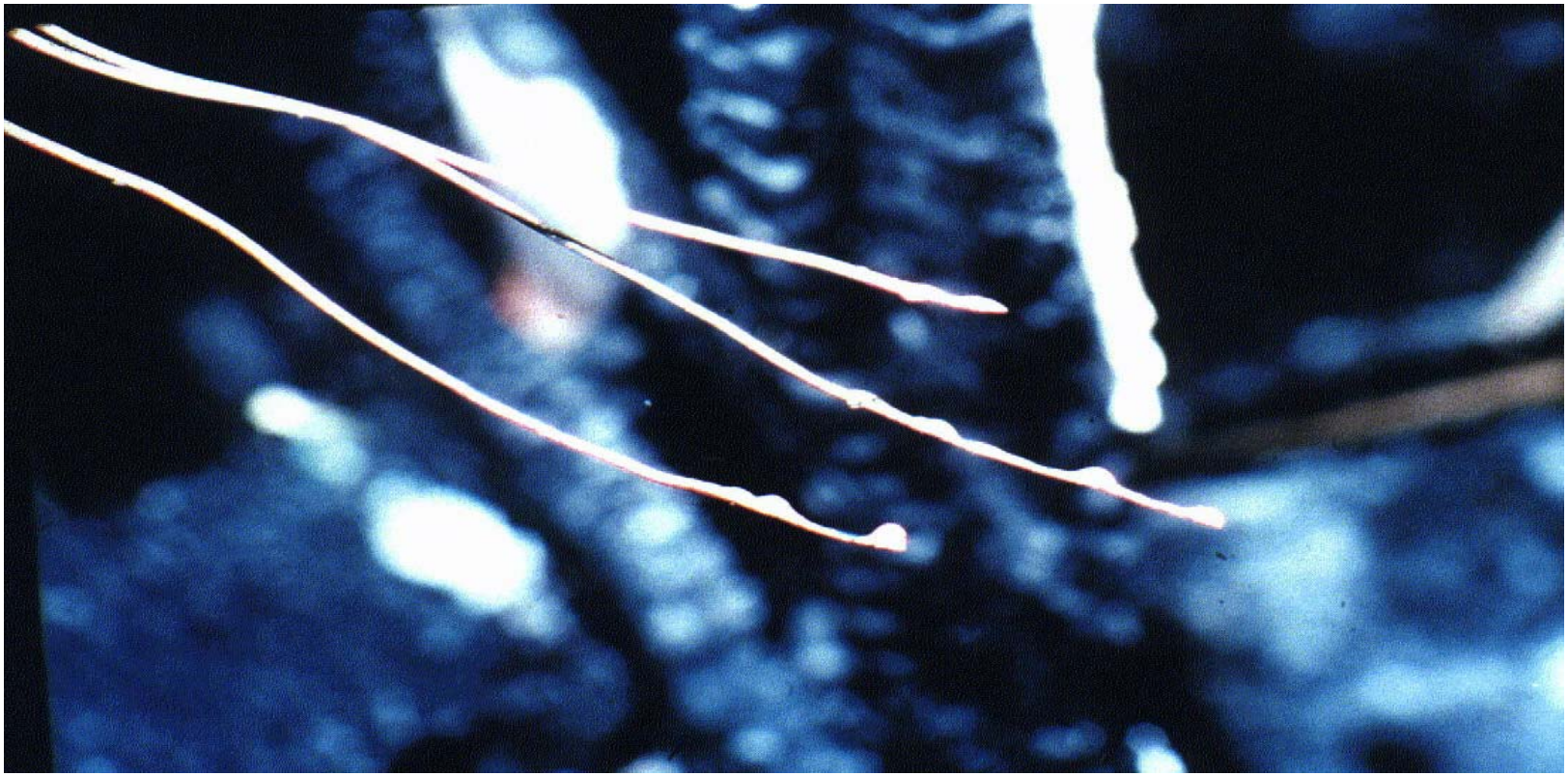
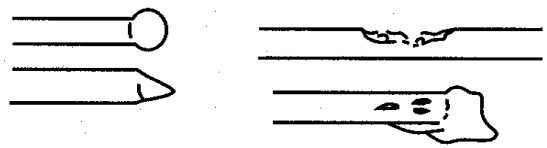
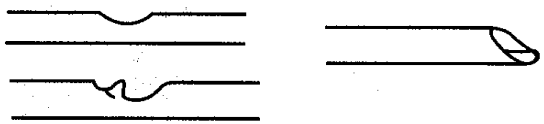
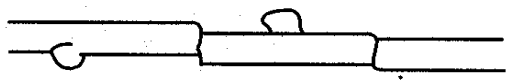
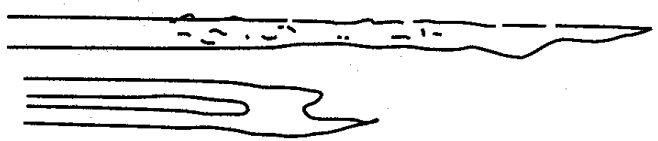
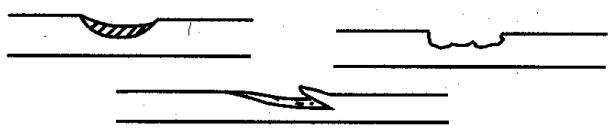
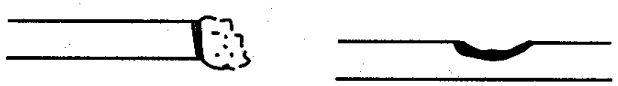
HEAT DAMAGED WIRE



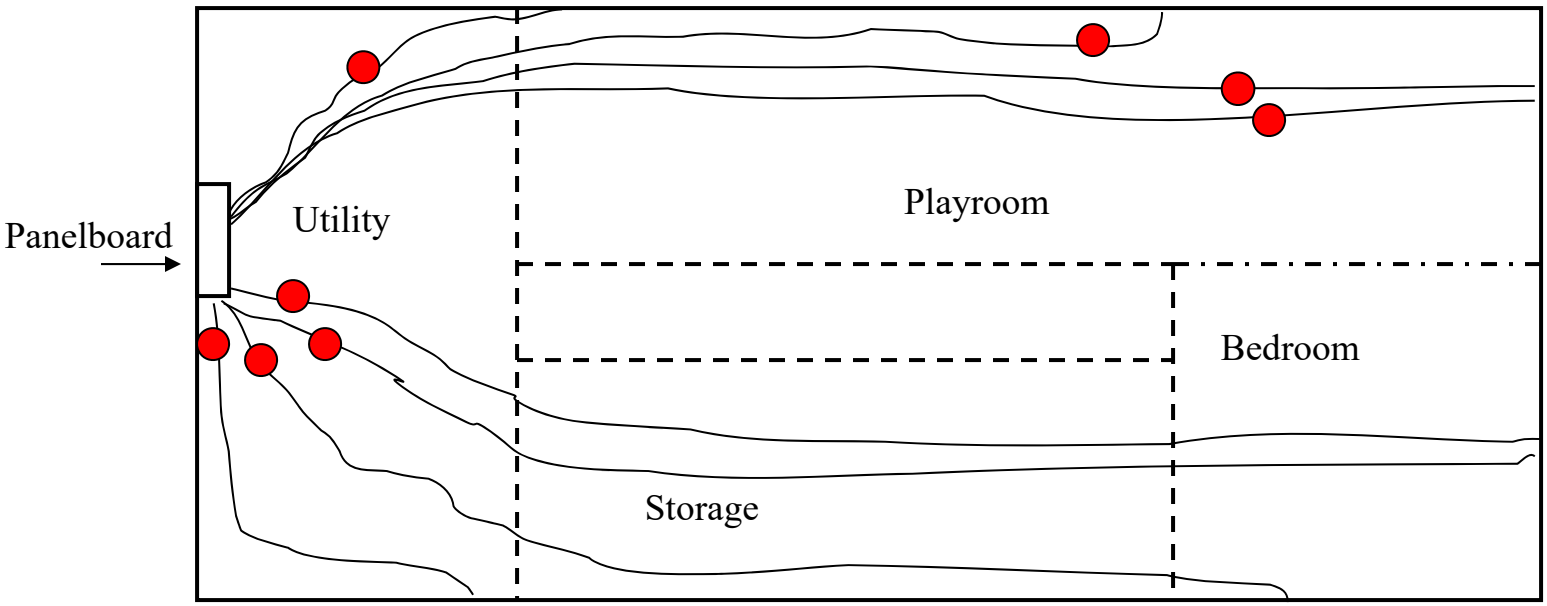
De-energized melting. This wire was exposed to temperatures in excess of 1980 degrees F° The wire has a tapered appearance. Balls and globules appear in several locations. The wire becomes brittle and fractures easily.

NFPA 921 - ELECTRICAL WIRE DAMAGE GUIDE

FIGURE 6.10.1 Guide for interpreting damage to electrical wires.

Mode of damage	Effects	Result of	Cause of fire?
Arcing through char		Direct fire heating	No, always a result of fire
Parting arcing		Heating at about 400°F (205°C) but no direct fire	Usually not
Overcurrent		Short circuit or failure in a device plus failure of overcurrent protection	Yes, but also may be a result of fire
Fire		Cable exposed to existing fire	N/A
Heating connection		Connection not tight	Yes
Mechanical		Scraping or gouging by something	No
Alloying		Melted aluminum on the wire	No

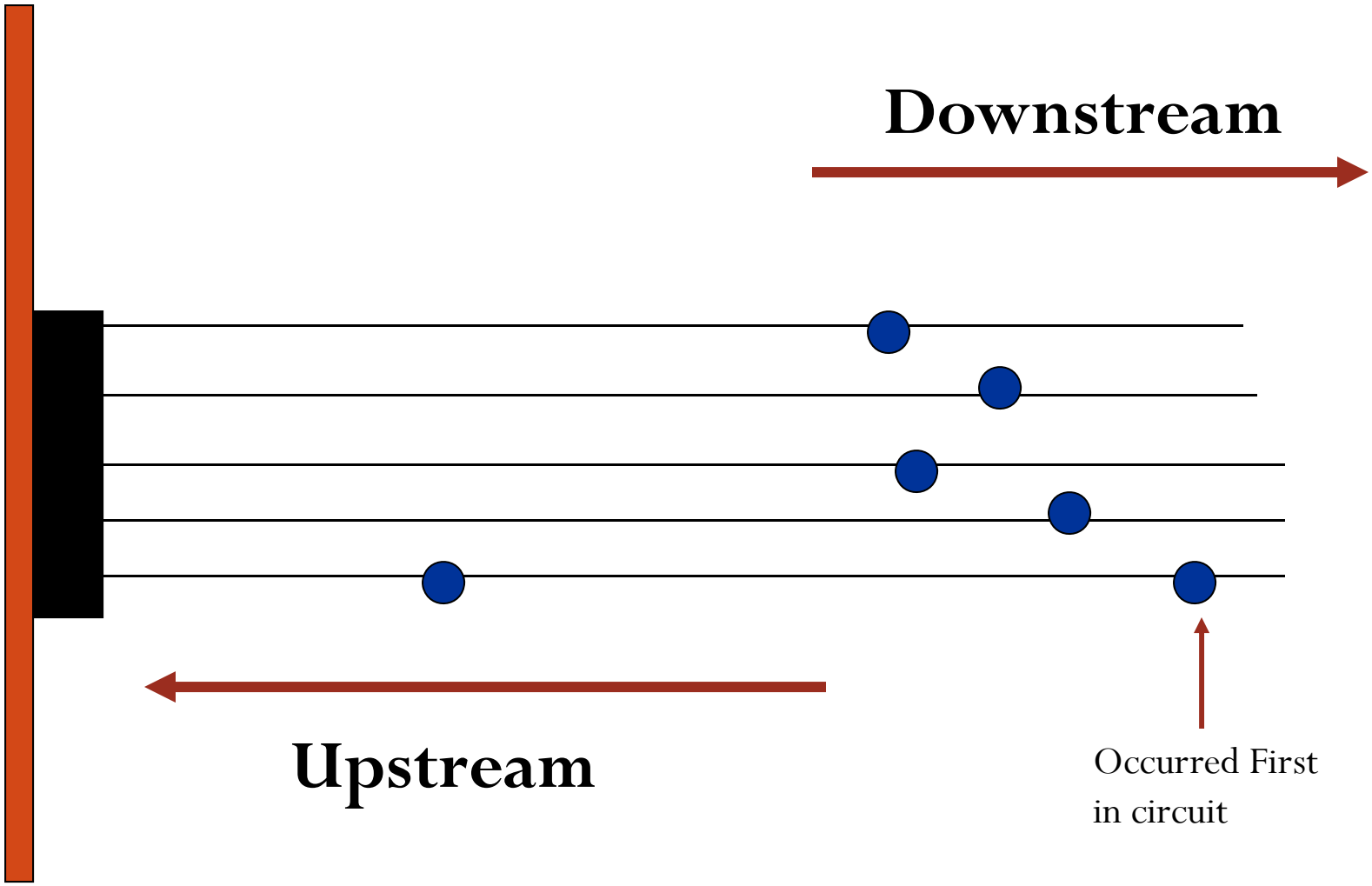
•Knowing how many tripped breakers or blown fuses gives an idea of how many faults you can expect to find
•Locate all faults and tag with tape
•Plot the location of faults on a drawing of each floor



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

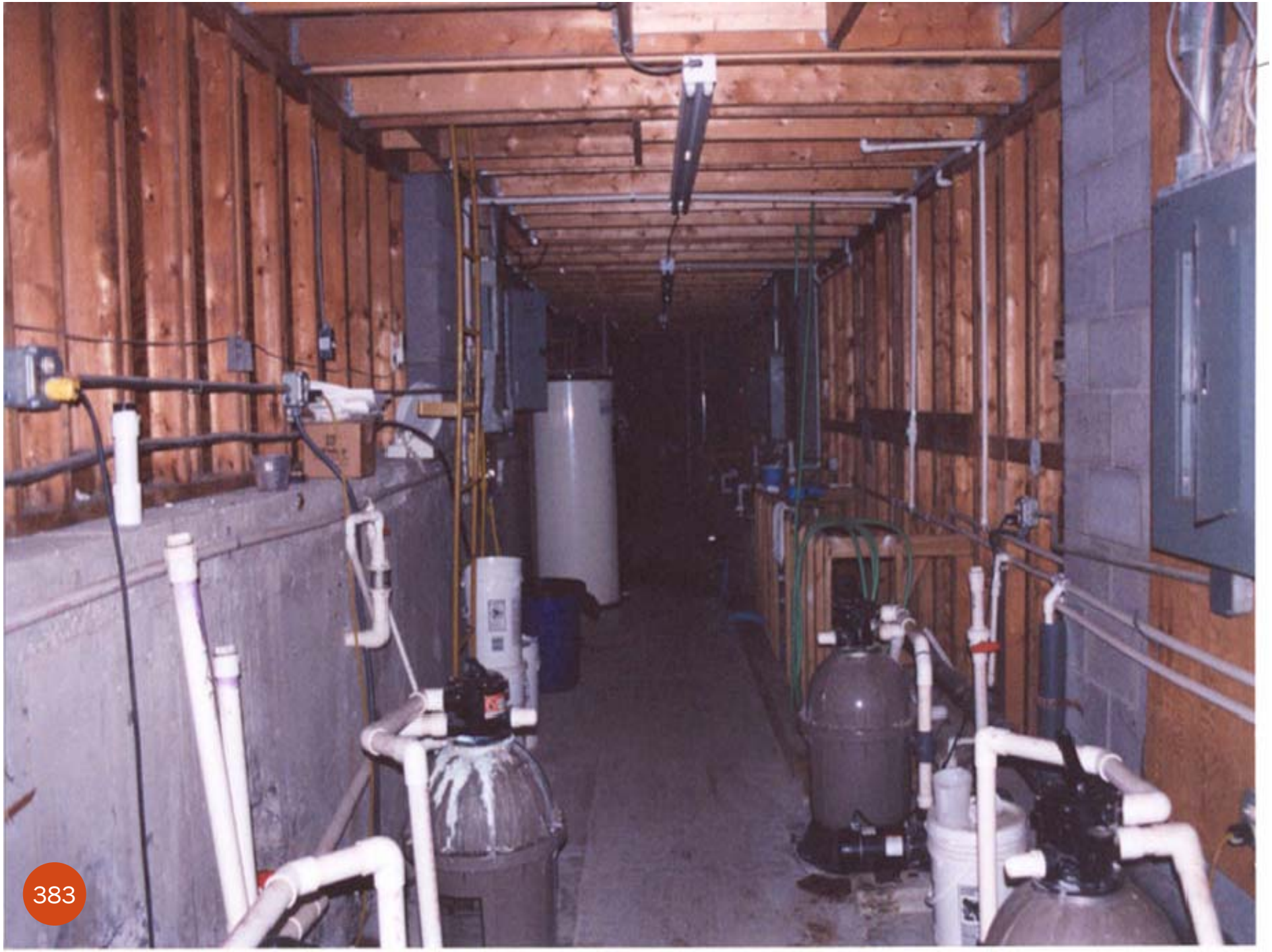
NFPA 921



UNIMART FIRE, Bloomsburg, Columbia Co, PA

CAESARS PARADISE STREAMS RESORT, Paradise Twp, Monroe Co PA

MONROE CO FIRE TRUCK



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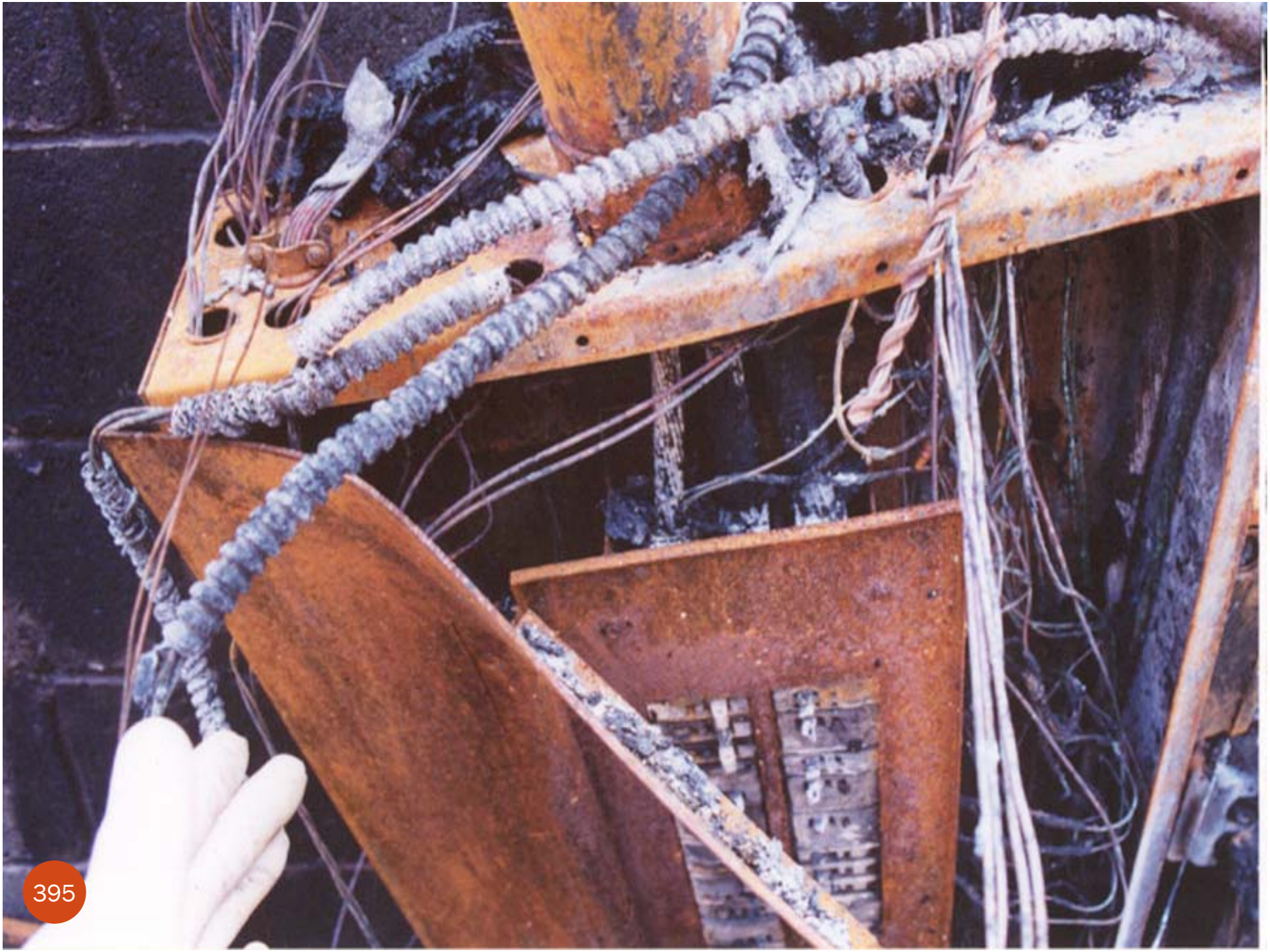
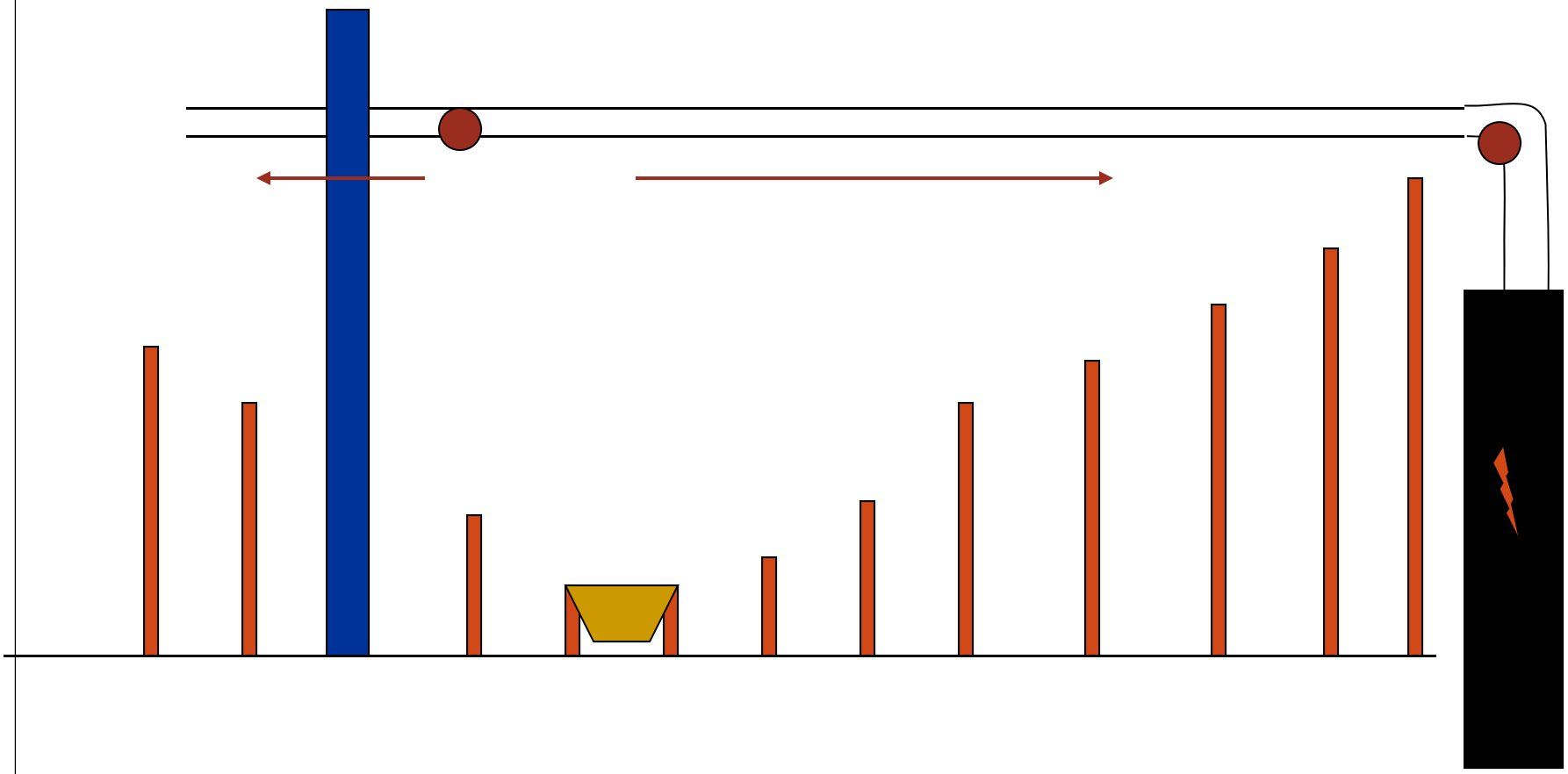




SO WHAT CAUSES ELECTRICAL FIRES?

Short Circuits ??

Overloads ??

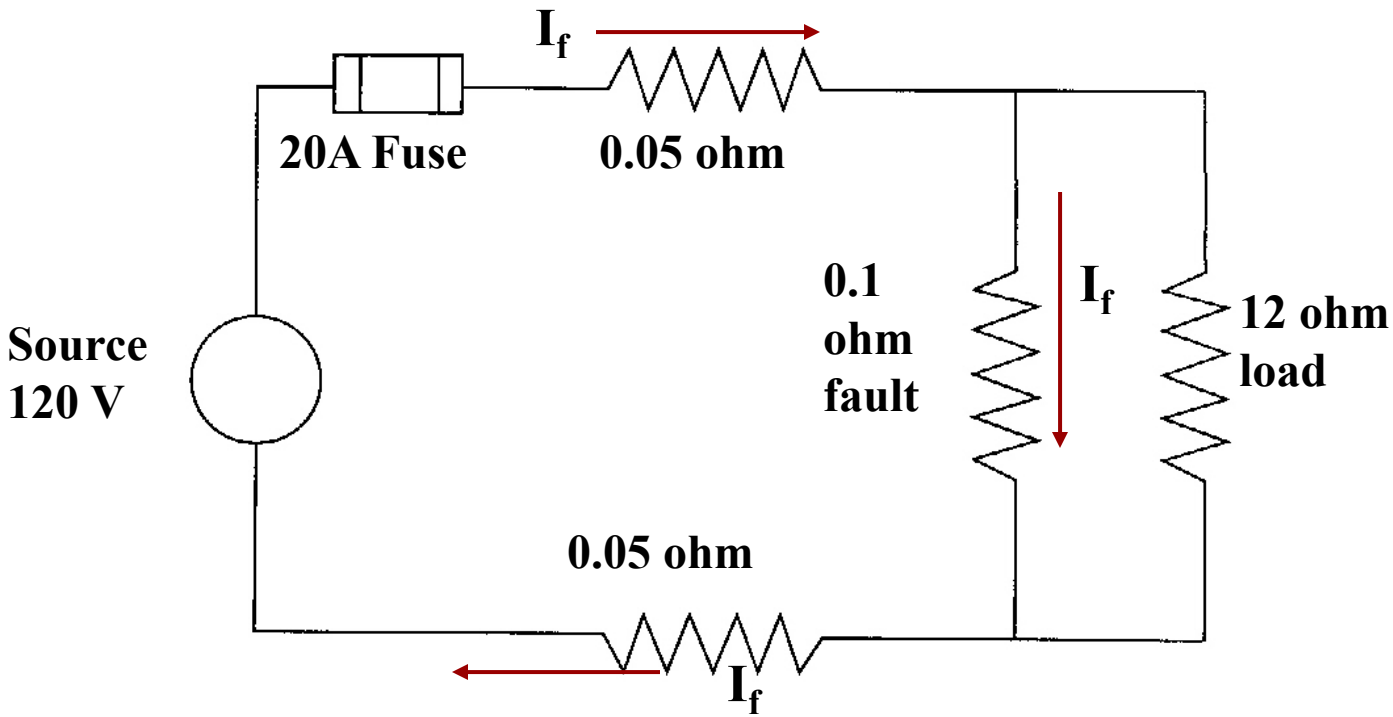
Loose or Failed Connections??

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

70–126 ARTICLE 310 — CONDUCTORS FOR GENERAL WIRING

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.

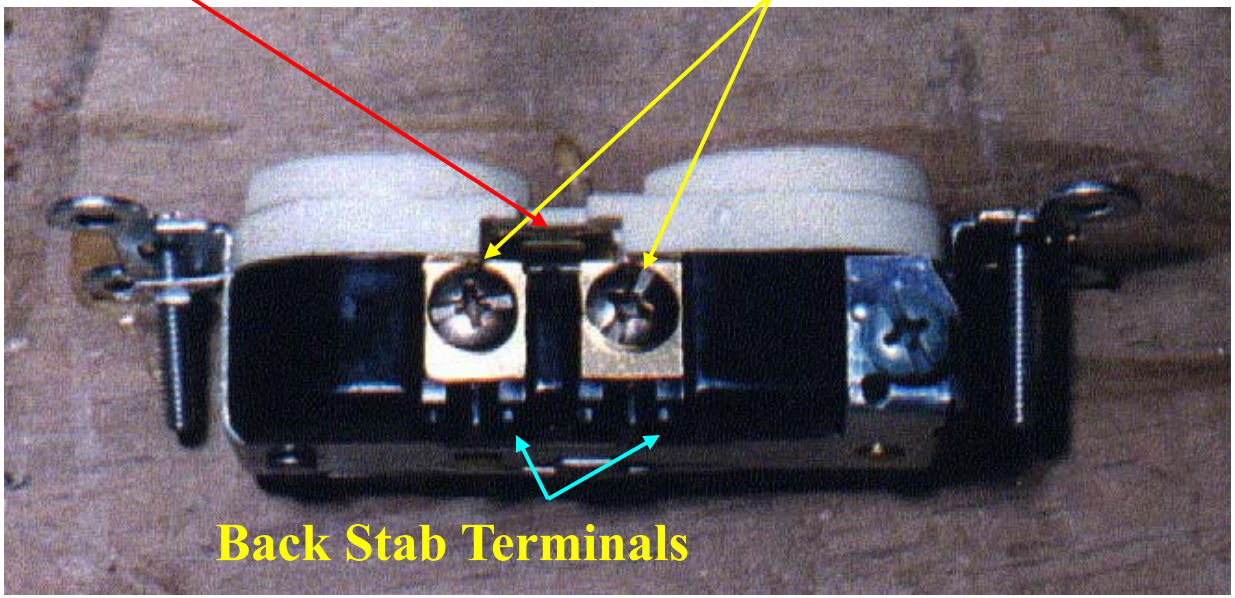
A 12AWG wire will not even begin to smoke until it is carrying 100 amps. However, you cannot connect 100 Amps to a properly protected branch circuit wired with 12AWG. The breaker or fuse will trip long before the wire burns.

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.

This was a 16 AWG extension cord. This cord had a 10 ampere rating. The combined load that was plugged into it was 25 amperes. That's 2.5 times the rating of the cord. The cord was wrapped 80% around the plastic reel, trapping heat. Even with this, only melting and light charring occurred. The cord produced heavy smoke. Had it continued undetected the insulation between conductors would have melted. When this happened, an arc fault between conductors would have probably occurred and tripped the breaker.

SO WHAT DOES CAUSE ELECTRICAL FIRES?

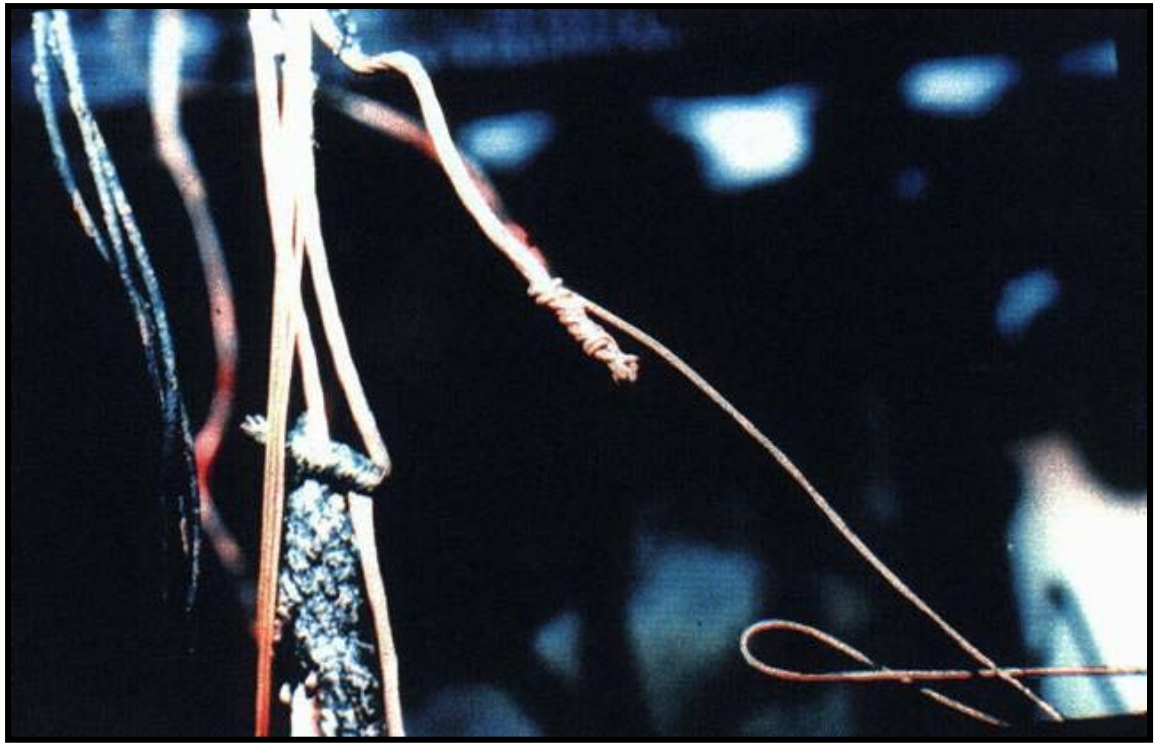
Note: By breaking this tab off, the receptacle can be wired as two different circuits. One for each outlet



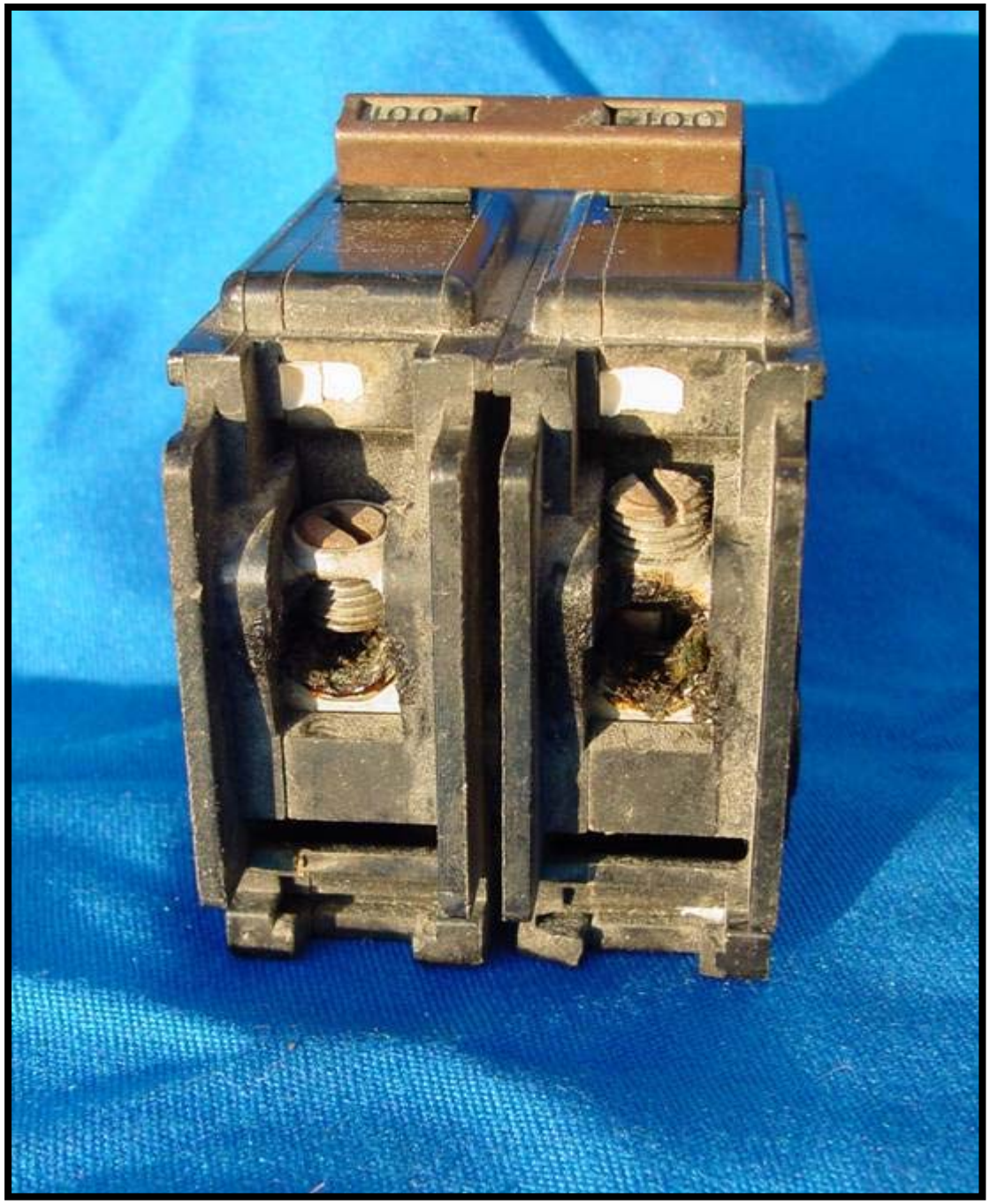
Loose or failed connections.

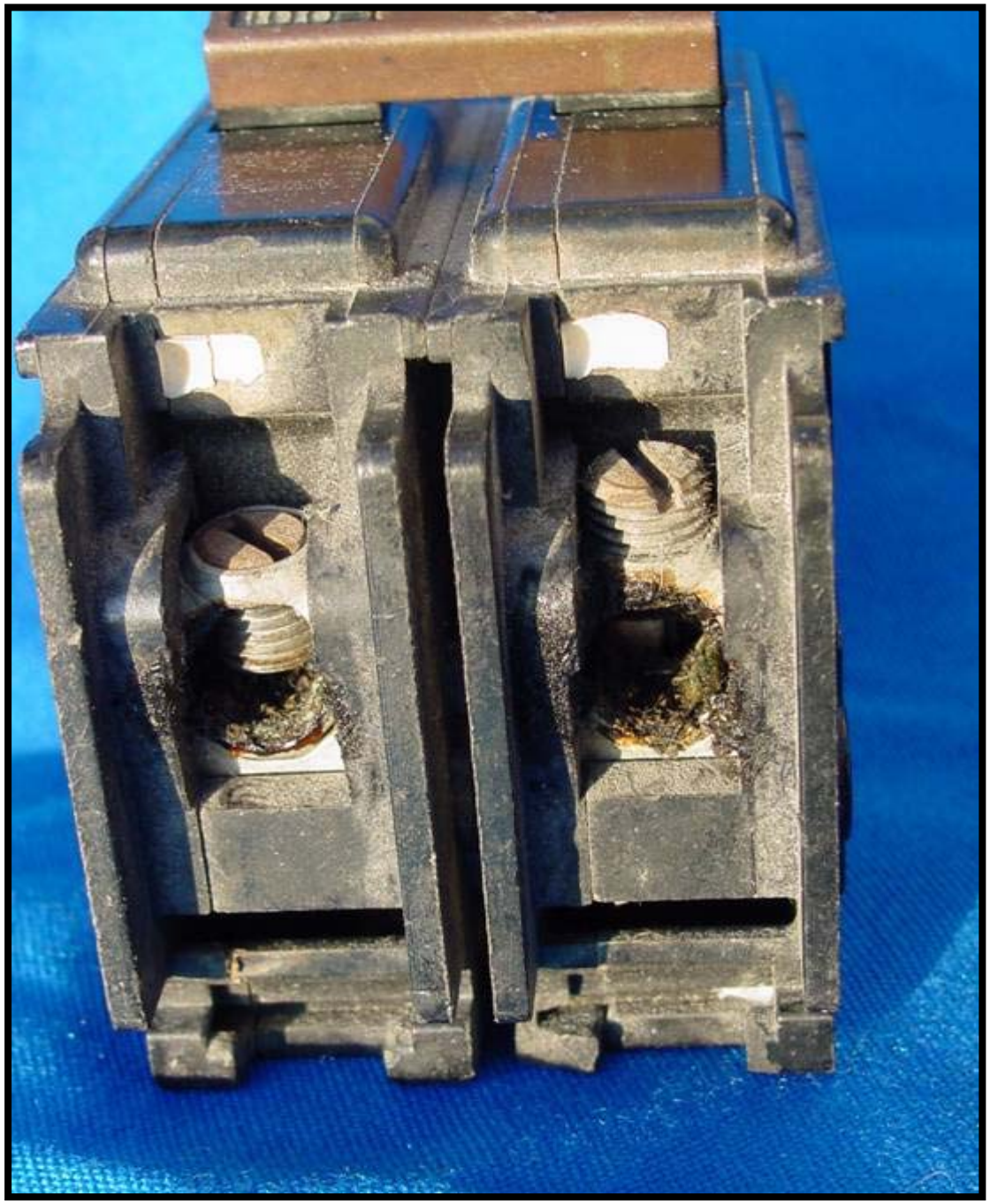
A standard receptacle can be screw terminal or push terminal ("back stabbed") connected. "Back stabbing" of connections caused fires in the past. Not because this is a bad way to connect wires. Instead, the terminals allowed the use of 12 AWG wire. When the receptacles were pushed back into the outlet box the heavy gauge wire placed pressure on the plastic body. Many bodies fractured resulting in loose and failed connections. These terminals will now only accept 14AWG or smaller wire. In fact, more fires result from loose or improperly made screw terminal connections.

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.





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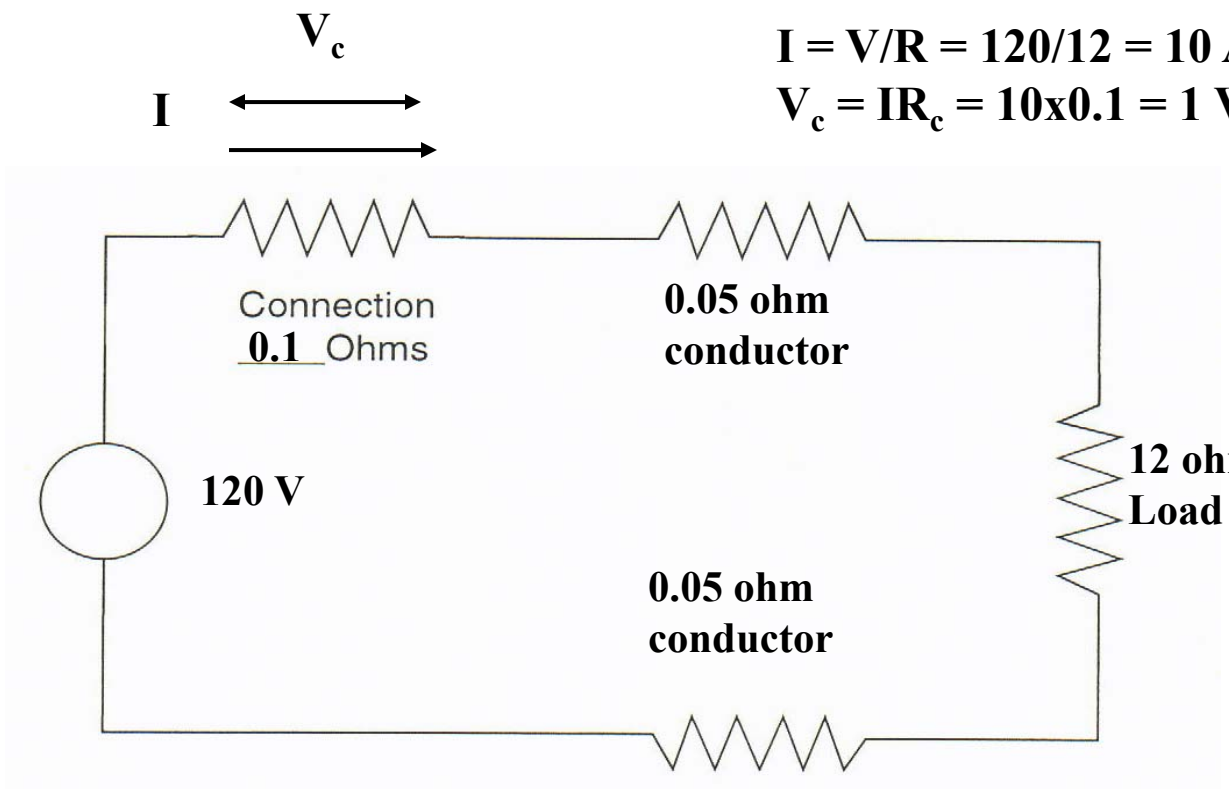
WHY DO LOOSE CONNECTIONS CAUSE FIRES?

Lets look at a circuit showing a loose connection. This connection only has 0.1 ohms of resistance. That's a very small resistance. Should cause no problem, Right?

$I = V/R = 120/12 = 10$ Amps

$V_c = IR_c = 10x0.1 = 1$ Volt



Would you notice a 1 volt drop in a 60 watt bulb?

A. NO

The power dissipated at the loose connection is: $P_c = IV_c = 10Ax1V = 10$ Watts
This 10 watts is dissipated at the 1/4 inch screw head.

SO THAT'S BAD?

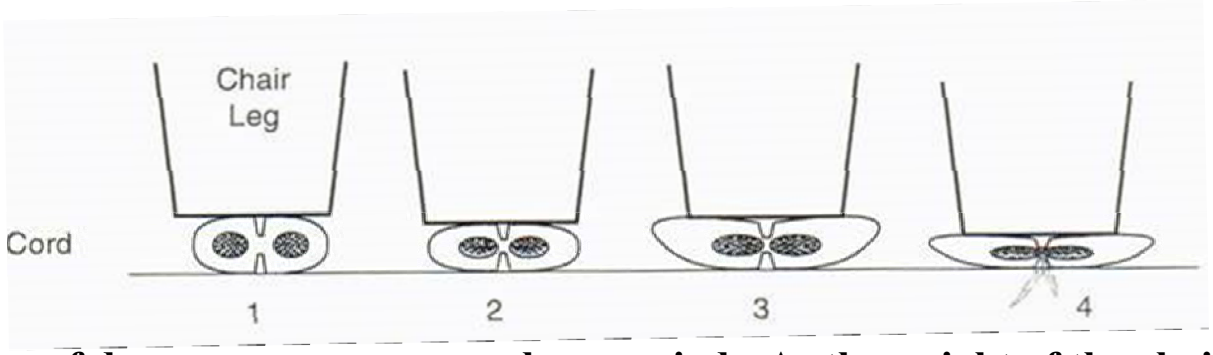
- 10 watts of heat being dissipated at the screw head raises the temperature at the screw.
- As the temperature increases the resistance increases.
- As the resistance increases the power being lost at the screw head increases.
- This cycle continues until the temperature stabilizes if all of the heat generated on the screw can be radiated or conducted away.

SO THAT'S BAD?

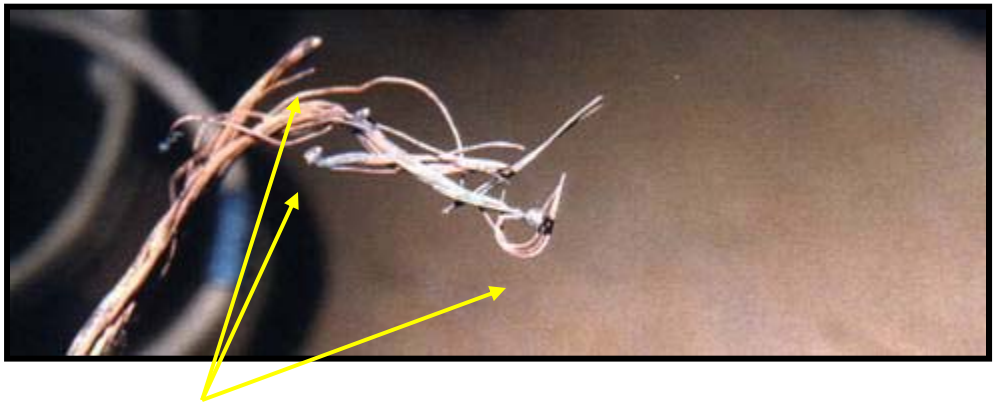
- Studies have shown the temperature can stabilize when the screw head is red hot. The screw head can reach temperatures well over 1000°F.

- The resultant long term heating breaks down the plastic receptacle body. As the plastic breaks down into carbon, a current limited fault path can occur. This results in excessive heating that can ignite nearby combustible materials.

PINCHED CORD FAULT

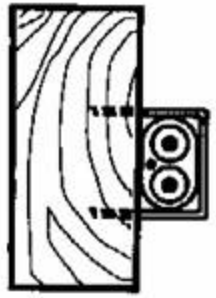


- **This type of damage can occur over long periods. As the weight of the chair squeezes the cord the insulation is compressed. Eventually the insulation can migrate from between the conductors. When this happens one or two strands can contact each other. If they blow apart during the arc, and the breaker does not trip, a current limited carbon path can be created. The result is a current limited fault that can reach temperatures that can ignite nearby combustible materials.**

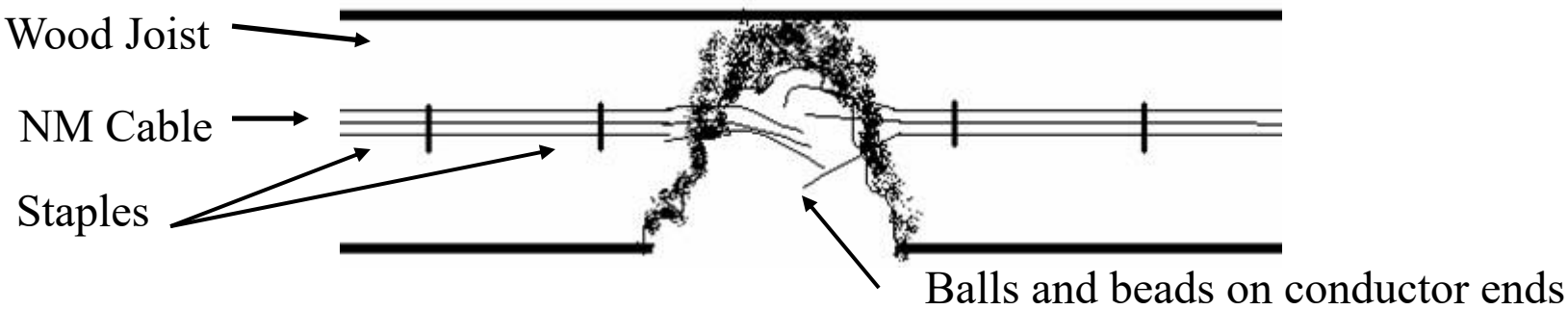


- **Look for balls and beads on individual strands. Unfortunately, external fire attack can leave the same balls and beads, so you need a pinch point and location in the area of origin.**

STAPLE FAULTS

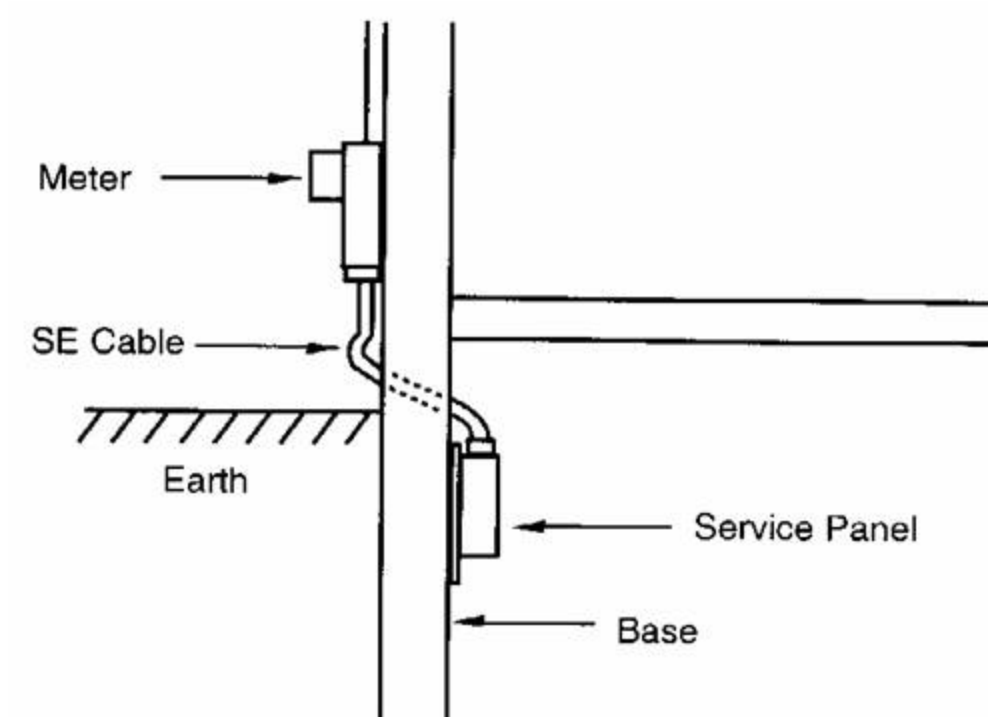


Similar to the pinched cord fault, overdriven staples can also cause faults. This type of fault can take years to occur. The tight staple crushes the insulation and eventually bridges the conductors. The initial contact can vaporize part of the staple or conductor and leave a current limited carbon fault path. Temperatures can be generated that can easily ignite nearby combustible materials.



What to look for - Tight staples at other locations. Evenly spaced staples with a burn area where a staple should have been. Arc severed conductors with balls and beads on the severed ends. Location of damage in area of origin. Staples are used to position cable not squeeze it. With properly installed staples the cable should be able to be moved under the staple.

SERVICE PANEL FAULTS

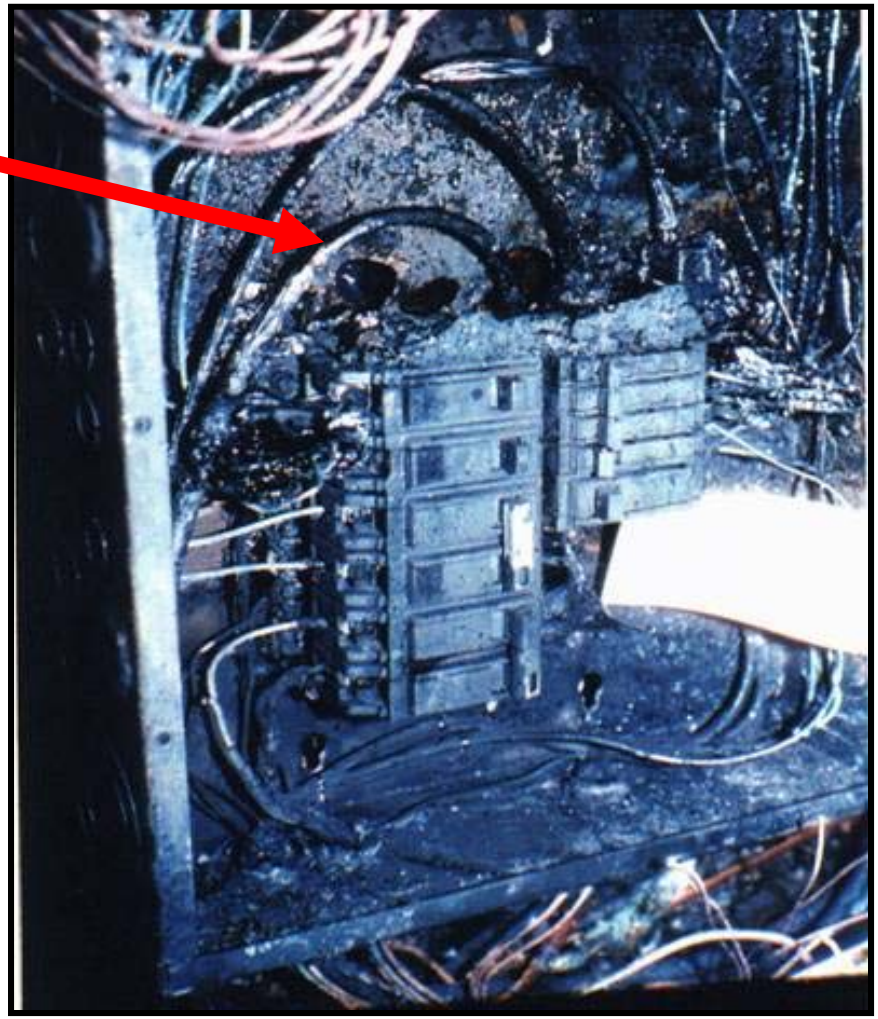


Moisture intrusion - If water enters the service panel through the service entrance cable it can run or wick into the service panel. The water can then bridge the connections between phases or between phase and the grounded metal enclosure.

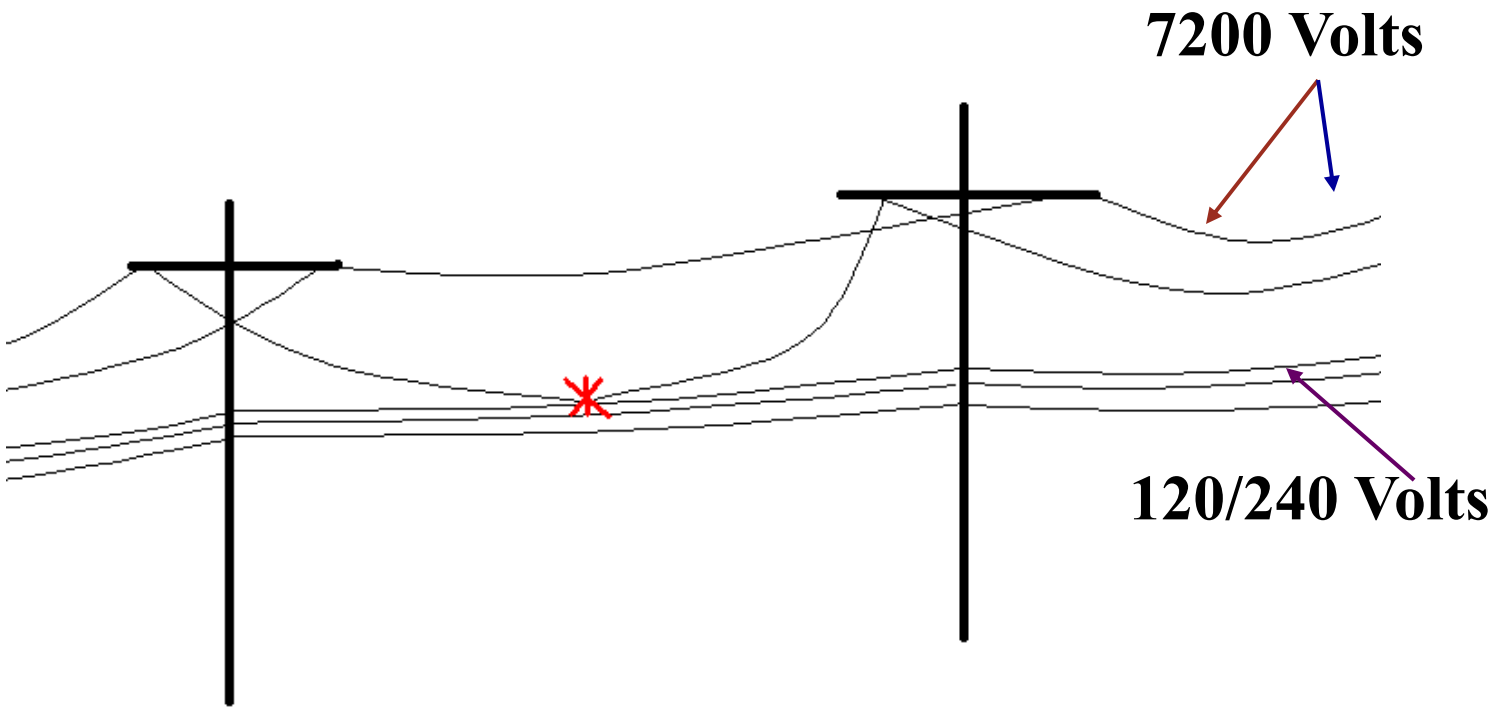
Lightning - Lightning damage can impose very high voltages on the electrical service. The high voltage can arc between parts with adequate separation for normal voltages.

SERVICE PANEL FAULTS (cont'd)

- Look for arc holes behind the main lugs. Path for water to enter the enclosure.
- Lightning may create several holes where moisture may only create one.
- Lightning may also destroy the main breaker.



HOT CROSS FAULTS



Hot cross faults occur when high voltage lines contact low voltage power lines. This can occur when a tree limb falls on the high voltage line, a car damages a power pole, etc. Remember, most high voltage power wire on a pole is not insulated – it is bare.

What to look for - Catastrophic panel failures. Multiple appliance failures. Power strips are destroyed. "Fire and sparks were shooting out of the receptacles" Multiple points of origin. Multiple structures may be involved.

HOT CROSS FAULTS

HIGH VOLTAGE CAN TURN MATERIALS THAT ARE ORDINARILY INSULATORS INTO CONDUCTORS!

HOT CROSS FAULTS

HOT CROSS FAULTS

Witnesses and first arriving firefighters at this fire observed that ALL of the tires, and the ground under the outrigger pads was on fire, with no other involvement of the truck.

Electricity will take ANY path it can find to ground.

This was fire was essentially caused by a "high resistance connection" between the 26KV overhead power line and the ground.

APPLIANCE AND FIXTURE FAILURE

Fluorescent Light Investigations

- Two main fire producing failure modes:

    1. Arc penetrations through the ballast and fixture.

    2. Arcing/Overheating at lamp holders.

Arc Penetrations Through Ballast Case

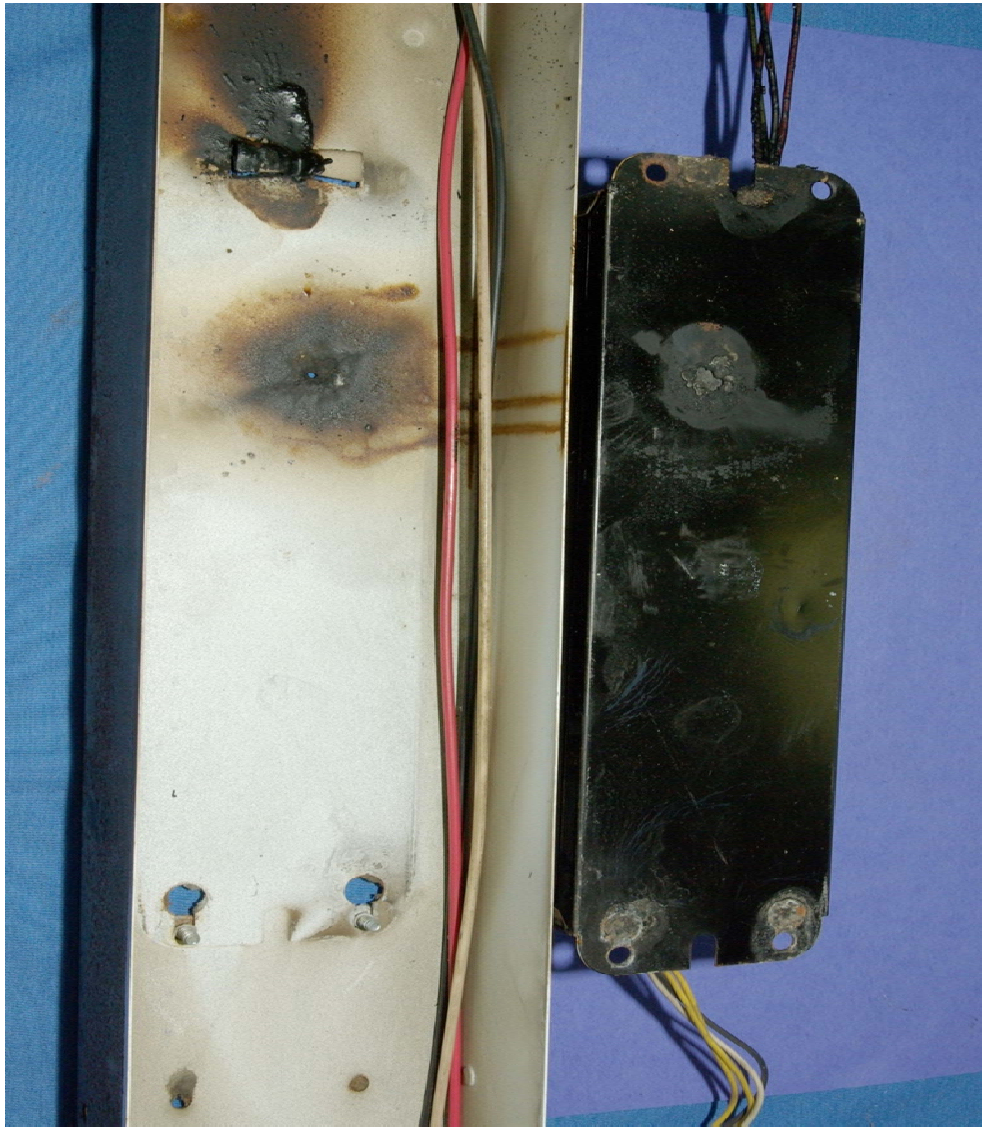
- Probably leading cause of ***magnetic*** ballast fires
- Can occur in thermally protected ballasts
- Can burn hole through fixture
- Can ignite materials above fixture such as:
  - Wood
  - Plywood
  - Combustible ceiling tiles

Arc Penetrations Through Ballast Case

- Can occur through side of the ballast case
- Can exit top or side of fixture and ignite:
  - Lens
  - Combustibles below
  - Lint or dust
  - Light weight materials

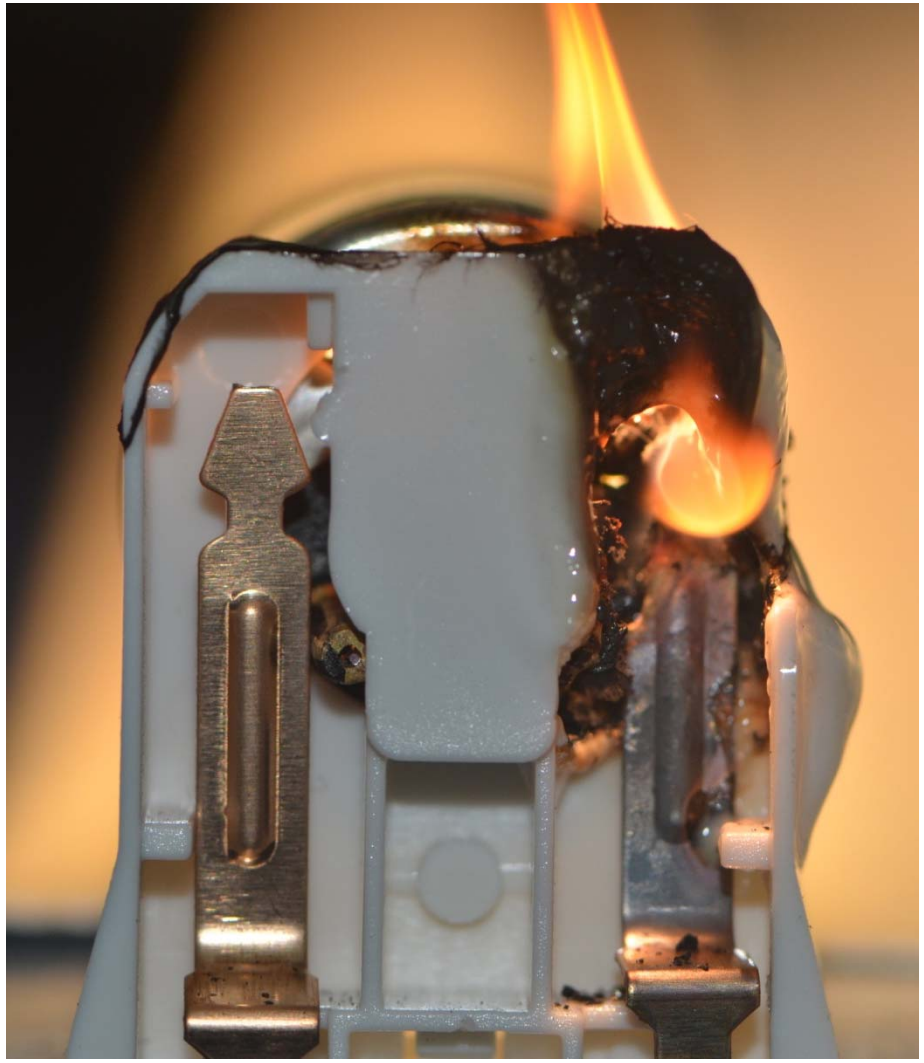
Ballast with Arc Penetration

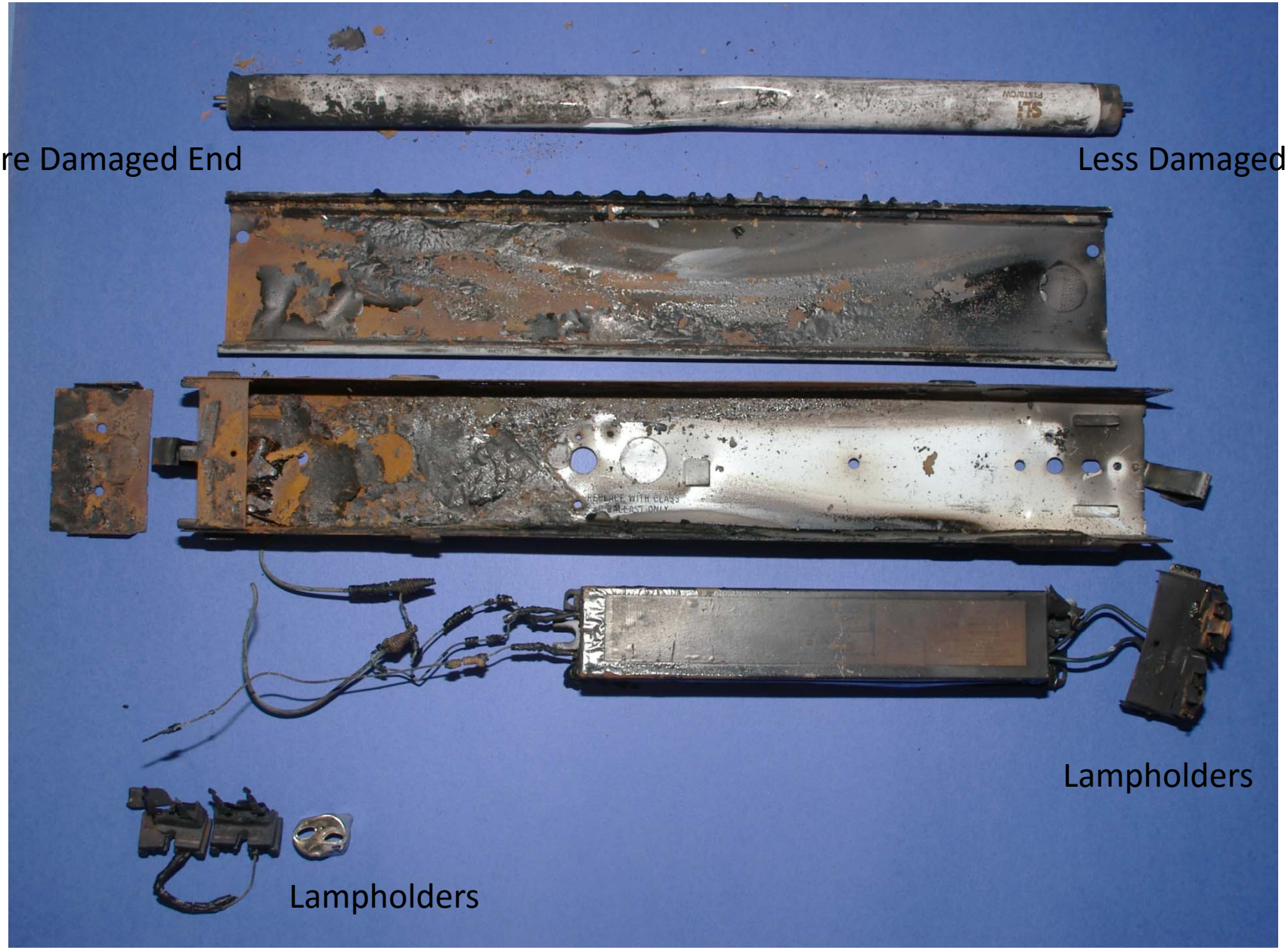
- Typical arc penetration through the back of a fluorescent ballast.
- Note the hot gases exiting the hole in both the ballast and fixture.



Fires Caused By Lamp Holders

- Typically result of poor connection to lamps
- Improper seating of the lamps
- 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 maintain an arc and it will!




More Damaged End
Less Damaged End
Lampholders
Lampholders

Arcing Damage

Re-locatable Power Tap (RPT)

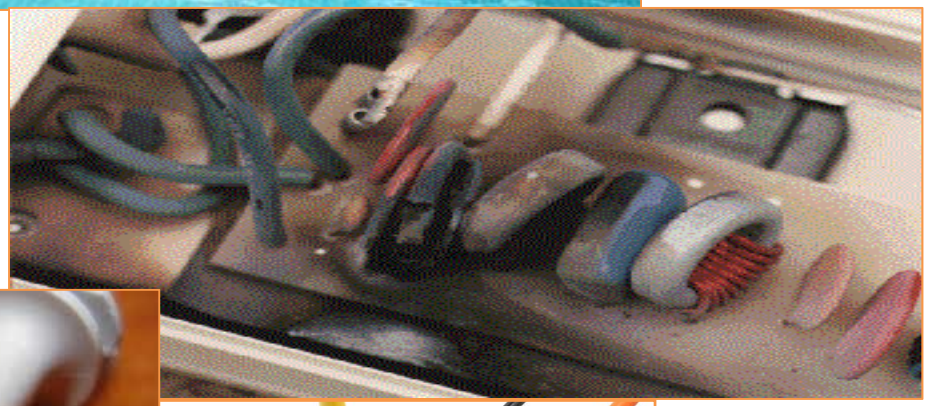
Provide multiple power outlets external to a wall receptacle

- Varying types & styles
- Number of outlets
- Power buses or individual outlets
- Switched/Fused/Surge Protection

Re-locatable power tap

Short Circuits

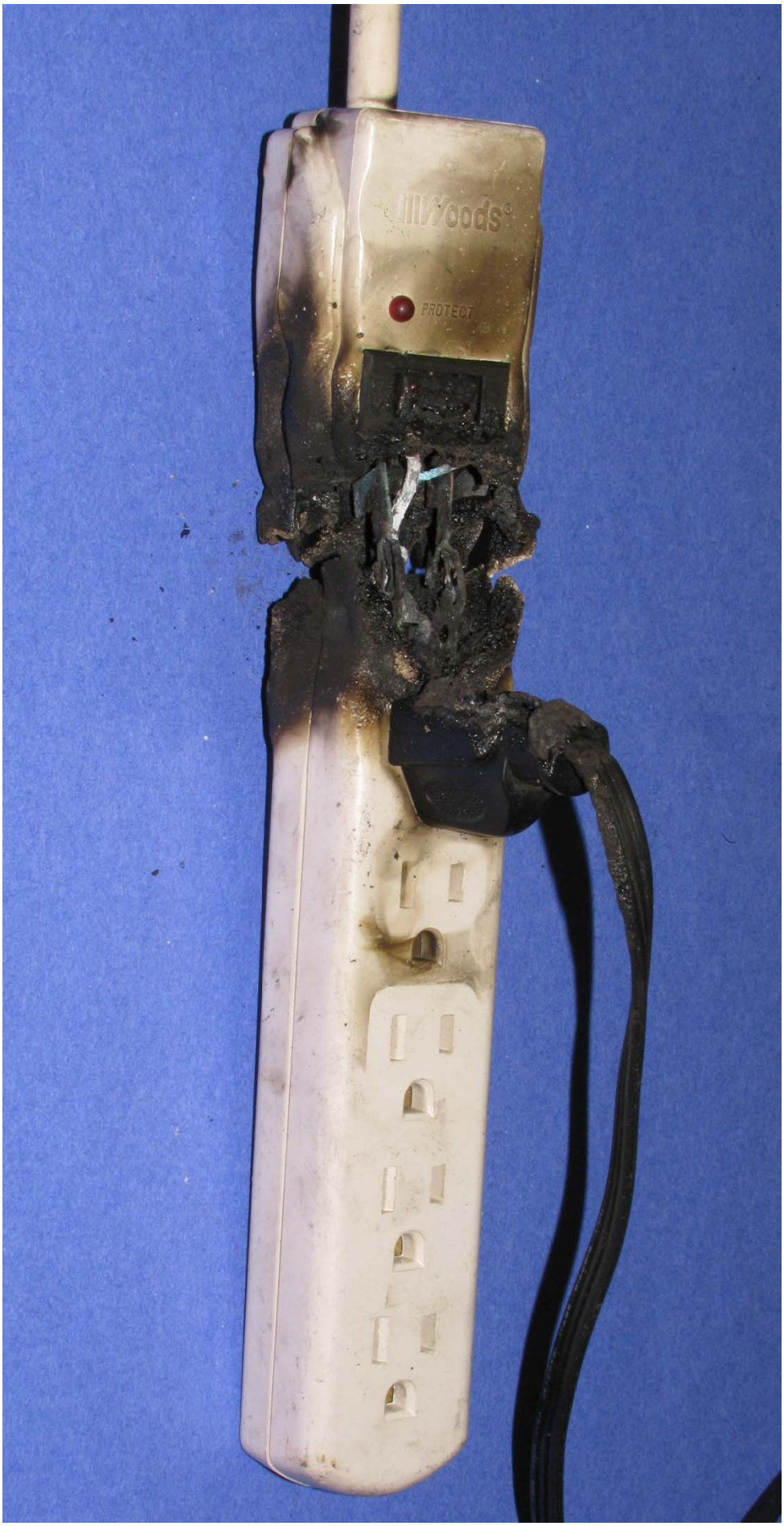
Surge Protection Failure



Damaged Wiring

Overloaded / Abused

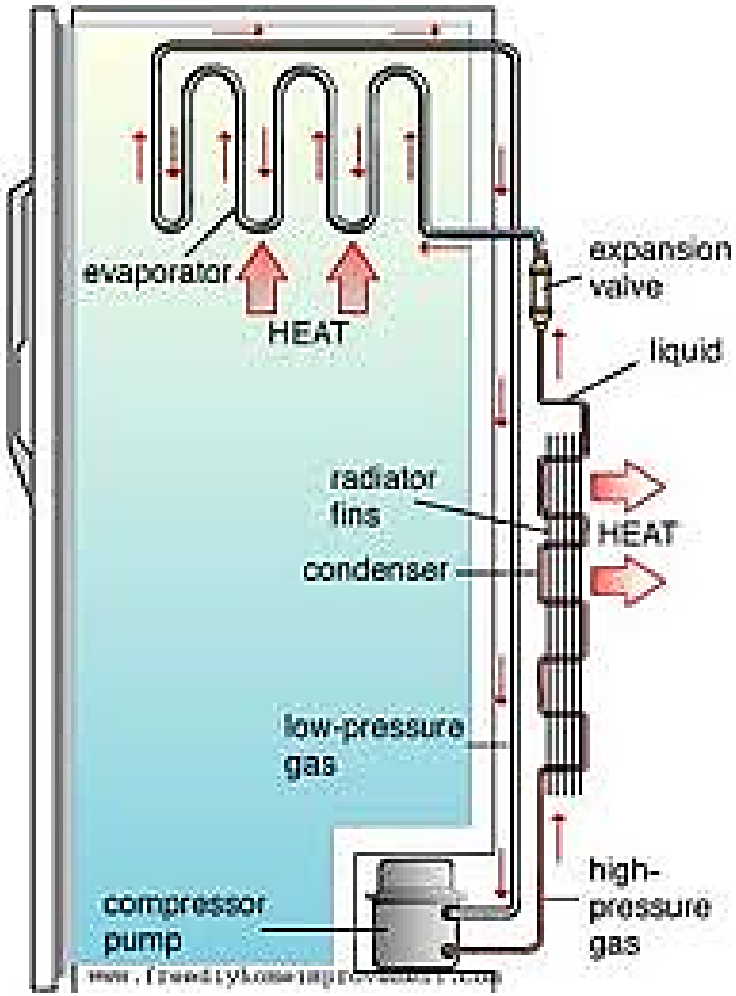
Re-locatable power tap


Woods
PROTECT

RESET
OFF

Refrigerators

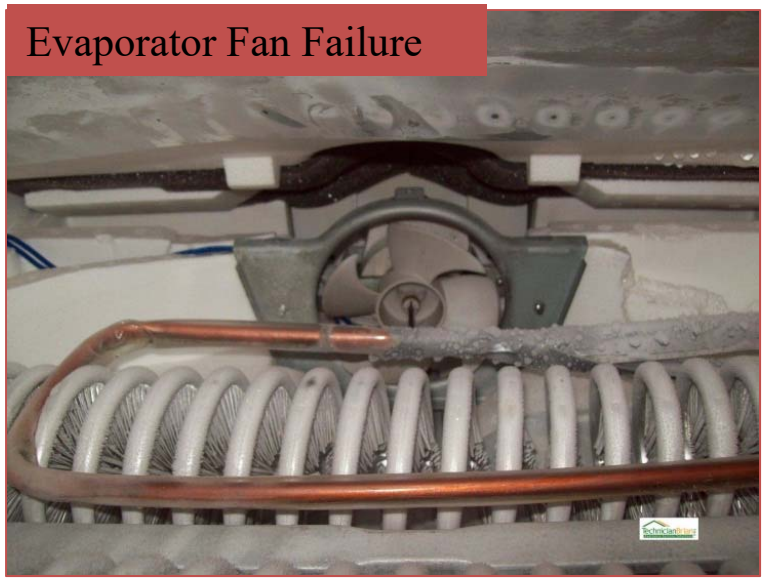
Uses refrigeration gas and compression & expansion to remove heat from the unit



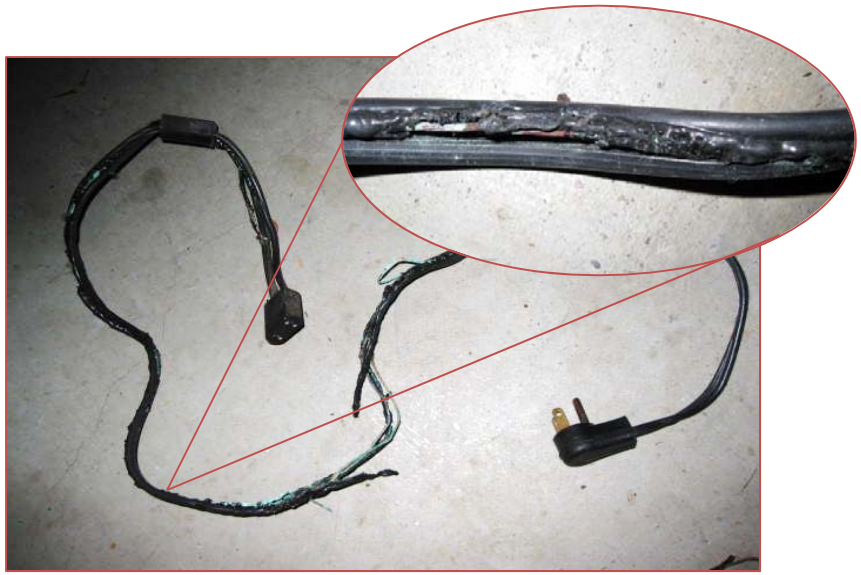
Main Components:

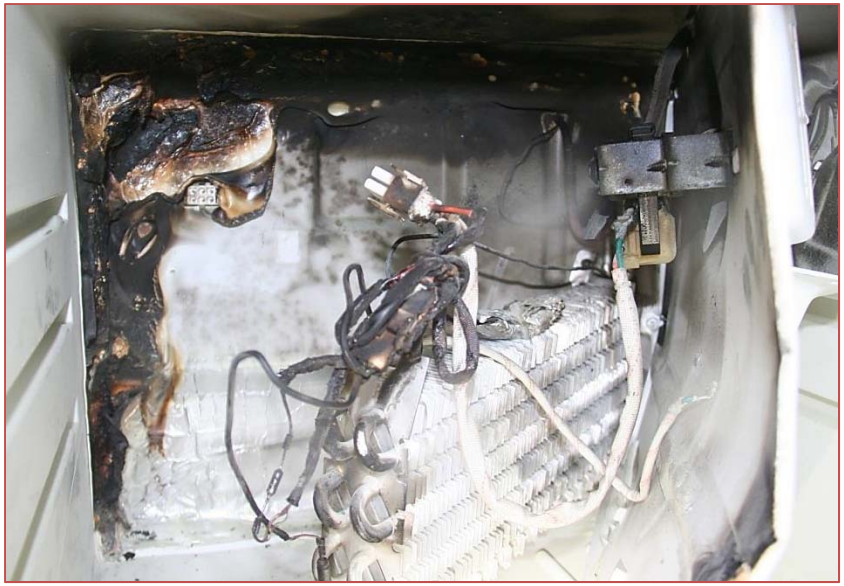
- Evaporator Coil
- Condenser Coil
- Cooling Fan
- Compressor

Refrigerator Failures



- Electrical Shorts
- Motor/Control Failures
- Defrost Control Failures
- Cord Damage/Abuse





DISHWASHER ELECTRICAL FAILURES

Failed Door Switch

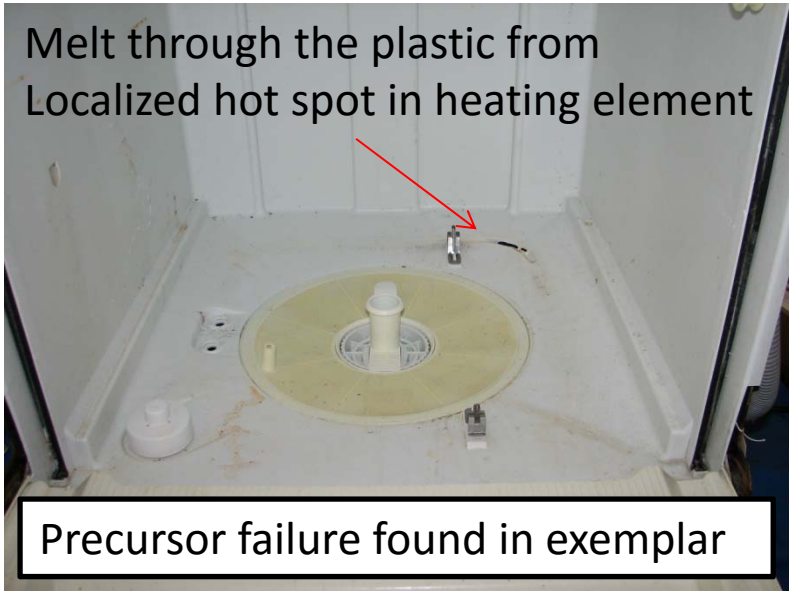
Failed Heating Element

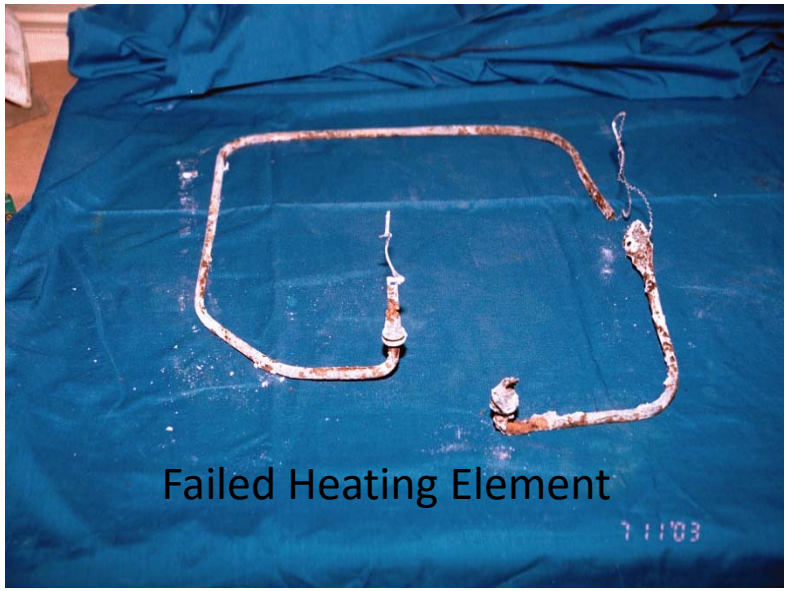
Failed Wiring Harness

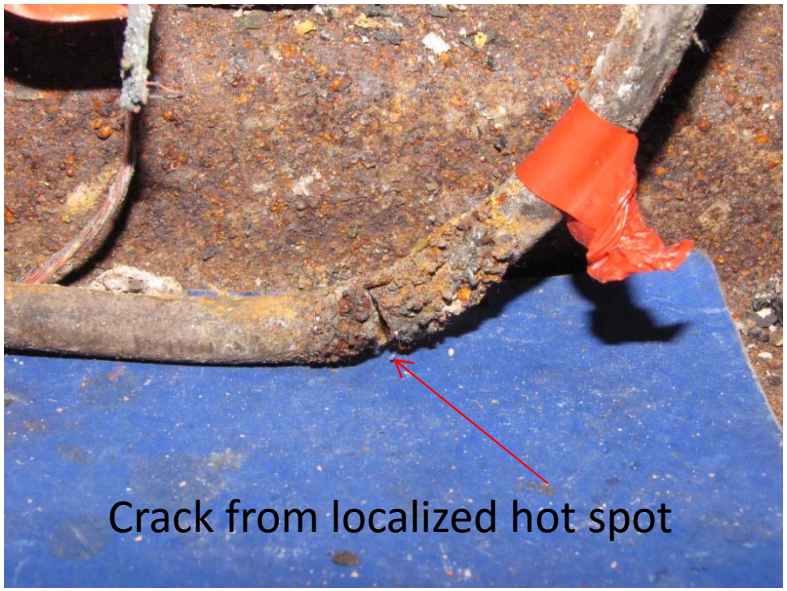
Failed Wax Motor Switch

High Resistance Connection

Heating Element Failures

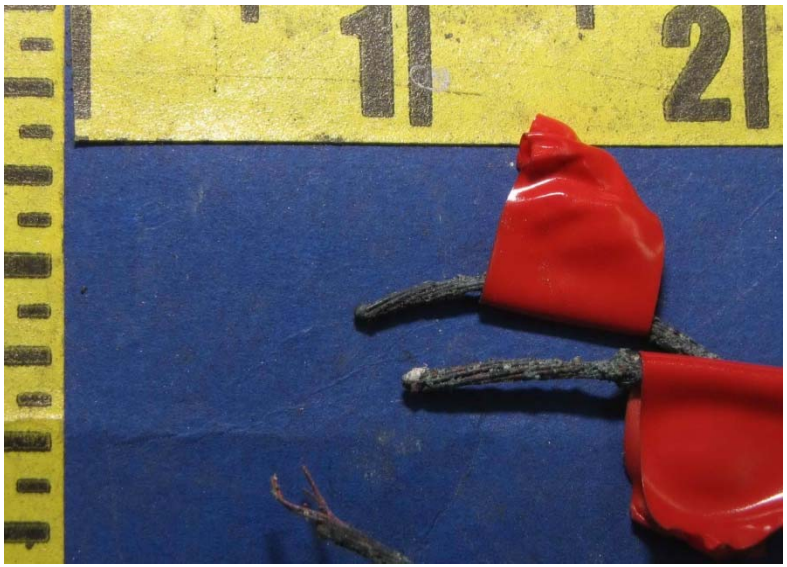






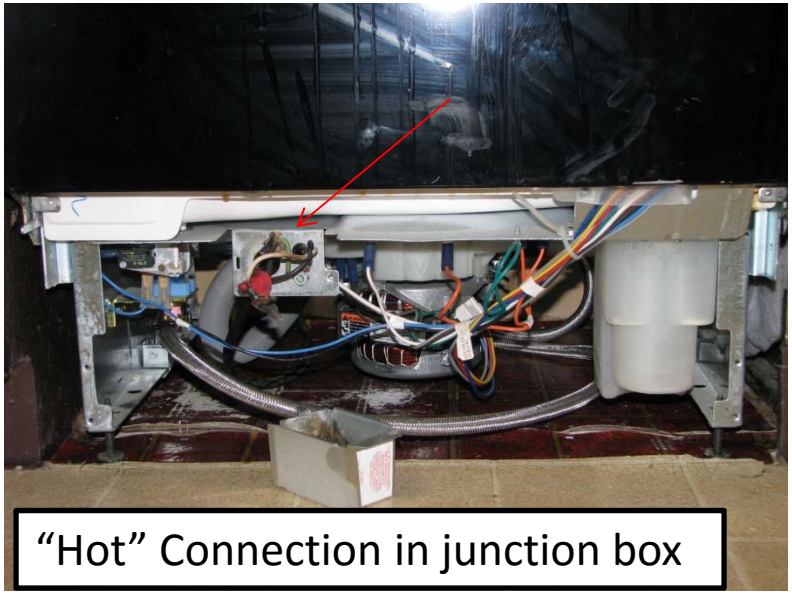
Wire Harness

Arced wires marked with red tape

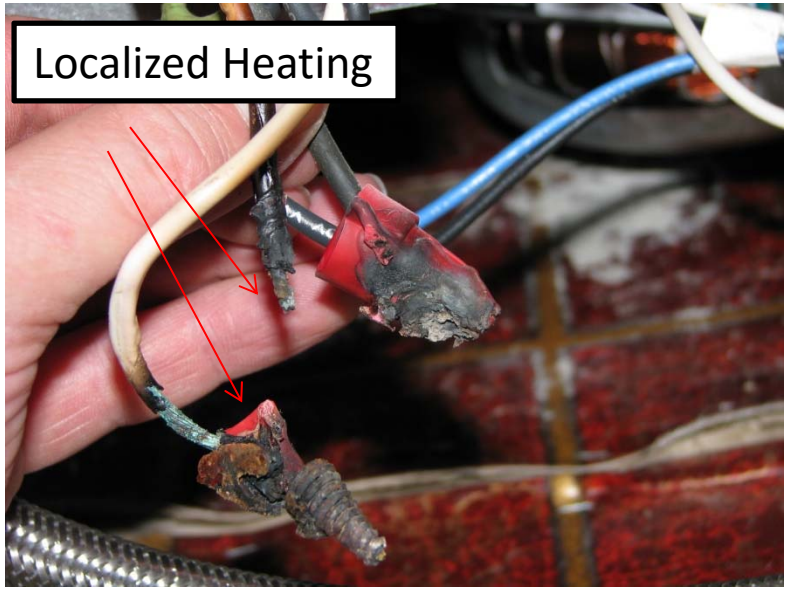


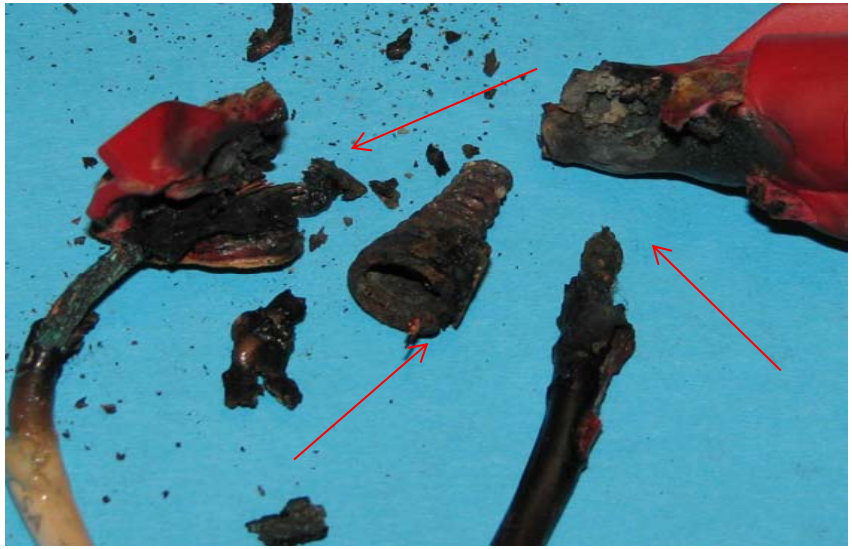
Wax Motor (switch)

High Resistance Connection

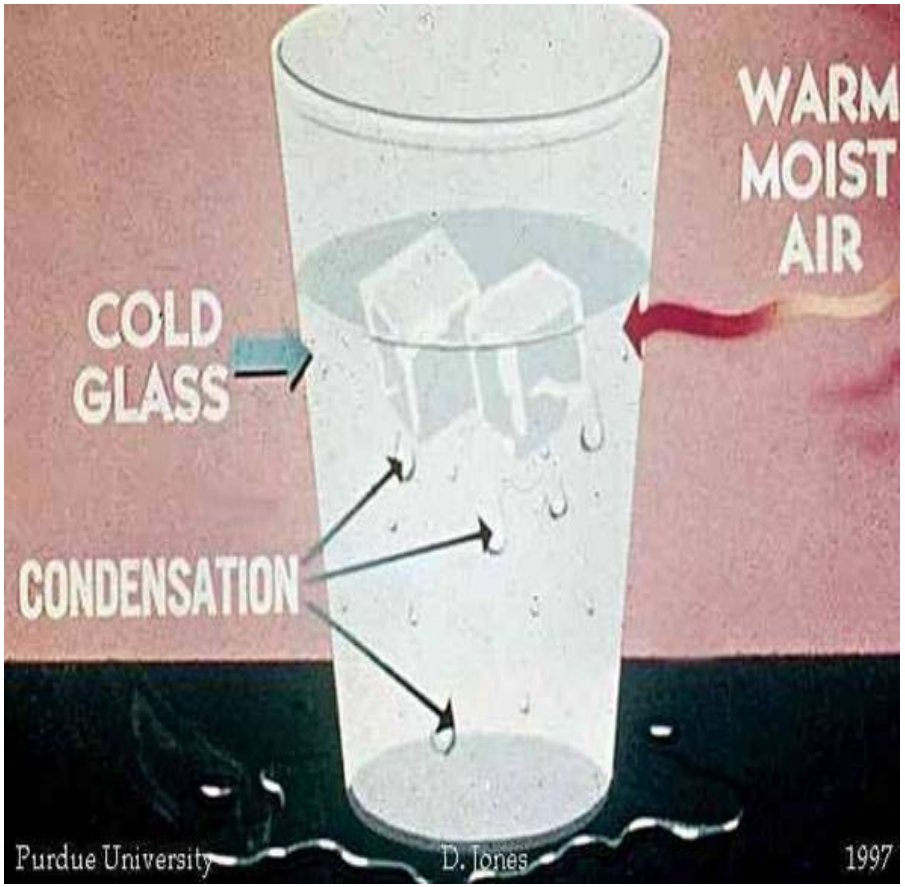


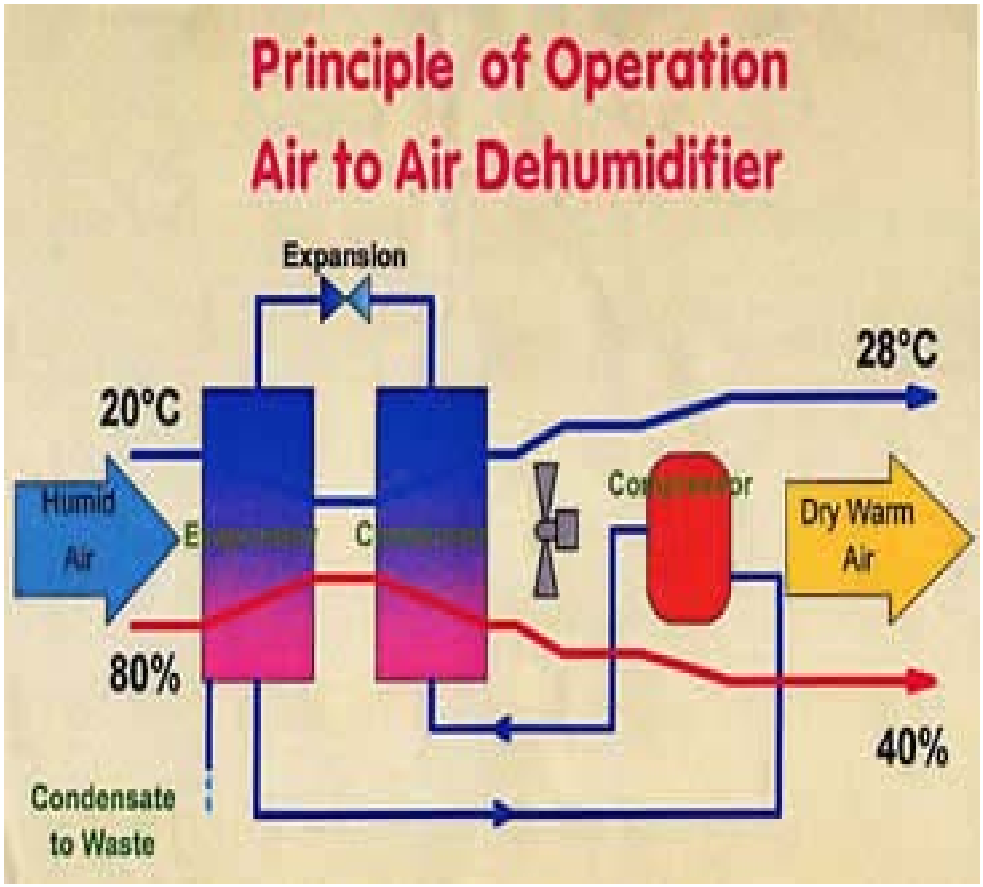
Localized heating at wire nut





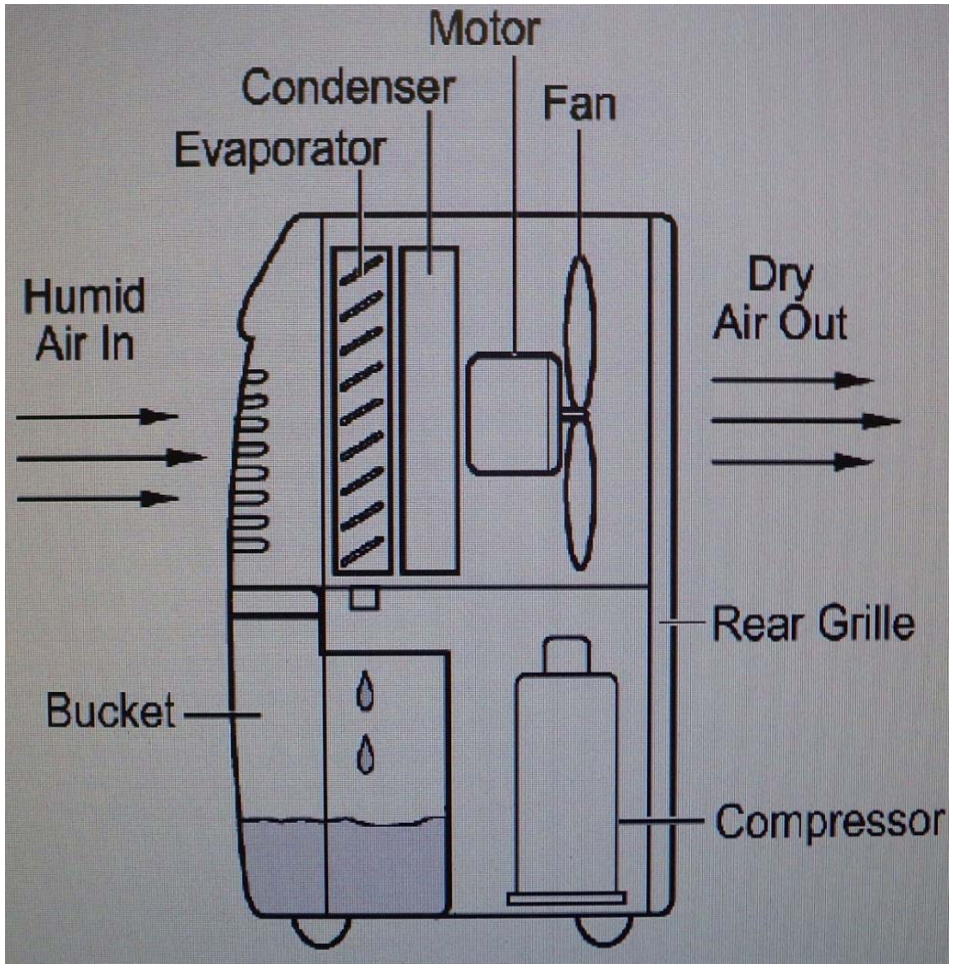
Dehumidifier Operations

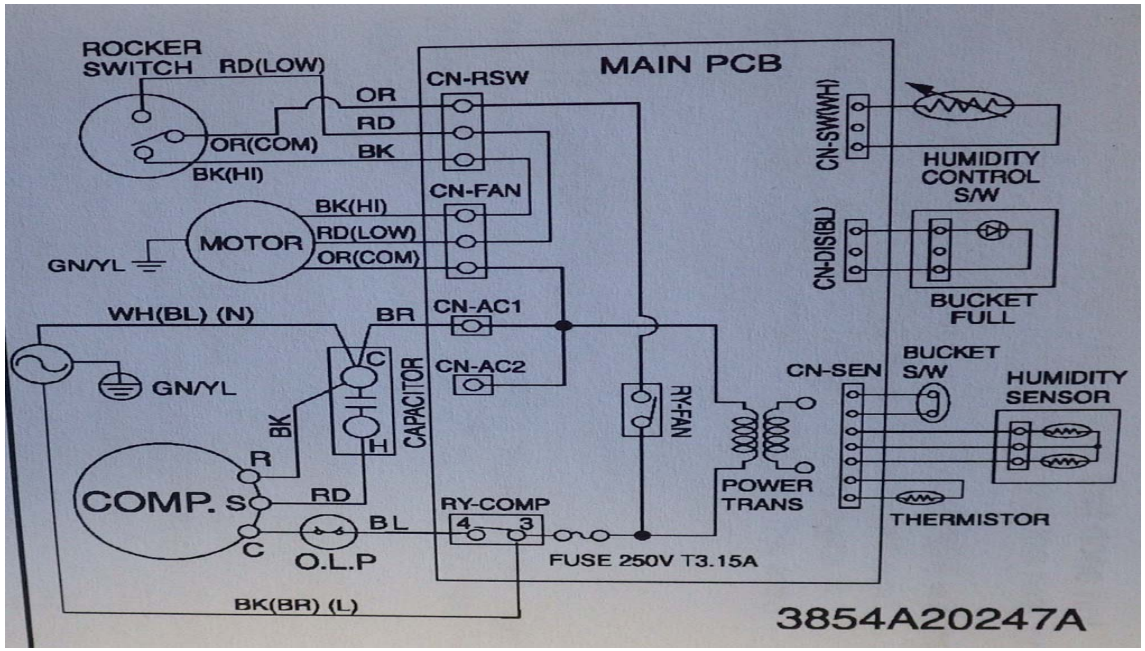




Dehumidifiers

- Warm, moist air is sucked in through a grille on one side of the dehumidifier. An electric fan draws the air inward.
- The warm air passes over the cold evaporator through which a coolant circulates
- As the air cools, the moisture it contains turns back into liquid water (condensates) on to the evaporator coil and drips downward off the evaporator coil.
- Now free of moisture, the air passes over a condenser ,through which a coolant circulates, which is warm and the air warms back up to its original temperature. The warm, dry air blows back into the room through another grille.





Failure Modes

- Compressor/compressor overload –overheating, welded contacts, switch failure
- Circulation fan- Shorted windings, high resistance connection
- Bucket switch- overheating, high resistance connection
- Power switch/humidistat-overheating, high resistance connection
- Main printed circuit board (PCB)- component failure, high resistance connection
- Power cord failure at the grommet – high resistance connection

Possibly contributing factors

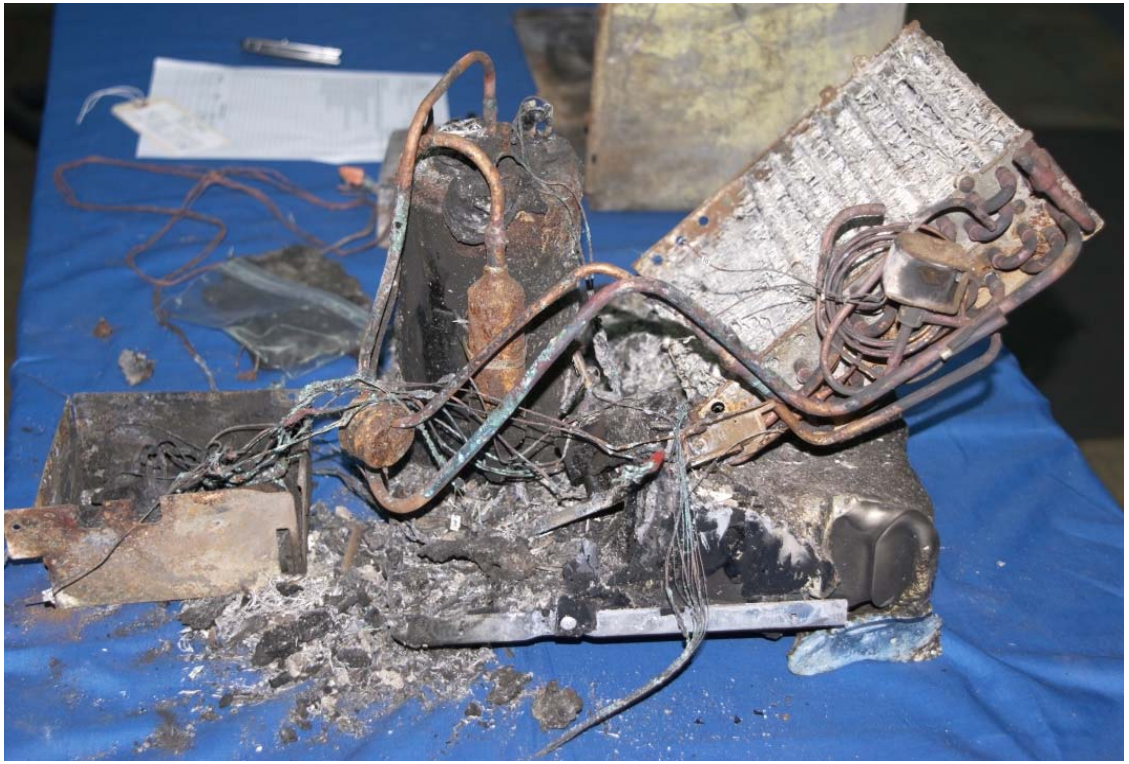
- Use of an extension cord- overload of cord, overheated compressor
- Dirty evaporator, condenser and/or compressor- over heat due to the lack of refrigeration effect, overheated compressor

Failures

Exemplar dehumidifier with the recall failure mitigated.

Precursor failure on the power wire to the mounting post.

Failures



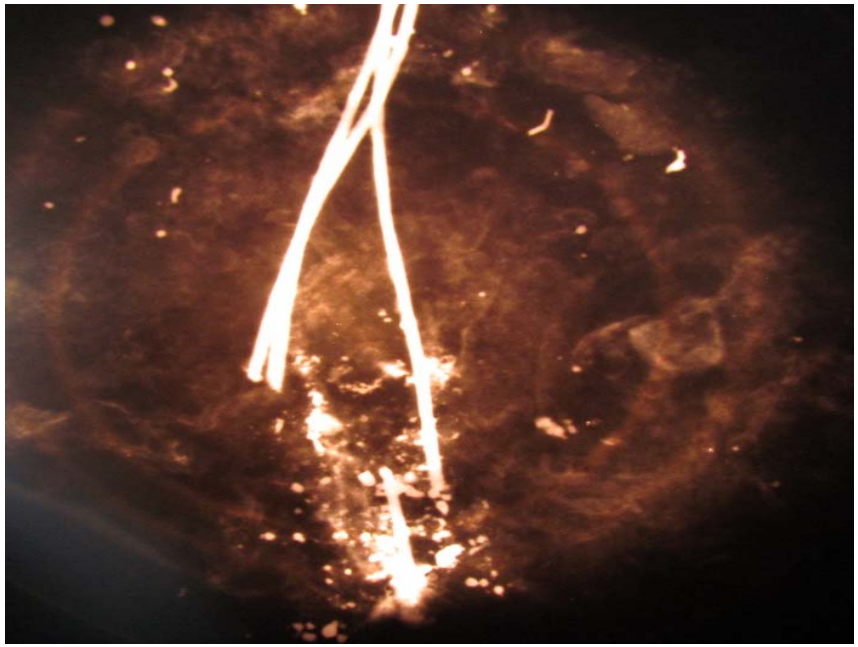
Remains of a dehumidifier with the enclosure removed.

Failure of the input power wire to the mounting post.

Δ Remains of a dehumidifier with the enclosure removed.

Δ Overall x-ray of the dehumidifier

∇ Close-up x-ray of the failure area

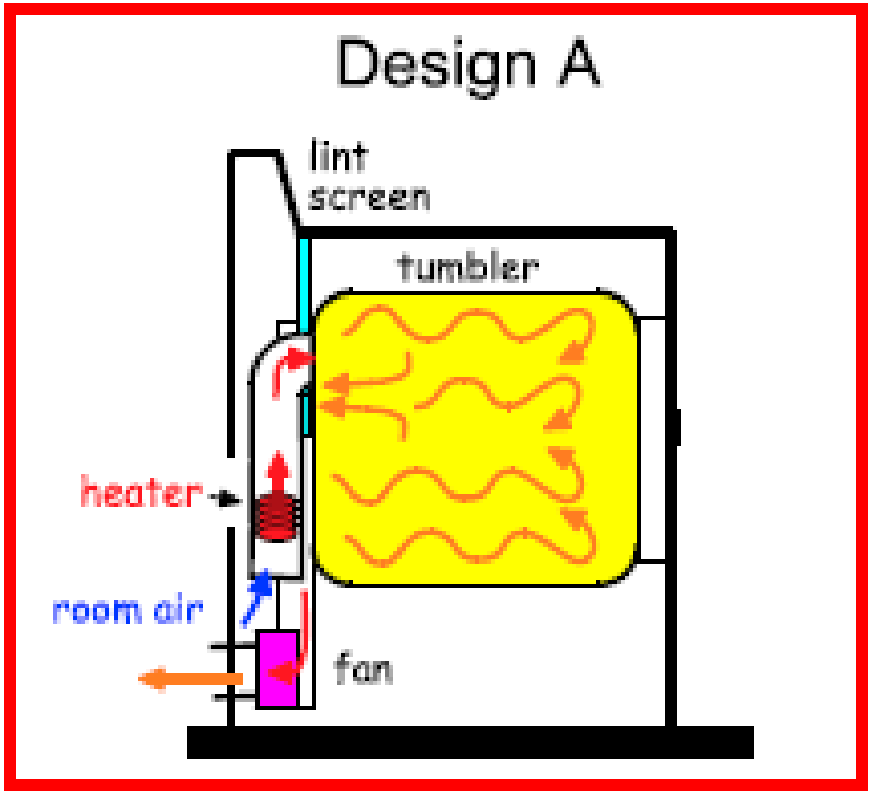


∇ Power cord excavated from the melted plastic

Dryer Fire Statistics - USFA

- Based upon statistics compiled through NFIRS for 3 years (2008-2010):
  - Clothes dryer fires account for an average of 2,900 residential structure fires, 5 deaths, 100 injuries and $35 million in property damage annually.
    - This is down from 12,700 clothes dryer fires occur in residential buildings resulting in 15 deaths and 300 injuries (2002-2004 statistics)
  - “Failure to clean” is the leading factor contributing to clothes dryer fires in residential buildings.
    - How can the public investigator reliably determine this?

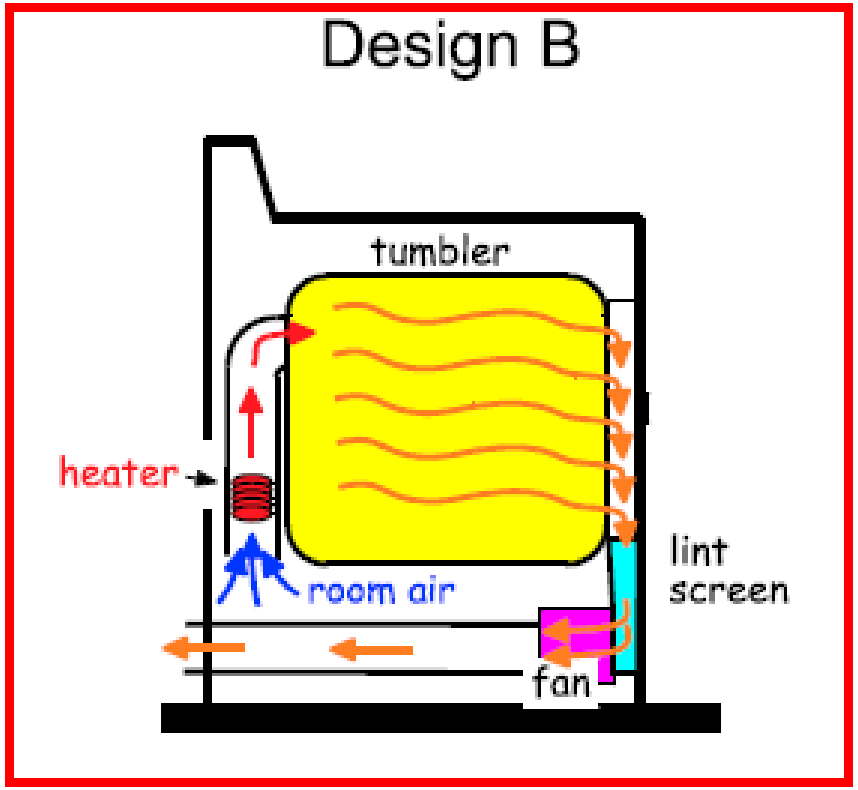
Dryer Design A



- Features
  - Two piece drum
  - Rear bulkhead with heat and exhaust ducts
  - Top-mounted lint screen
- Brand
  - Whirlpool (Original)

Image courtesy of : CPSC Final Report on Electric Clothes Dryers and Lint Ignition Characteristics, May 2003

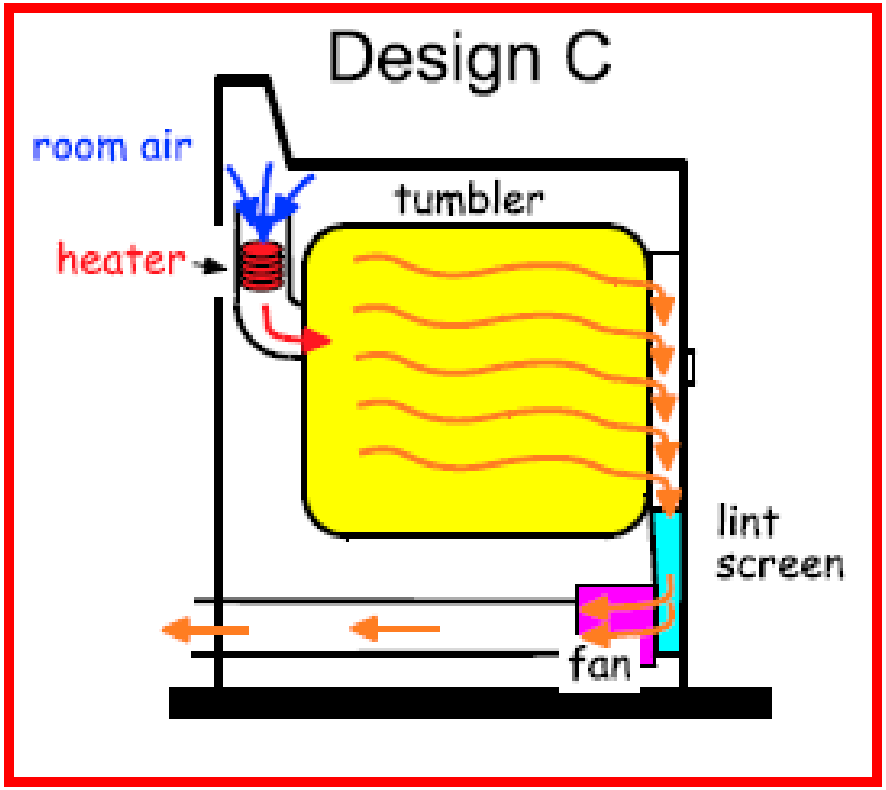
Dryer Design B



- Features
  - Two piece drum
  - Rear bulkhead with heat duct
  - Front-mounted lint screen
- Brand
  - Maytag, Whirlpool (New), LG, Samsung, Electrolux (New)

Image courtesy of : CPSC Final Report on Electric Clothes Dryers and Lint Ignition Characteristics, May 2003

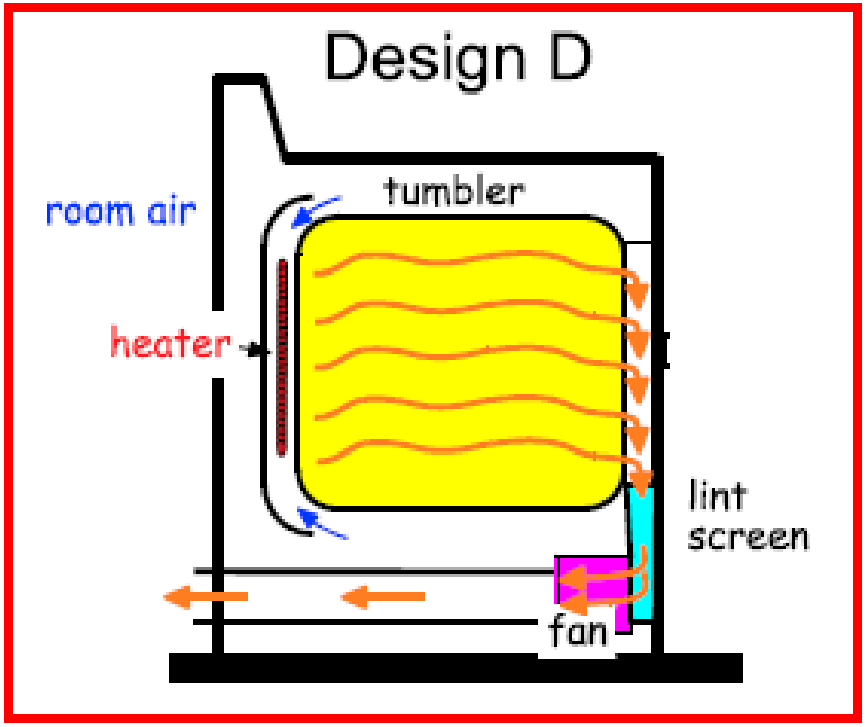
Dryer Design C



- Features
  - Two piece drum
  - Rear bulkhead with heater Compartment
  - Front-mounted lint screen
- Brand
  - Amana
- DISCONTINUED

Image courtesy of : CPSC Final Report on Electric Clothes Dryers and Lint Ignition Characteristics, May 2003

Dryer Design D



- Features
  - One piece drum
  - Heater pan located behind drum
  - Front-mounted lint screen
- Brand
  - Electrolux (Original), GE

Image courtesy of : CPSC Final Report on Electric Clothes Dryers and Lint Ignition Characteristics, May 2003

Origin Determination Patterns

Origin Determination Patterns

Growth Patterns: Internal Fuels

Timeline

- A timeline is helpful in understanding the history of the dryer, the events leading to the fire and potential cause scenarios

- It is important to obtain key timeline information:
  - Home: Date built, date purchased
  - Dryer: Dryer purchase date, venting install/change dates and maintenance/service history for life of dryer and venting.
  - Fire: Timeline of loads on day of, time last load was dried, length of time dryer was running (or resting if cycle finished) until discovery.

Heat Source: Electric Element

Heat Source: Gas Burner

First Fuels: Cabinet Lint

First Fuels: Lint in Heater Pan

First Fuels: Lint Encroachment

Common Causes

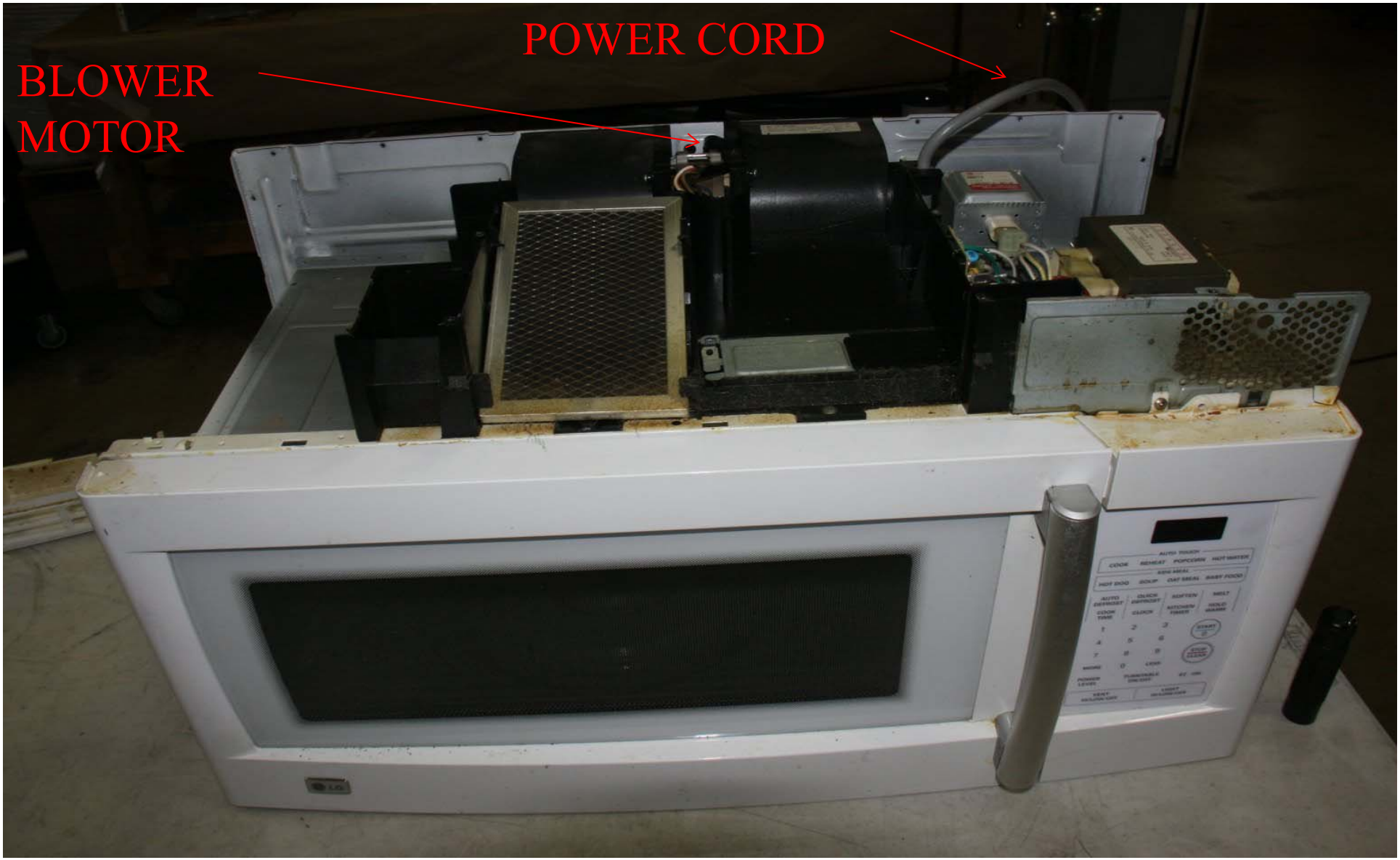
- If the fire is verified to originate within the dryer, the following are potential causes:
  - Lint ignition at or near the heat source
  - Mechanical or electrical component failure
  - Contamination of the load by flammable liquids or materials prone to spontaneous combustion
  - Overheated electrical connection
  - Foreign object contacting the heating element
  - Failure of the single rear drum bearing/pivot resulting in the drum arcing against the heating element

Microwave Styles

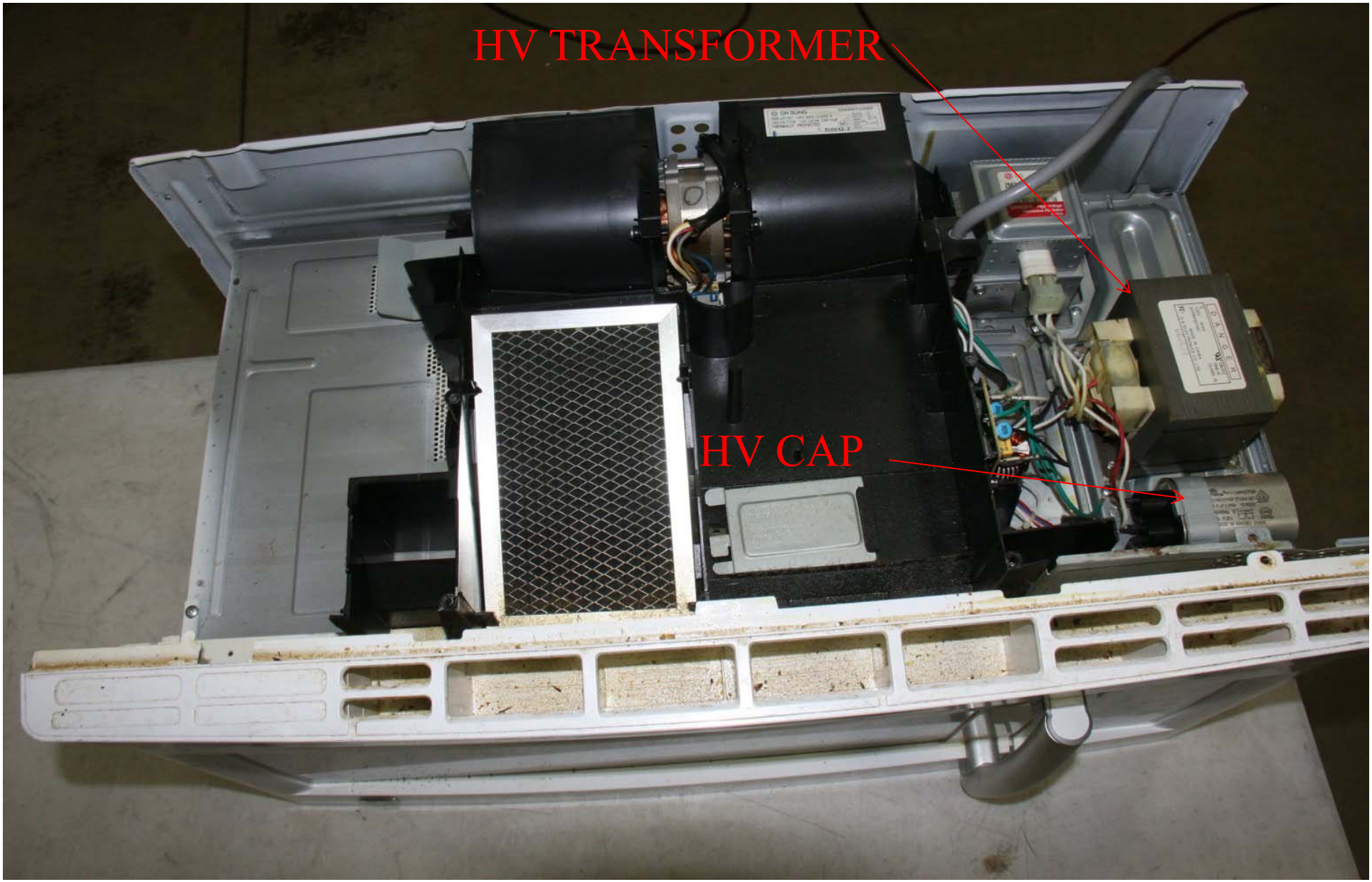
FAULT ANALYSIS

- HIGH RESISTANCE
- GROUND FAULTS
- ARC TRACKING
- PRINTED CIRCUIT BOARD
- DOOR SWITCH
- MONITOR SWITCH
- HV TRANSFORMER
- HV CAPACITOR
- HV DIODE
- MAGNETRON
- BLOWER MOTOR
- 20 AMP FUSE

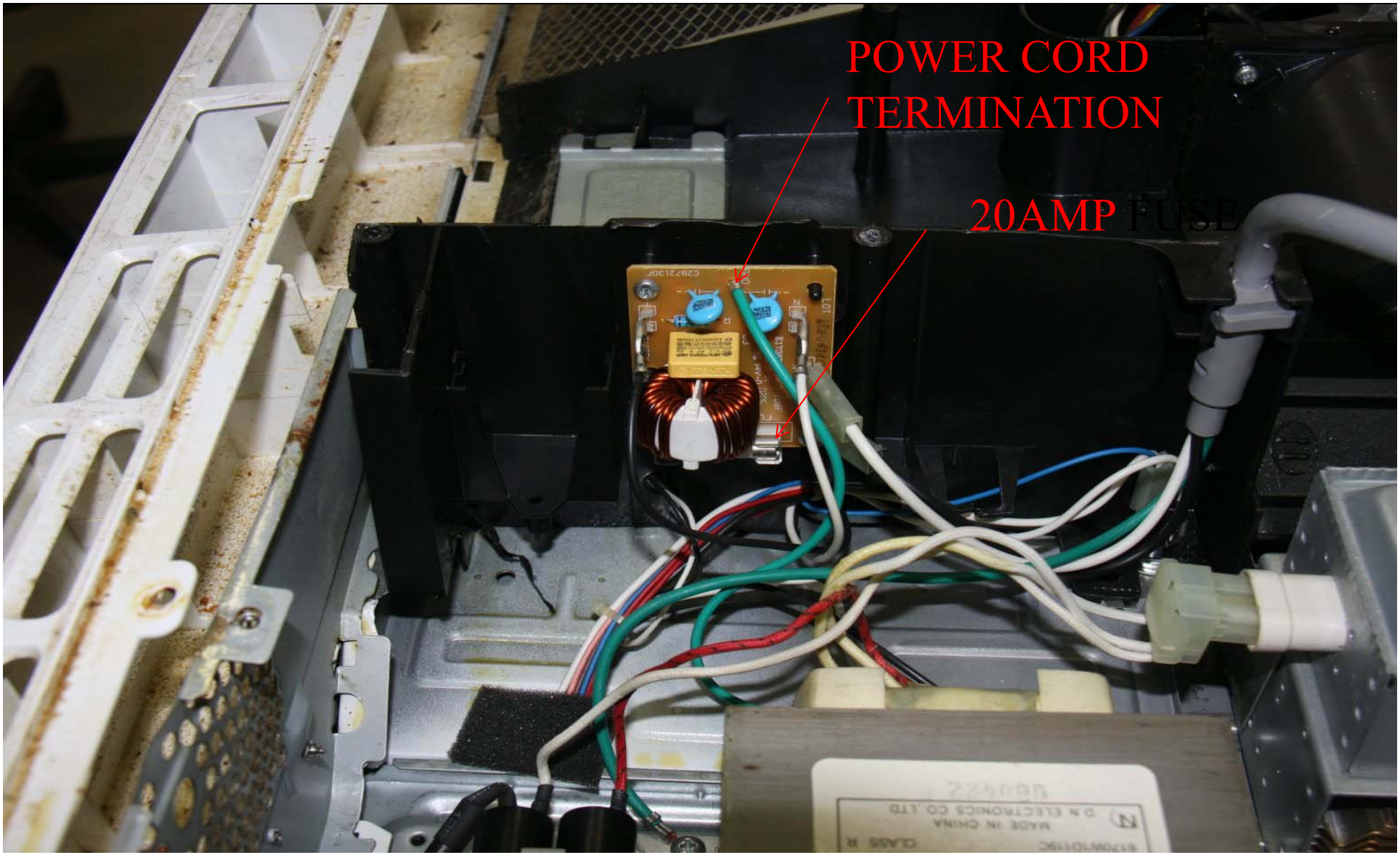
Internal Component View



Component View Cont.

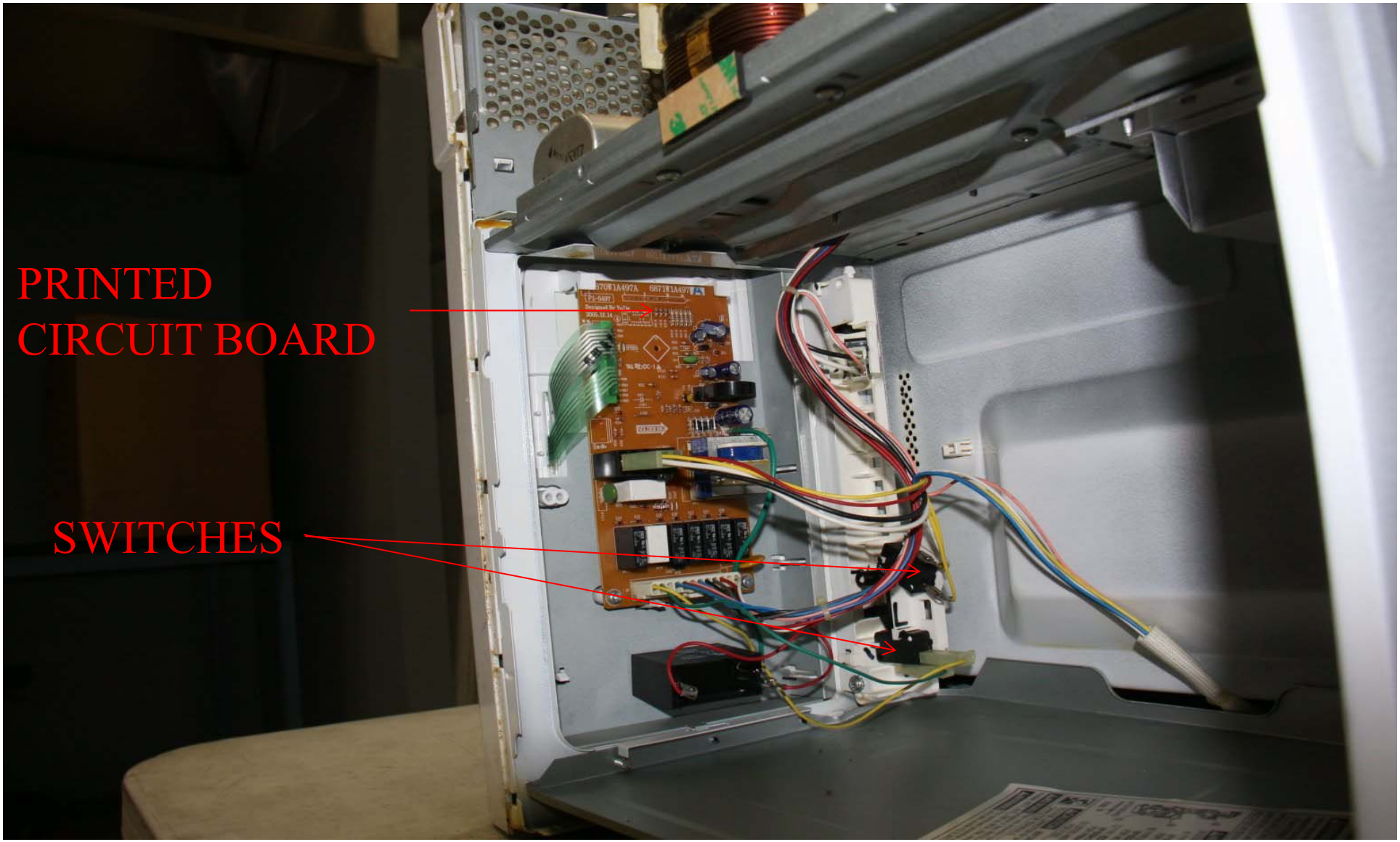


Component View Cont.



Component View Cont.

Component View Cont.



MICROWAVE NOTES

- Not all microwaves are the same they have different features and configuration.
- Over the range microwaves typically contain temperature controls that turn on a blower.
- Certain Models contain Thermal Cut Offs for the Magnetron, Fan, and Flame Sense.

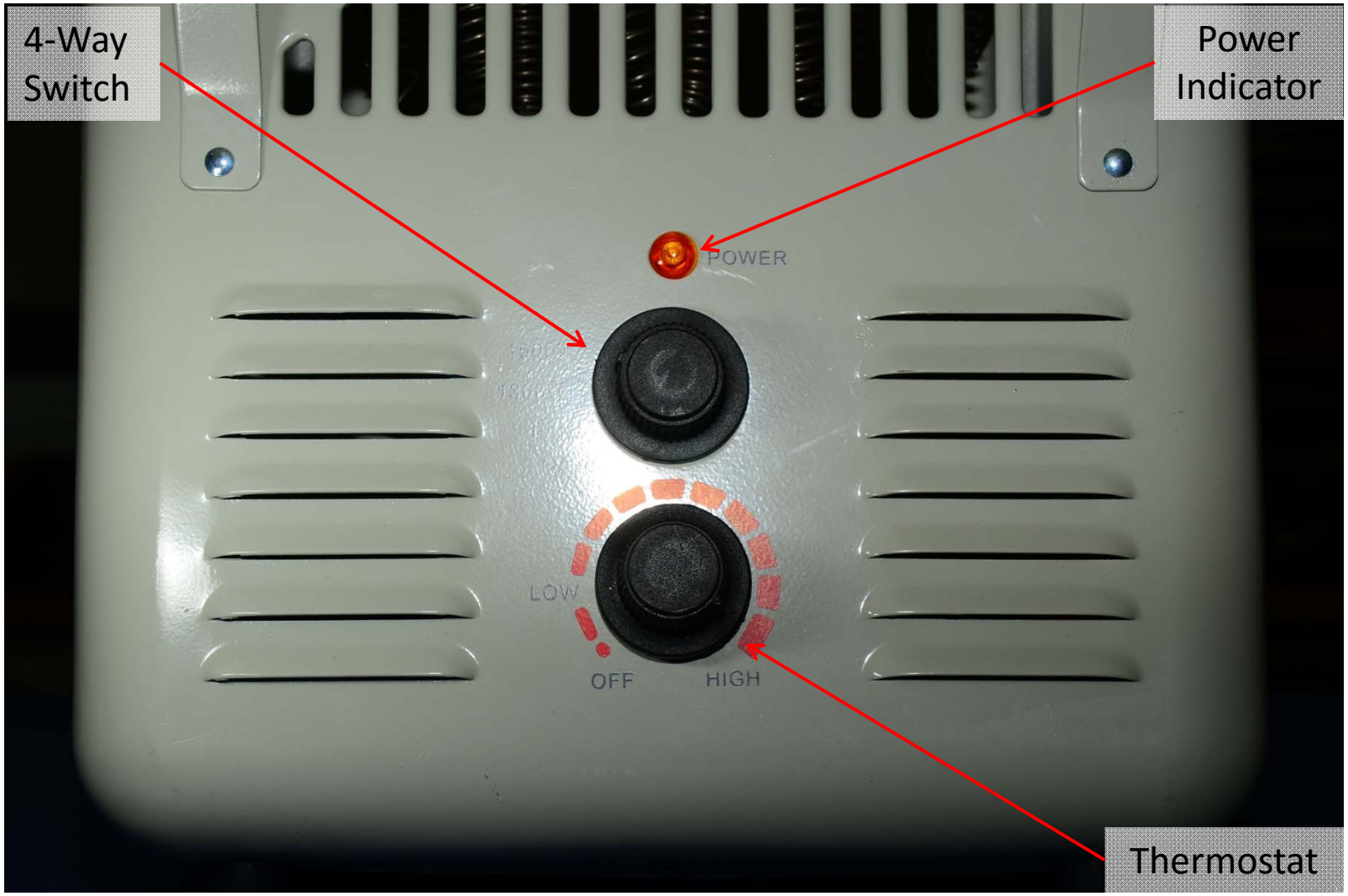
Radiant Space Heaters

Ignition Handbook

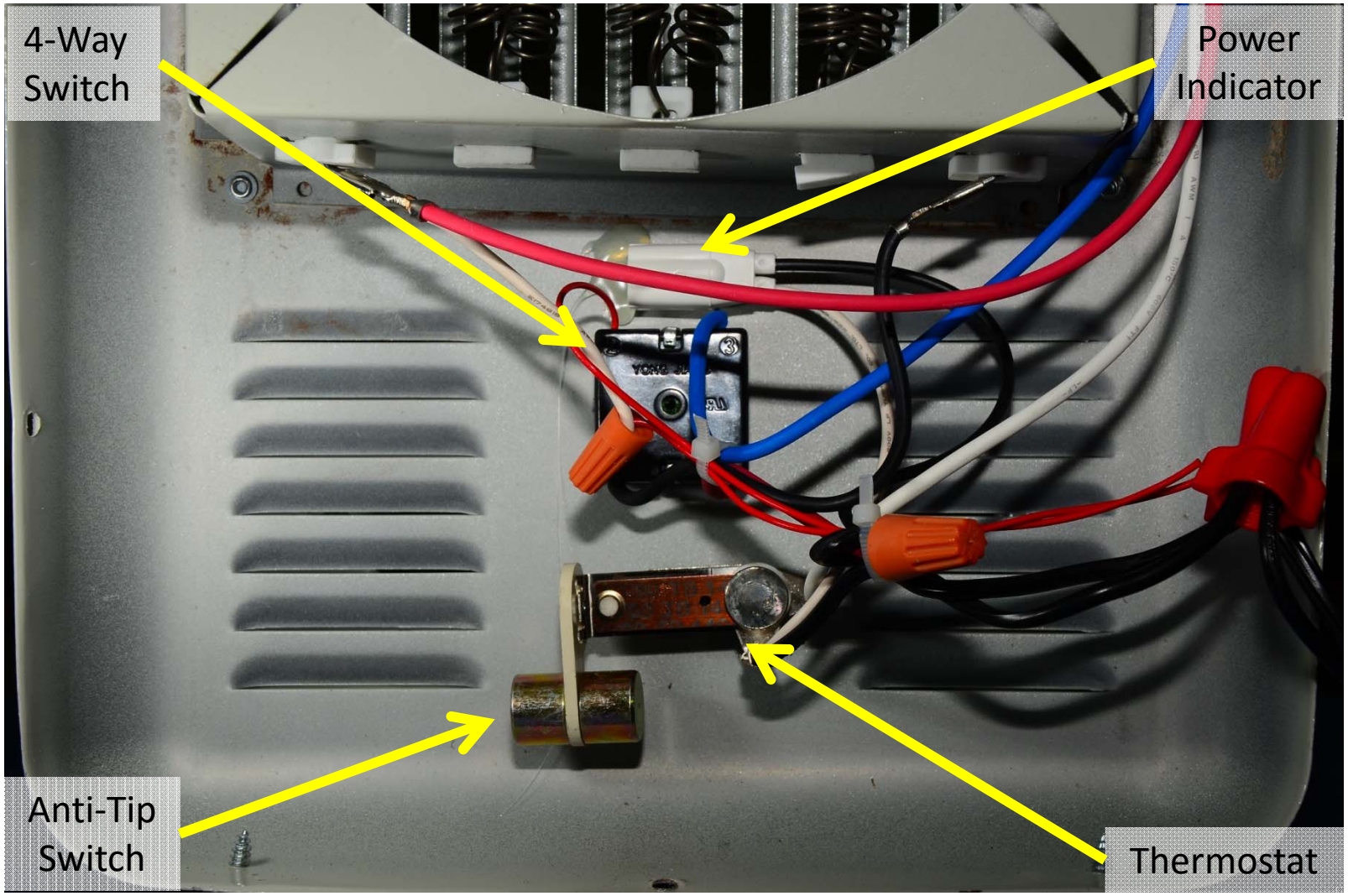
- Radiant electric heaters commonly produce a heat flux around 10 kW/m^2 at the face of the grille and the value drops rapidly with distance .
- Unless overt electrical failure occurs, it can be assumed that there is no source of pilot ignition .
- The question of interest then becomes what materials might auto-ignite at a heat flux of 10 kW/m^2 or lower. Fabric and paper goods generally require substantially higher heat fluxes for auto-ignition. But cardboard can be ignited at fluxes below 10 kW/m^2 .
- Of course, pushing any combustibles up to the face of a radiant heater is a misuse of the heater and, in that same vein, more abusive misuses are possible : stuffing material inside the grille or blocking the entire face of the heater. In the latter case, however, a properly design thermal cutout should operate .

Forced Air Space Heater

Controls

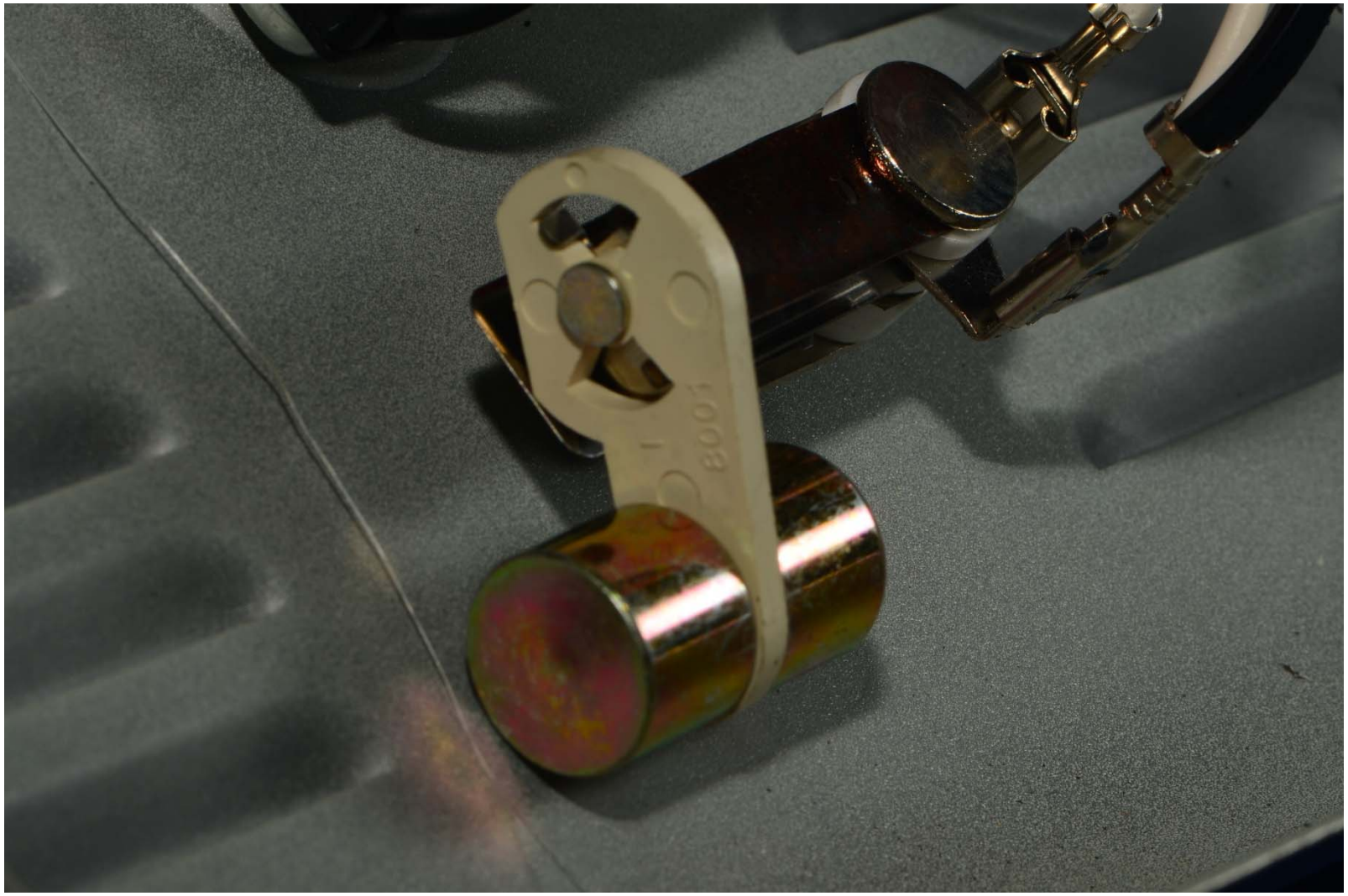


Controls

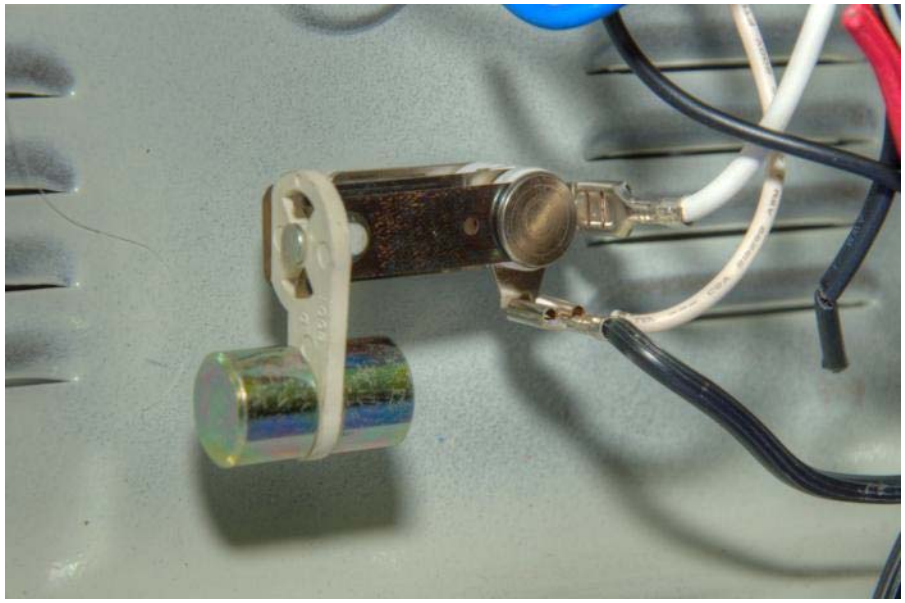


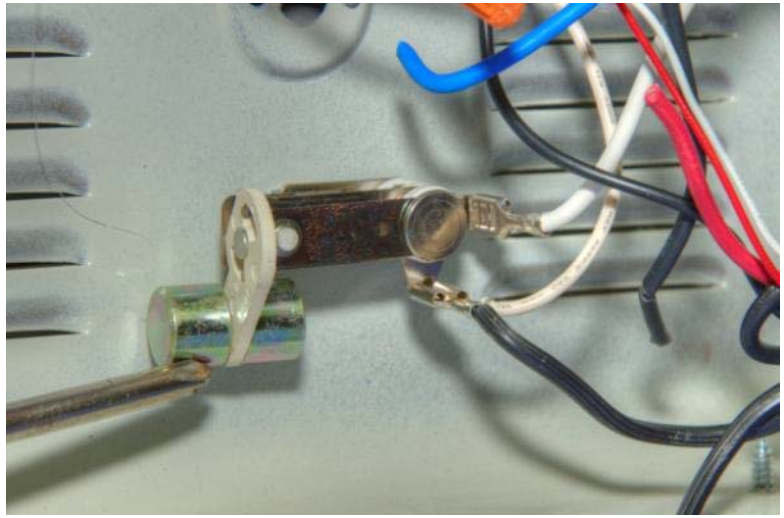
Anti-Tip Switch

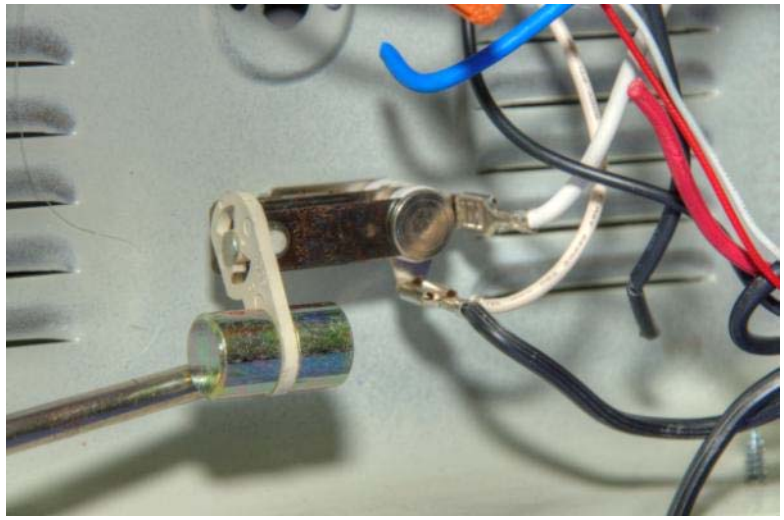
Anti-Tip Switch



Anti-Tip Switch

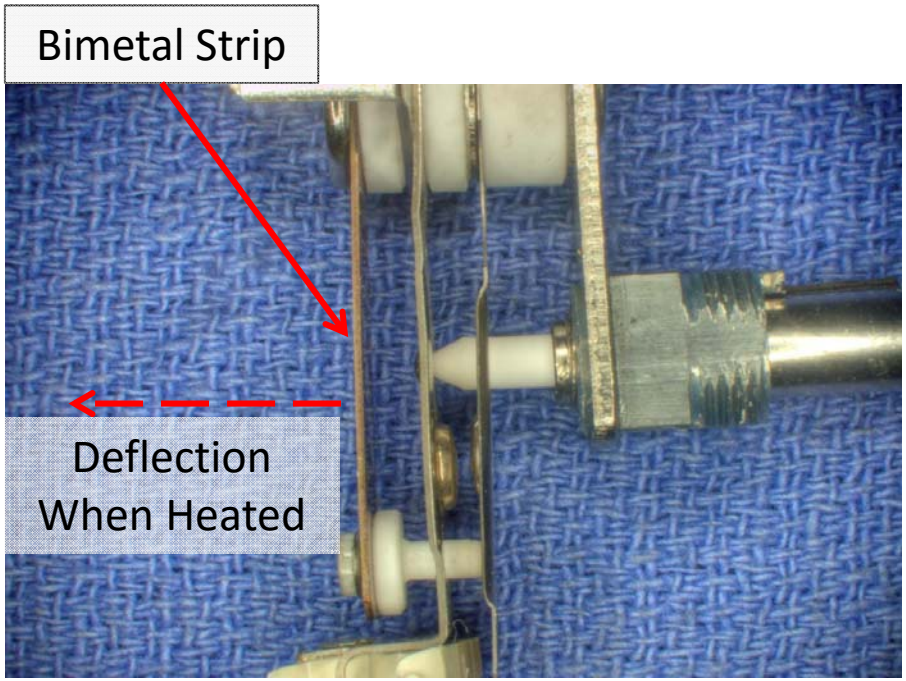


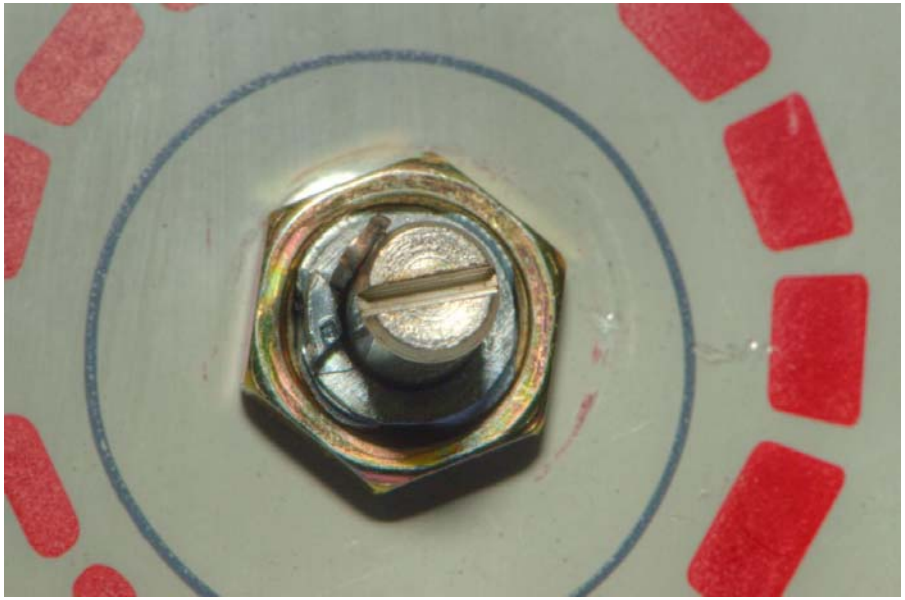




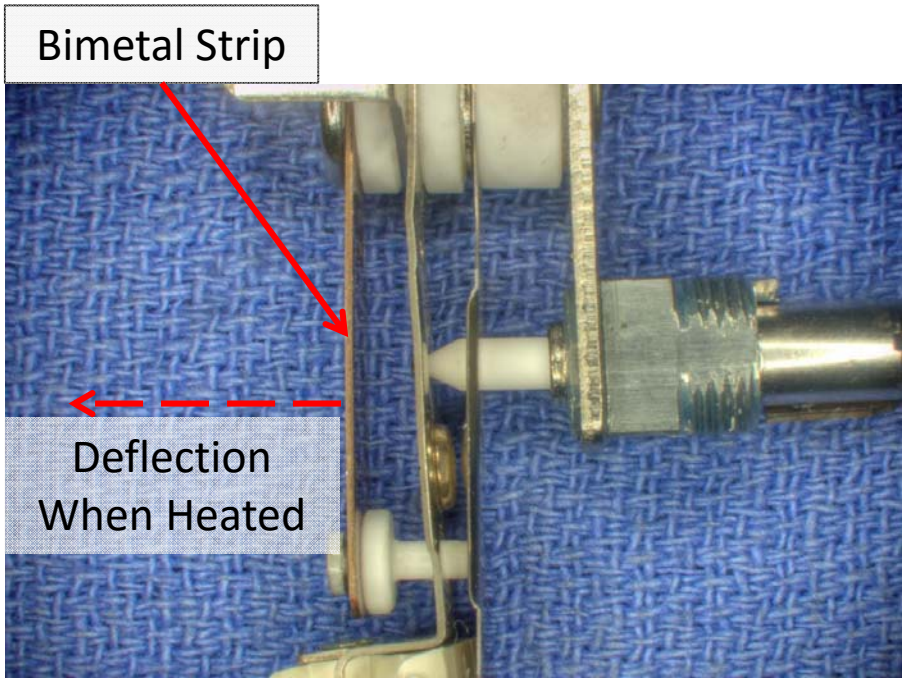
Thermostat Position

Thermostat – Full CCW

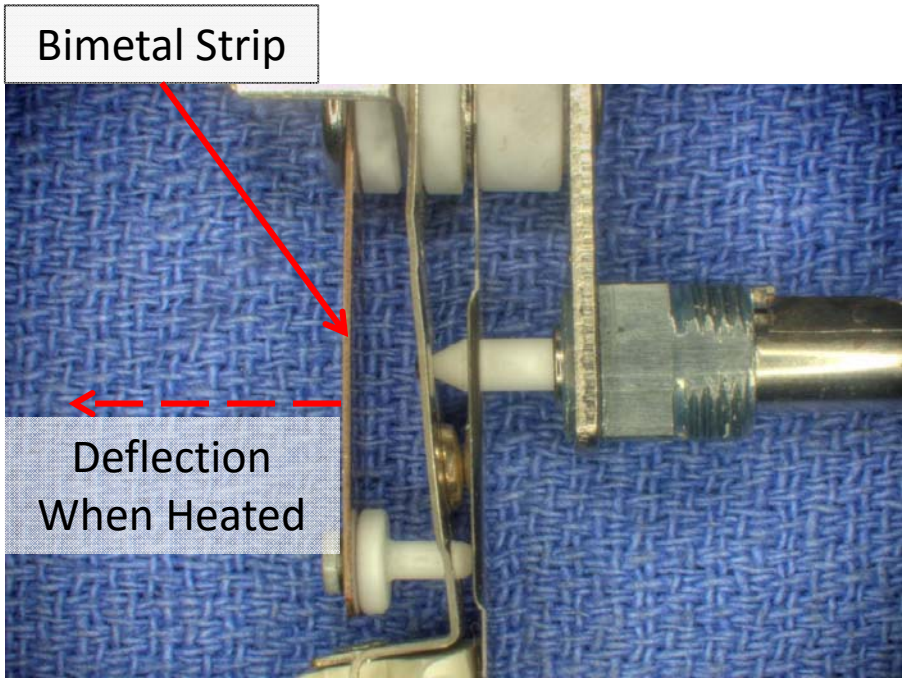


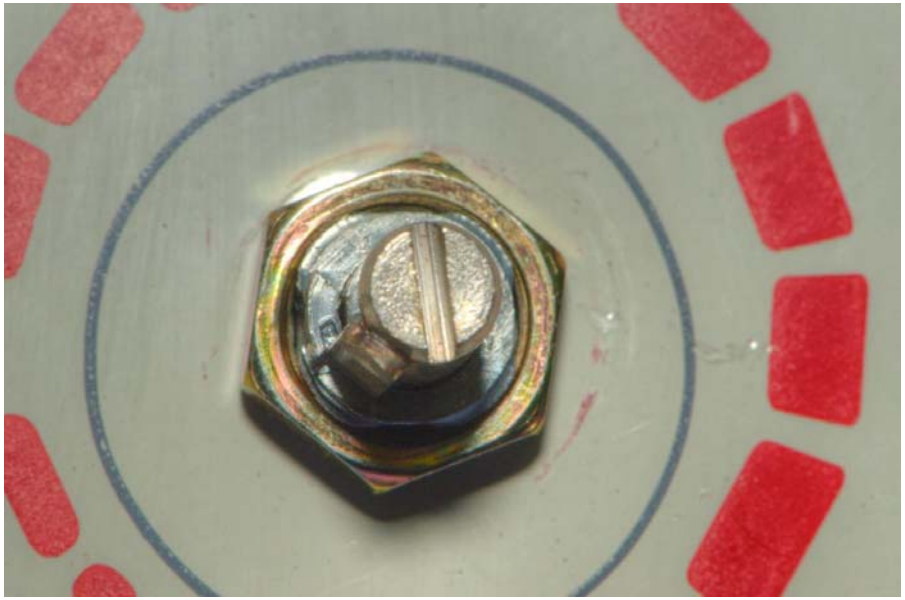


Thermostat– Half Rotation

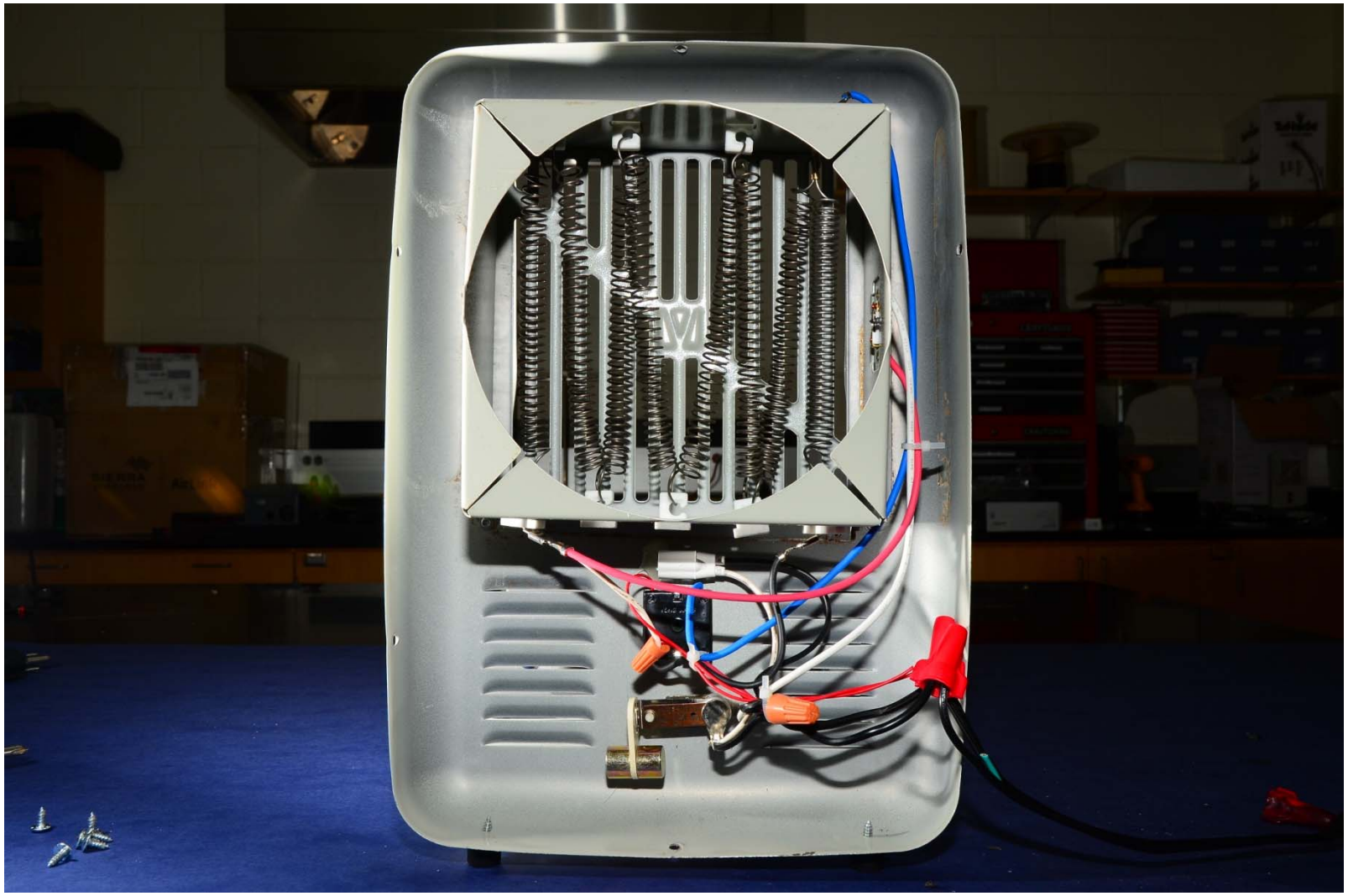


Thermostat – FULL CW





Radiant Coils



General Considerations

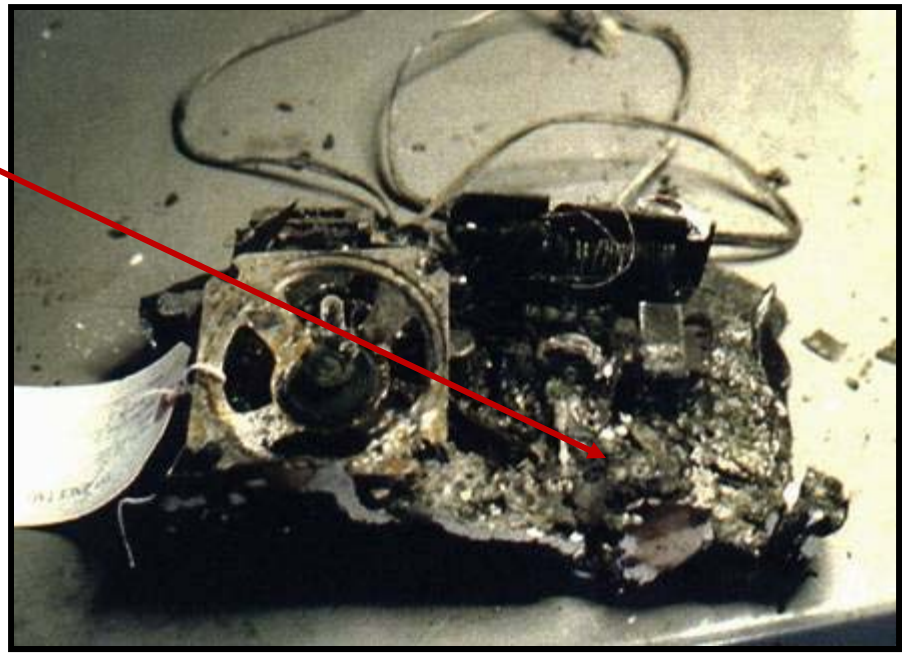
- Electrical activity within the appliance typically supports cause.
- Electrical activity outside of the appliance on the power cord typically supports fire attack not cause.
- Complete and proper electrical evaluation and analysis is typically required to make these determinations.

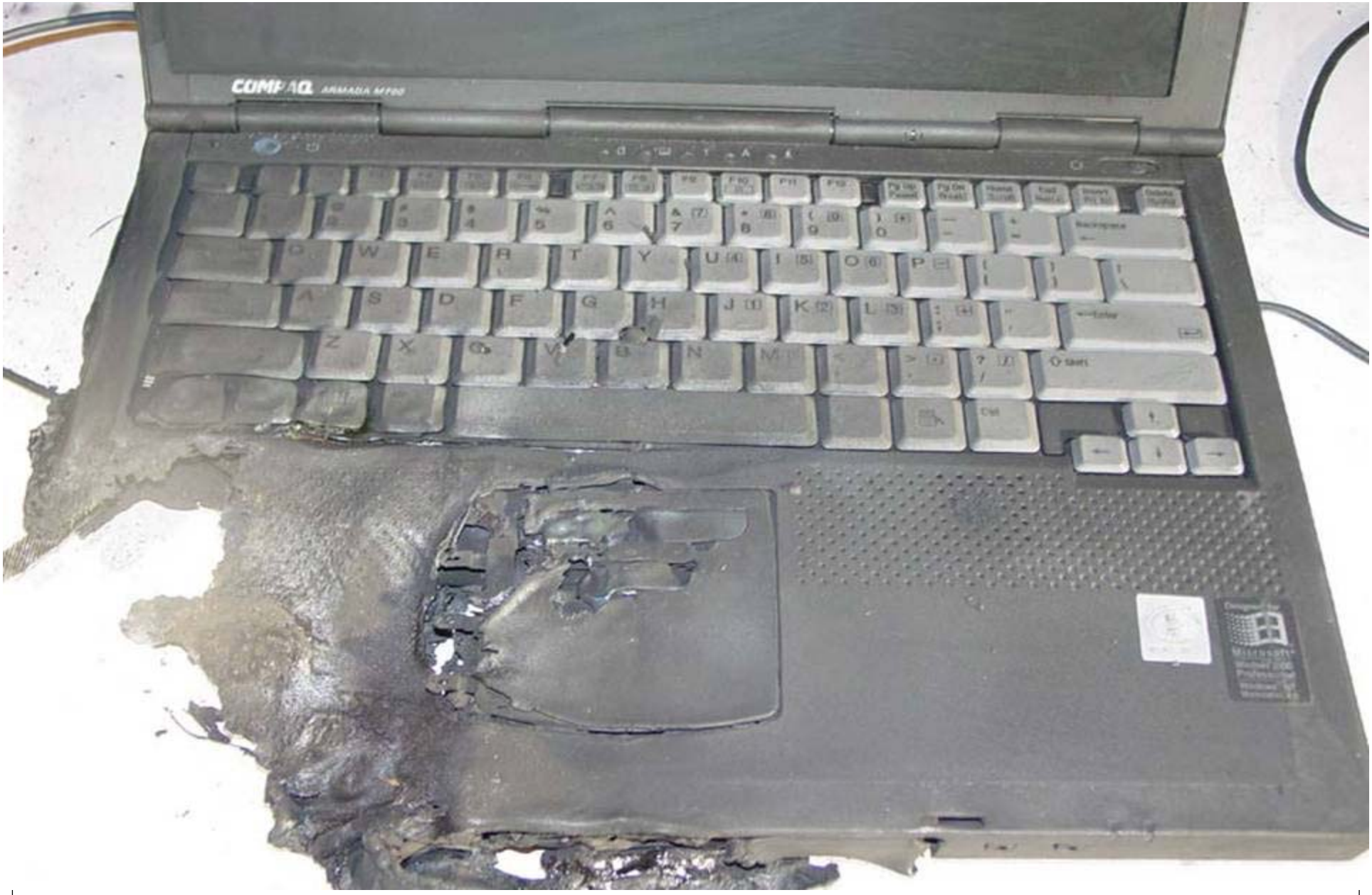
ELECTRONIC DEVICE FIRES

There are too numerous types of devices to cover here. However, there are a few common failure modes that result in fires.

Power supply failures.
Switch and connection failures.
Pinched or damaged cords and plugs.

Look for - Local damage at switch or power supply. Signs the enclosure burned from the interior out. Location in area of origin.




COMPAQ

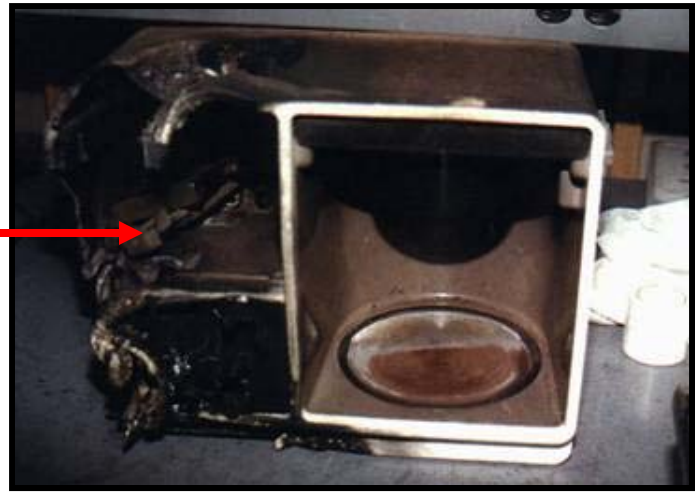
COFFEE MAKER FIRES

Coffee maker fires are less common today as in the past. Current designs employ redundant thermal cutouts to prevent failure of one to result in thermal runaway.

Failure modes - Heater energized with no water or continuously energized.
Control component failure.
Pinched or damaged cord fault.

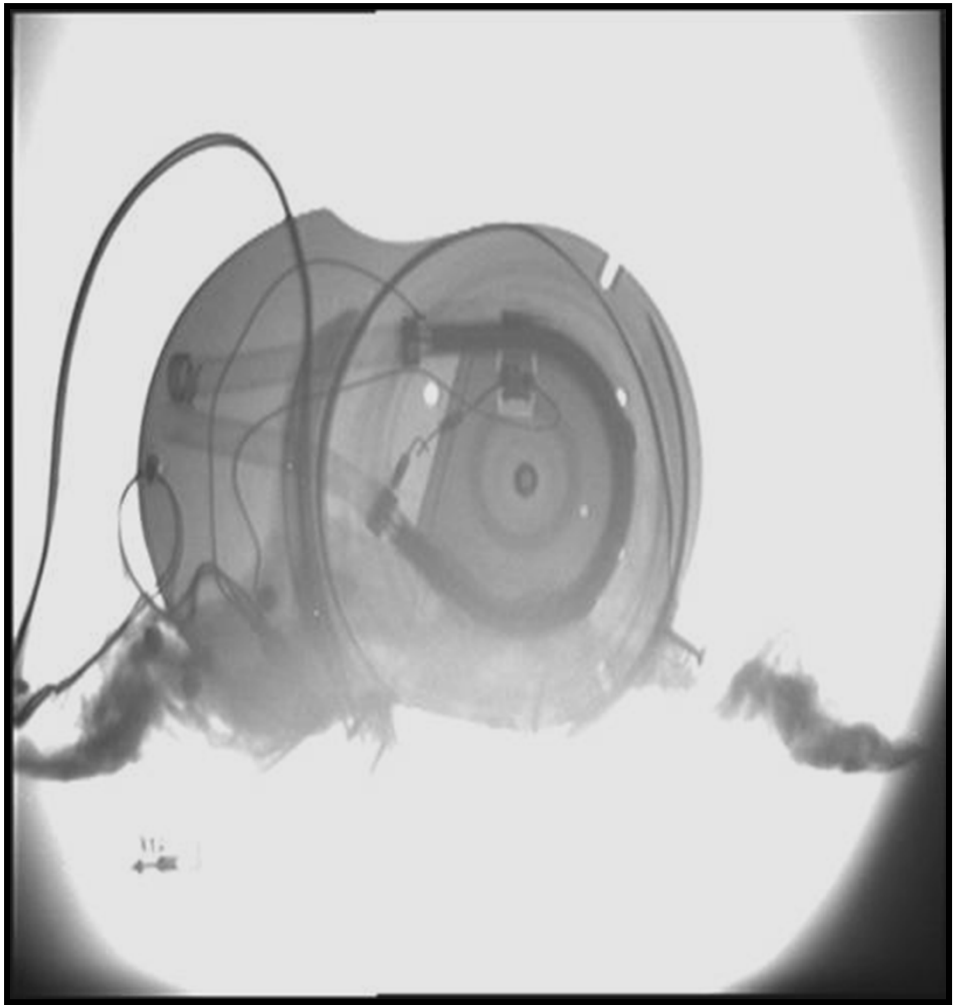
Look for - Device clearly in area of origin. Heating elements show severe melting damage. Removed or tampered with thermal cutouts.
Burning to enclosure clearly emanating from interior.
Destructive examination and x-ray analysis can detect signs of component failure or tampering that may not be visible.

Control component failure



COFFEE MAKER FIRES

Destructive examination and x-ray analysis can detect signs of component failure or tampering that may not be visible.



PRACTICAL EXERCISES

Hands-on wiring of service entrance panel and associated branch circuits.

Appliance Failures

Practical Electrical Demonstrations

PRACTICAL EXERCISES

Hands-on wiring of service entrance panel and associated branch circuits.

Appliance Failures

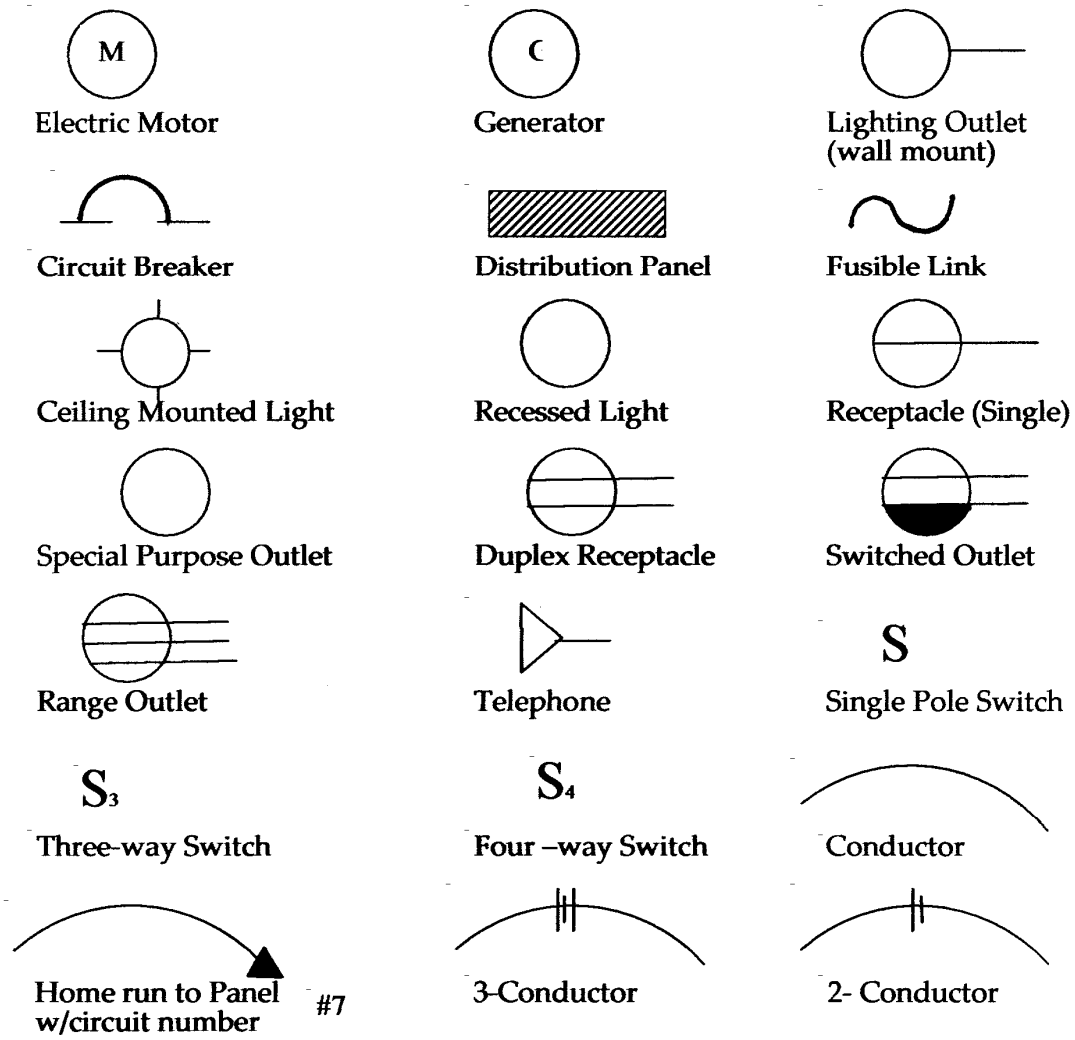
Practical Electrical Demonstrations

BRANCH CIRCUITS

- Now that we have all this knowledge and information lets looks at electrical circuits and to properly wire them and evaluate them. This will be the hands on section of the class. Understanding what a properly wired circuit looks like, understanding the use of the "conductor" and not the color will be an asset when examining circuits found in the fire scene.

- The attached statement pages are a general overview and guideline for the proper installation of electrical circuits. The "jobs" that are listed are the same circuits most commonly encountered in residential and commercial structures. Looking at electrical circuits on a set of blueprints may be somewhat confusing; therefore some basic knowledge of symbols and cable diagrams is needed. The "jobs" will begin with building a 100-amp service entrance system and the following jobs will be built from that service panel. Below are some symbols commonly found on electrical blueprints, these are the same symbols used to draw the branch circuit cable diagrams.

COMMON BLUEPRINT SYMBOLS



RULES FOR PRACTICAL EXERCISES

All jobs are to be done in accordance with the statement papers, proper grounding will be required will be required. When the assignment is complete the circuit will have to work as defined and all wiring shall be in a workmanship like manner. Remember these circuits will be energized, so please be careful when working on the boards. Treat all the tools with safety. Use of metering equipment will also be demonstrated when the job is completed. All jobs will require a cable and wiring diagram to be considered completed, except the service entrance. All power supplies will be taken from the 100-amp service panel.

HANDS-ON EXERCISES

A 100 amp service entrance, grounds will be simulated attachment, however they must be installed.

1-Light controlled from one location, power at the switch.

2-Light controlled from two locations, power at the light

3-Single pole switch controls light, power to a GFCI outlet and one duplex outlet protected by GCFI

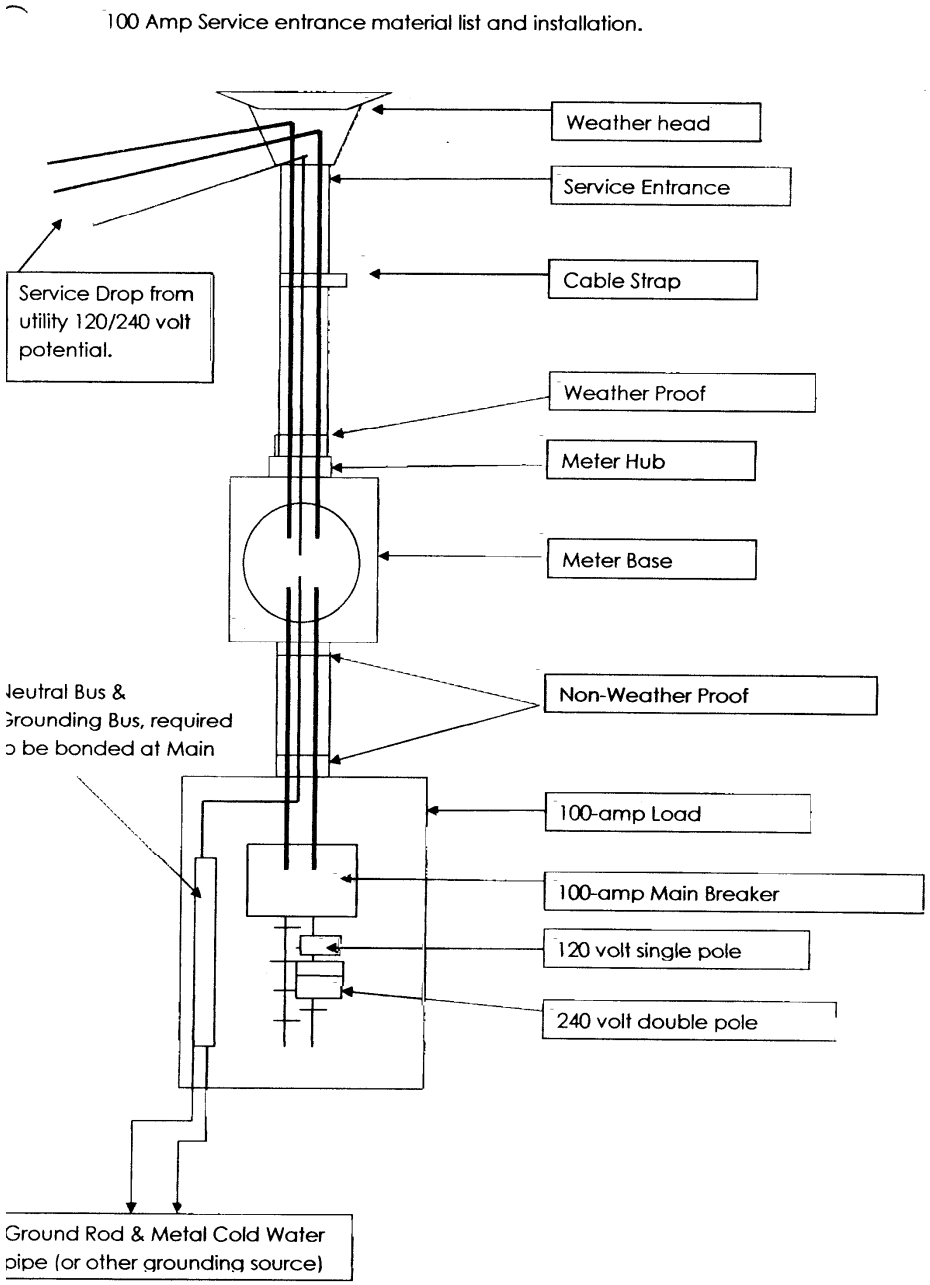
4-Two lights controlled from two locations, power at the switch box

5-One light controlled from three locations, power source is at the 4-way switch.

6-Half of duplex outlet controlled from two locations, the other half is always hot, install a duplex outlet that is always energized. Power in at the switch box, refer to diagram in handout.

7-Multiiwire circuit bring 240 volts 3 wire circuit into a junction box, derive two separate circuits and install a duplex outlet outlets according to diagram.

100-AMP SERVICE ENTRANCE

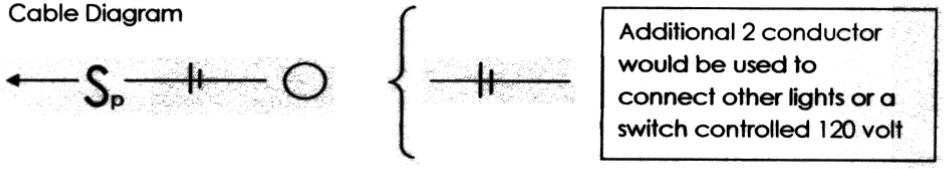


CABLE AND WIRING DIAGRAMS

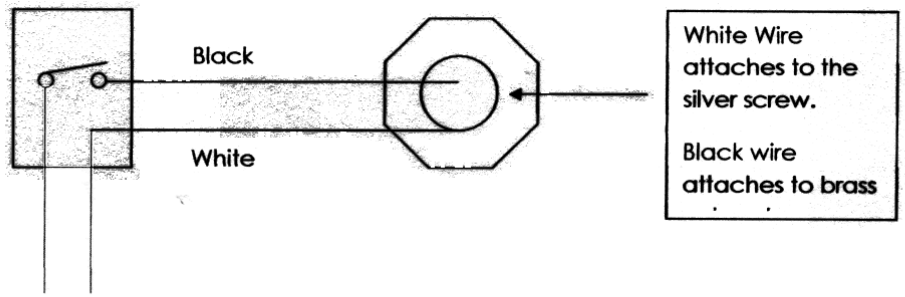
Branch Circuit wiring job #1

Single Pole switch circuit, one switch controlling light(s) or a 120 volt device from only one location. In this exercise the power source is derived at the switch box.

Cable Diagram



Wiring Diagram



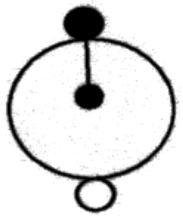
Circuit taken from load center or other 120 volt source.

WIRING DIAGRAMS

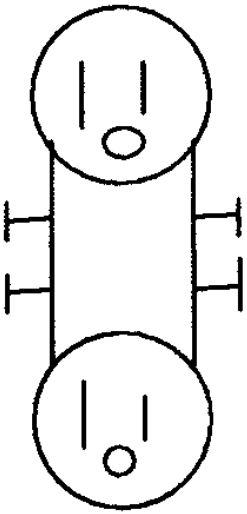
- Below is a sample of the components used to make wiring diagrams. This is not a code standard; this is just an example of how to draw the devices you will be working, based on their mechanical operation and design.

- The simplest way to draw the devices is simply know what points of attachment are available and how the device is intended to be use.

LIGHT SOCKET AND RECEPTACLE

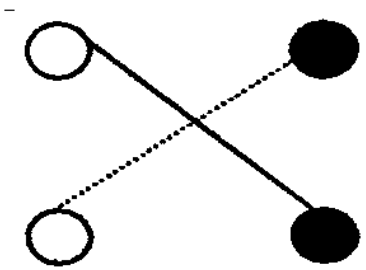


Light fixture, white wire attaches to silver screw, dark screw is "hot" side

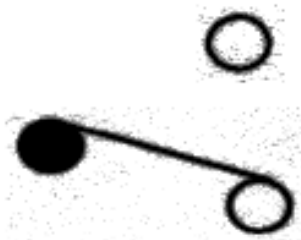


Duplex outlet, note if this was switched outlet; the solid line on the side by the screw would be broken.

4-WAY AND 3-WAY SWITCHES



Four way switch, depends on the make, the paired connections will have same color screws



3 way switch, common screw is darker

Spoliation

Defined: Loss, destruction, or material alteration of an object or document that is evidence or potential evidence in a legal proceeding by one who has the responsibility for its preservation. (NFPA 921)

Repercussions:

- Sanctions
  - ✓ Dismissal of claims or defenses,
  - ✓ Preclusion of evidence, and the
  - ✓ Granting of summary judgment for the innocent party.

Spoliation

DO NOT:

- ✓ Take "Trophies" or Souvenirs…. its stealing!!

- ✓ Destroy contents without reason
- ✓ Take appliances / devices / evidence apart
- ✓ Demolish the structure unless there is a life safety issue! (Extinguishment of Fire vs. Nuisance)

Public and Private Sectors

What's the difference?

- Public does not typically engage in failure analysis
- Private will engage in failure analysis when investigation warrants it.
- Insurance has the "cooperation" clause
- Insurance has outside expertise
- Money!

The classification of ***"Accidental"***

NFPA 921

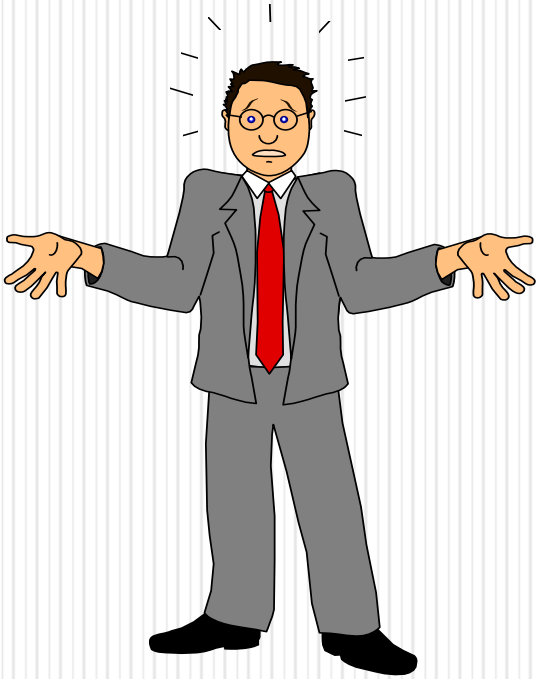
19.2.1.1 Accidental fires involve all those for which the **proven** cause does not involve an intentional human act to ignite or spread fire into an area where the fire should not be. When the intent of the person's action cannot be determined or proven to an acceptable level of certainty, the correct classification is undetermined.

Public and Private Sectors

Subrogation

- 3rd party; Circumstances in which an insurance company tries to recoup expenses for a claim paid out when another party is responsible.
- Plaintiff in an action

- **Liability**

  - Being responsible for someone else's loss/damages.
  - Defendant in an action

QUESTIONS?