2019 Fire Prevention Institute

Fire Investigation Track

Electrical Aspects of Fire Investigation

Michael G. Abraham, PE

Who Am I?

ATF FIRE RESEARCH LABORATORY

- Support fire investigations and the resolution of fire related crimes for Federal, State, Local, and International Authorities.
- On Scene Support
- Evidence Examinations
- Full Scale Testing
- Research, Training, and Education

BUREAU OF ALCOHOL, TOBACCO, FIREARMS AND EXPLOSIVES 1972

FIRE RESEARCH LABORATORY ATF

Electrical Engineer

- Electro-Mechanical Scene Examinations

- Vehicle Examinations
- Gas Systems
- Appliances
- Artifacts
- Components

Fire Protection/Fire Research Engineer

- Scene Examination and Documentation
- Fire Modeling / Scale Testing
- Statement Evaluation
- Timeline
- Pathological/Toxicological Considerations

Laboratory Engineer

- Test Specifications and Parameters
- Coordination with Laboratory Technicians (contractors)
- Test Documentation (Photo/Video)
- Instrumentation
- Data Acquisition

Alcohol Flame Jet High Speed

The Money Shot

Molotov Cocktail

NFPA 1033 (2014 Edition)

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

1.3.8 The fire investigator shall remain current in the topics listed in by attending formal education courses, workshops, and seminars and/or through professional publications and journals.

ELECTRICAL IGNITION

NFPA 921 (2017 Edition)

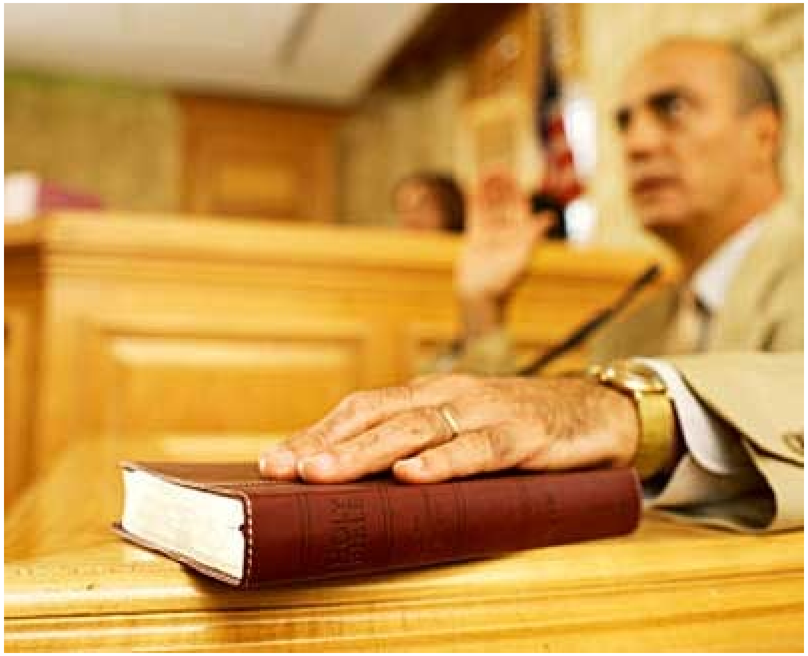
9.9.1.1 Ignition by electrical energy involves transferring sufficient heat to a fuel (i.e., competent ignition source) by passage of electrical current to ignite material that is close. Sufficient heat may be generated by a wide variety of means, such as short-circuit and ground-fault parting arcs, excessive current through wiring or equipment, resistance heating, or by ordinary sources such as lightbulbs, heaters, and cooking equipment. The requirement for ignition is that the heat transfer from the electric source be maintained long enough to bring the adjacent fuel up to its ignition temperature, with air present to allow combustion.

NFPA 921 (2017 Edition)

- Chapter 18 – Origin Determination
  - Witness Information and/or Electronic Data
  - Fire Patterns
  - Fire Dynamics
  - Arc Mapping
- Chapter 19 – Fire Cause Determination
  - Fuel Analysis
  - Source of Ignition and Competency
  - Ignition Sequence

The Key Witness

WHY IS THIS A CONCERN?



- As part of a fire investigative team you will need to be qualified as an expert witness.

- Your ability to rule in or rule out electrical ignition sources will be an issue during testimony.

OUR TRANSLATION

- In a properly installed, properly operating electrical system, ignition by electrical energy is not necessarily a simplistic event because something that was designed not to happen has to happen.

- Through normal operation, failure, or improper installation, an appliance or device must heat an adjacent combustible material long enough to allow ignition without first causing an overcurrent or thermal protection device to operate

  - or -

  A device or appliance must fail and eject enough molten material that possesses enough energy to ignite the combustible material that it lands on after it has escaped from the enclosure designed to contain the event.

- If the investigator concludes an electrical ignition event was part of the fire's cause, they should be able to forensically identify what occurred.

AS AN EXPERT…

…how can you rule in or rule out an electrical item without understanding:

- Normal operation
- Failure modes

Scene Safety


05/27/03 MB1 C47 10:51:24

Common Hazards

- Common hazards when working with energized electrical equipment include:
  - Electric Shock
  - Arc Flash
  - Blast
  - Burns

Shock Hazard

- Effects of 60 hertz electricity

  0.001 amps: Threshold of perception (1 milliamp)

  0.005 amps: Maximum “harmless" current (5 milliamps)

  0.01 - 0.02 amps: Maximum "let-go" current (10 – 20 milliamps)

  0.05 amps: Pain, possible fainting, mechanical injury. Heart and respiratory functions continue (50 milliamps)

  0.1 - 0.3 amps: Ventricular fibrillation will start, respiratory center remains intact (100 to 300 milliamps)

  > 0.3 amps: sustained myocardial contraction temporary respiratory paralysis burns if current density is high (300 milliamps)

- 0.833 amps: current in the 100 watt light bulb in your house (~830 milliamps)

De-energize the Scene

- Use observations and testing equipment to verify that electricity is disconnected.
- NEVER assume that power has been disconnected.
- Remember that a de-energized scene also preserves evidence.

De-energize the Scene

- Electrical hazards may be present on a fire scene long after the fire is over.

- NEVER assume that just because the structure suffered heavy damage that all sources of electrical energy have been safeguarded.

- NEVER assume that because you were told the site is de-energized that it is.


hosted at
NothingToxic.com

Fort Worth Fire Department

De-energize the Scene

- Electrical energy can be present in the form of energized circuits or stored energy.

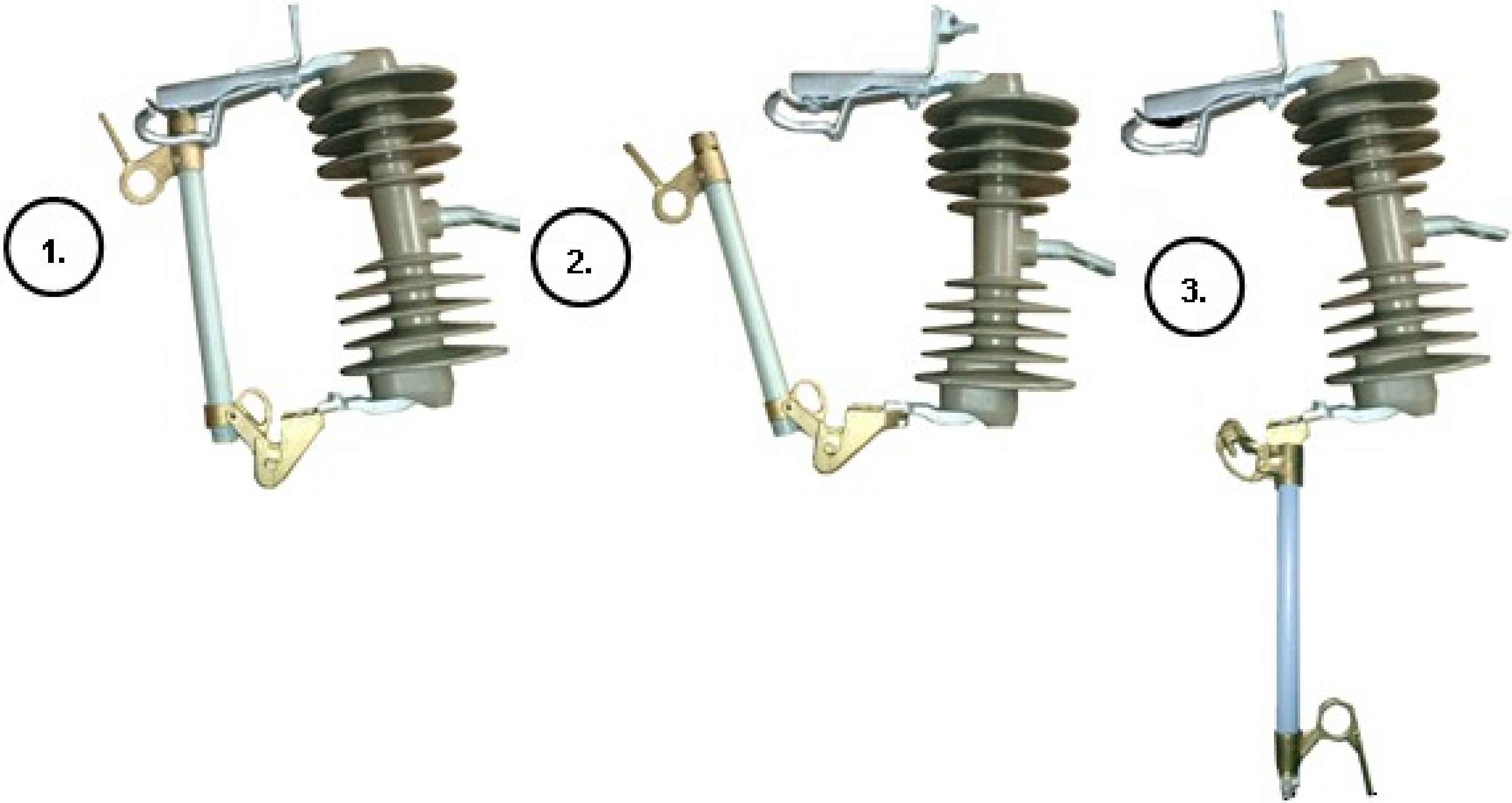
- ALWAYS remember that electrical service may be brought to a structure from multiple sources both overhead and underground.

- NEVER attempt to disconnect electrical utility service from the structure. This should only be accomplished by the utility representative.
  - Request a line supervisor be present on the scene.

Pole Mounted Fuses are Open

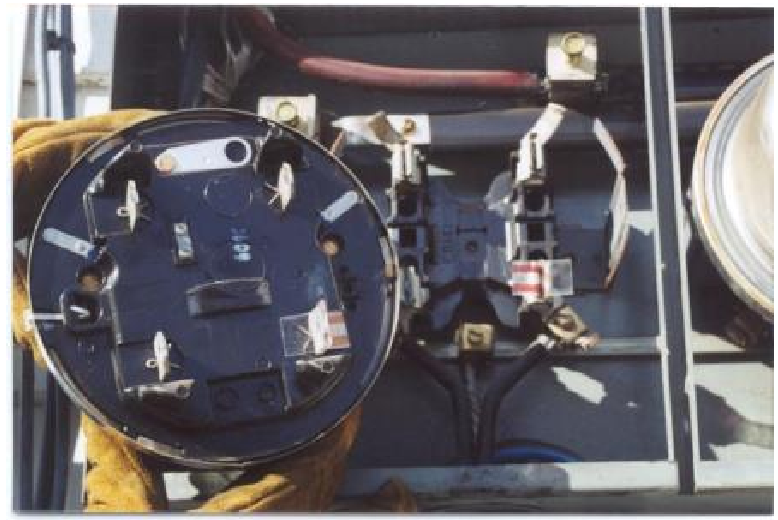
Pole Mounted Fuses Removed

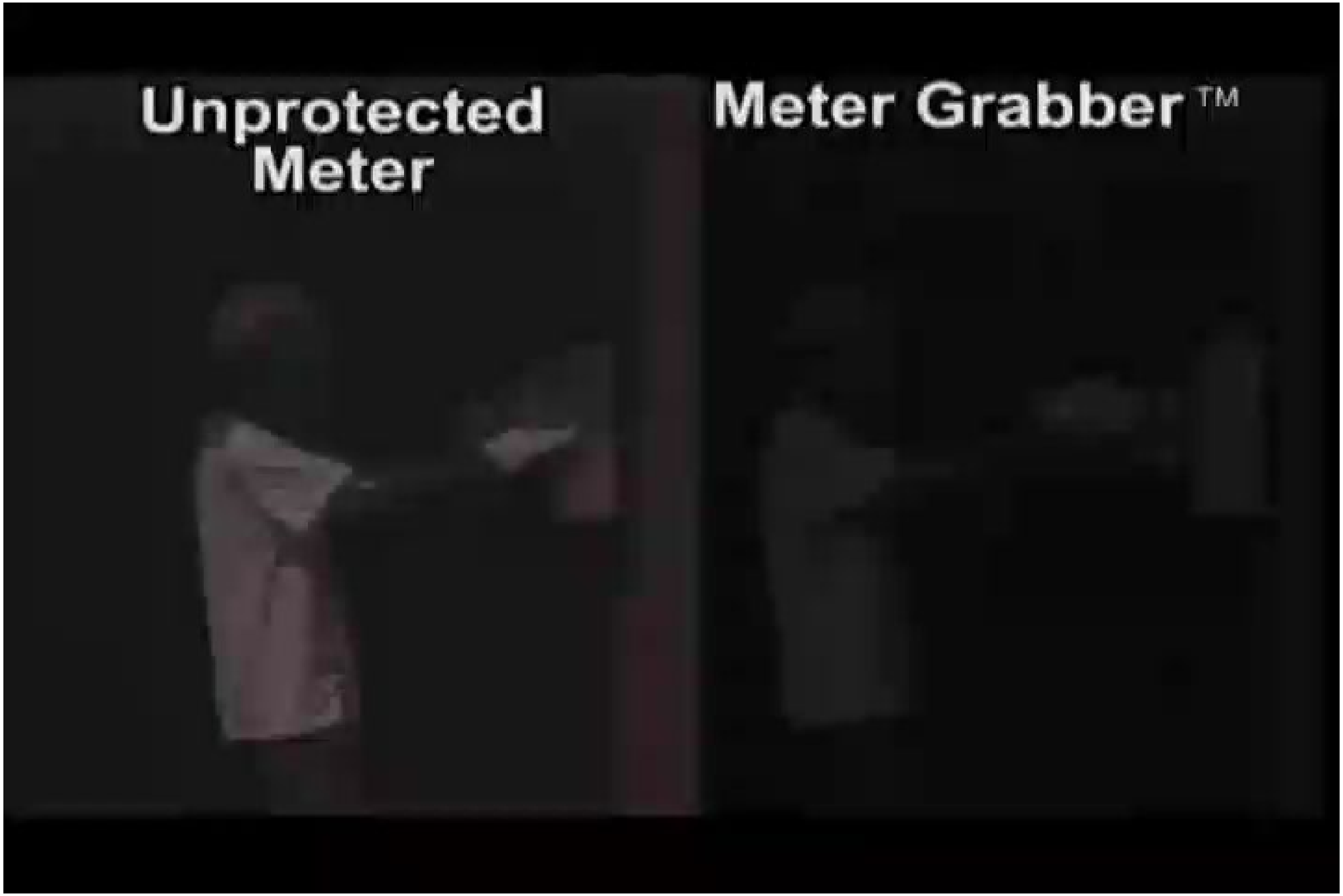
Fused Cutout



Pad Mount Transformer Fuses

Plug-in Meter is Removed (Service ≤ 200 A)




Unprotected Meter
Meter Grabber ™

Current Transformer Meter (Service > 200 A)

Lock-Out Tag-Out

- Switches and/or disconnects must be locked-out and tagged- out before examination, preventive maintenance or servicing is performed
- The only guarantee that it is off is if YOU did the lock-out / tag-out
- Lock outs and tag outs are only supposed to be attached after the equipment is turned OFF and tested to ensure that power is OFF
- Lock-out / Tag-out equipment is designed for multiple locks. You can always add you lock to existing equipment.
- NEVER REMOVE A LOCK OUT OR TAG OUT THAT IS NOT YOURS!!!

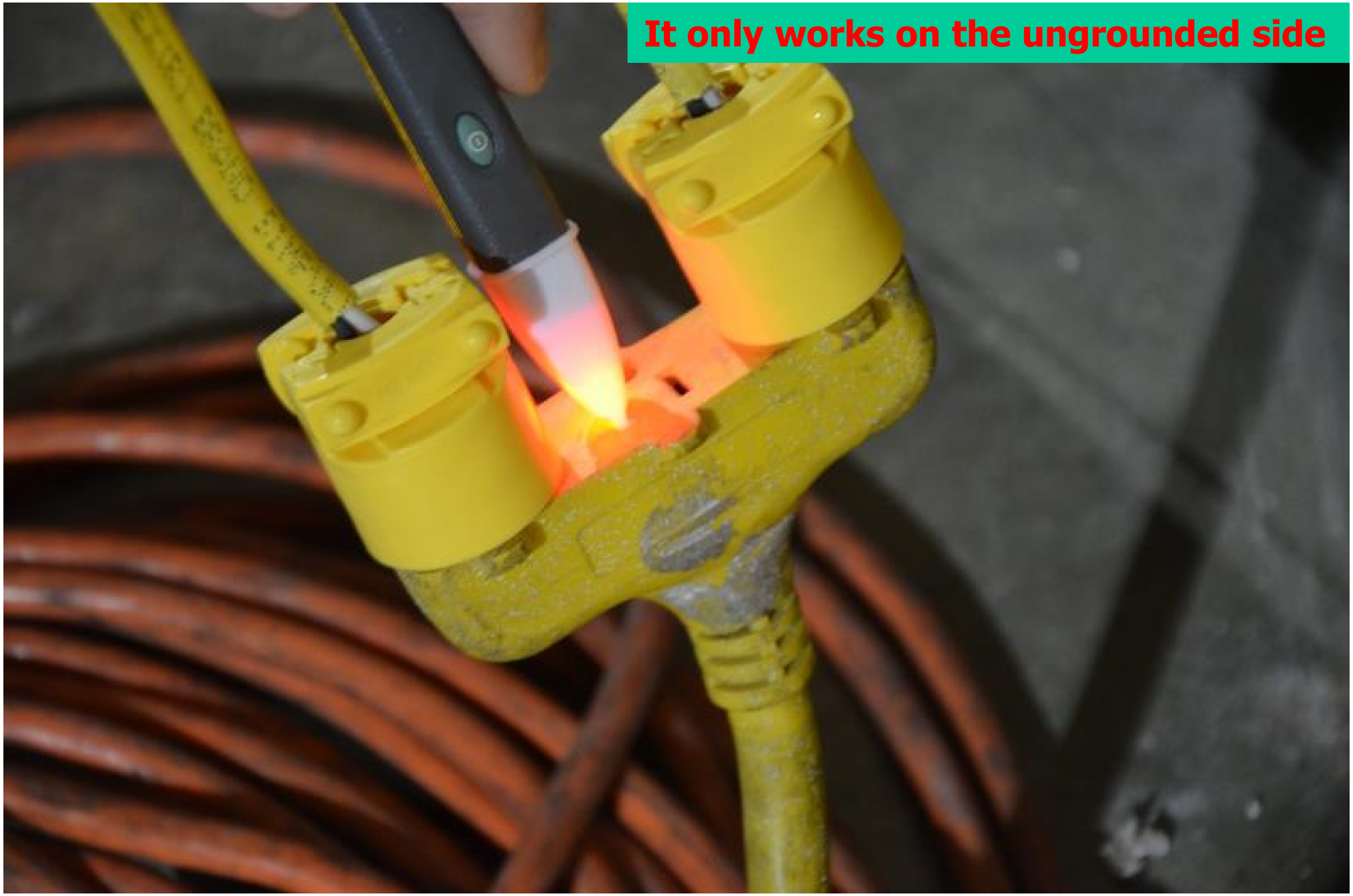
Proximity Tester

- Also known as tic tracers.
- Tic Tracers detect the electrostatic field generated around an AC conductor.
- The device provides an audible signal as voltage is detected.
- Need to check against a known source.
- Need to check batteries.
- The operator needs to have physical contact with ground.

Proximity Tester on a Wall Receptacle

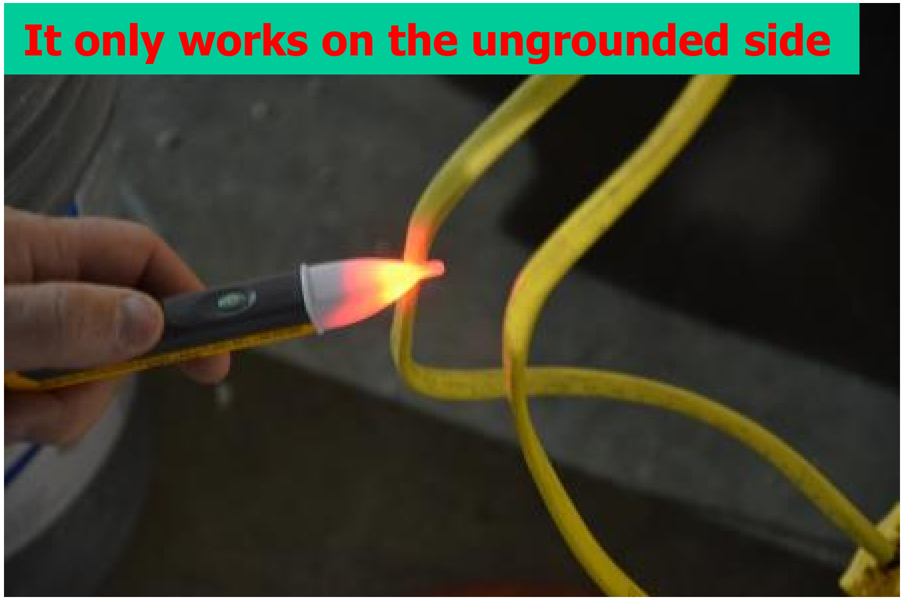
Proximity Tester on a Wall Receptacle

Proximity Tester on an Extension Cord



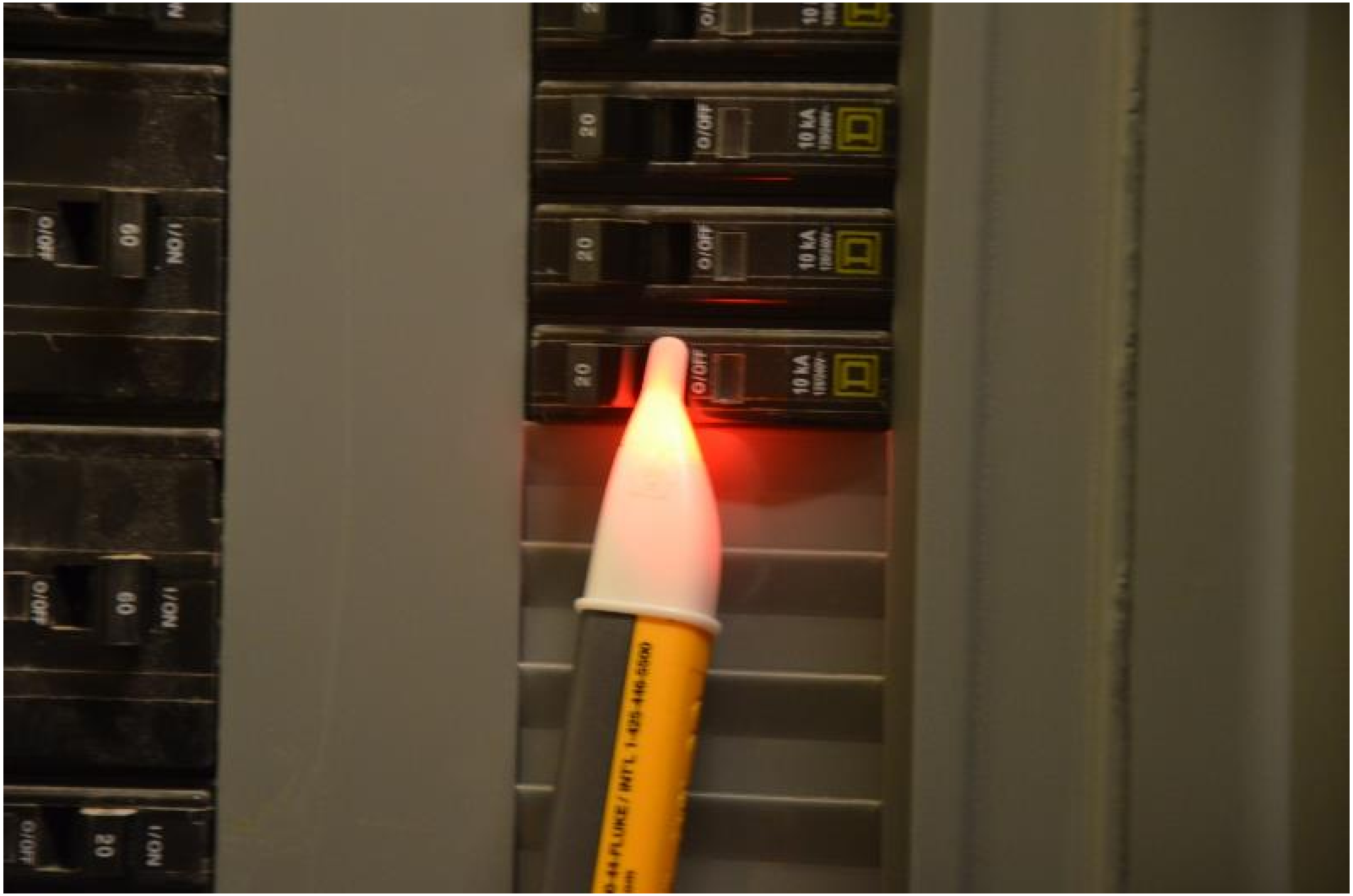
It only works on the ungrounded side

Proximity Tester on a Cable



Proximity Tester will NOT work on the Grounded Enclosure or Conduits Associated with an Energized Panelboard

Proximity Tester in an Energized Panelboard



Do you trust one of these guys to tell you that something is off?

Definitions / Terms

According to Webster's…

Electricity

1 : a fundamental form of energy observable in positive and negative forms that occurs naturally (as in lightning) or is produced (as in a generator) and that is expressed in terms of the movement and interaction of electrons, electric current or power

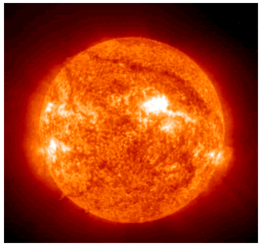
2 : a science that deals with the phenomena and laws of electricity

3 : keen contagious excitement
“I can feel the electricity in this room.”

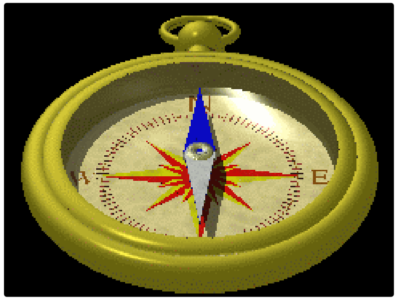
Electricity

- It's the flow of electrons due to a difference in energy potential between two points on a conductor

Observable Effects of Electron Flow

- Heat 

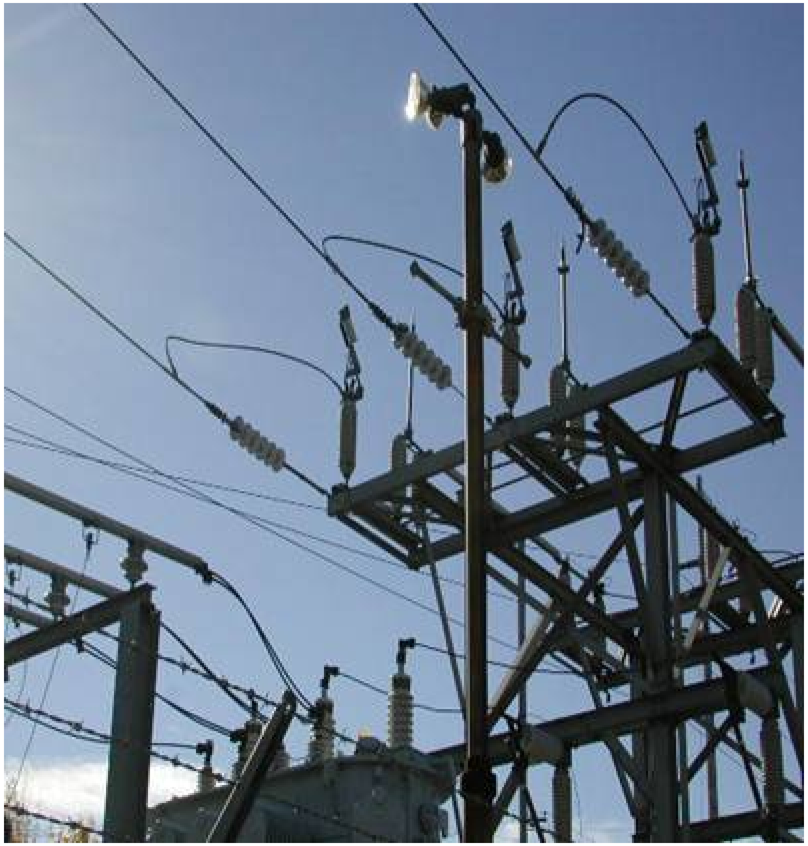
- Light 

- Magnetism 

Conductors

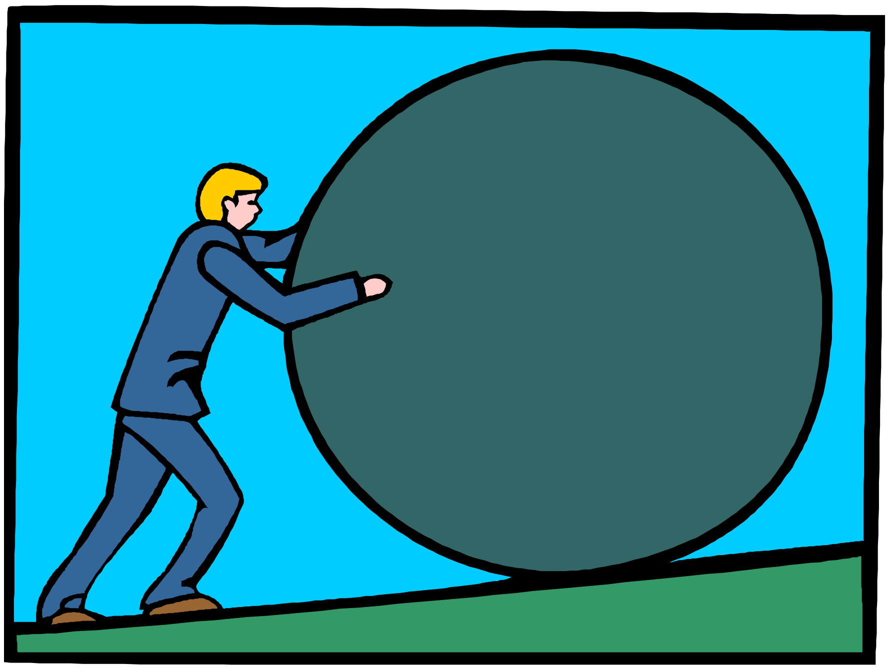
- Materials that allow current to flow freely with minimal resistance
- Copper and aluminum are two of the most recognized
- Both used in electrical systems
- Gold and silver are also used, but usually at point of contact

Insulators



- Materials that oppose or stop the flow of current
  - Glass, porcelain, air, and pure water
- However, a high enough voltage may defeat the insulator

Voltage



- Electrical pressure that moves the electrons through the conductor
- EMF
- E (volts)

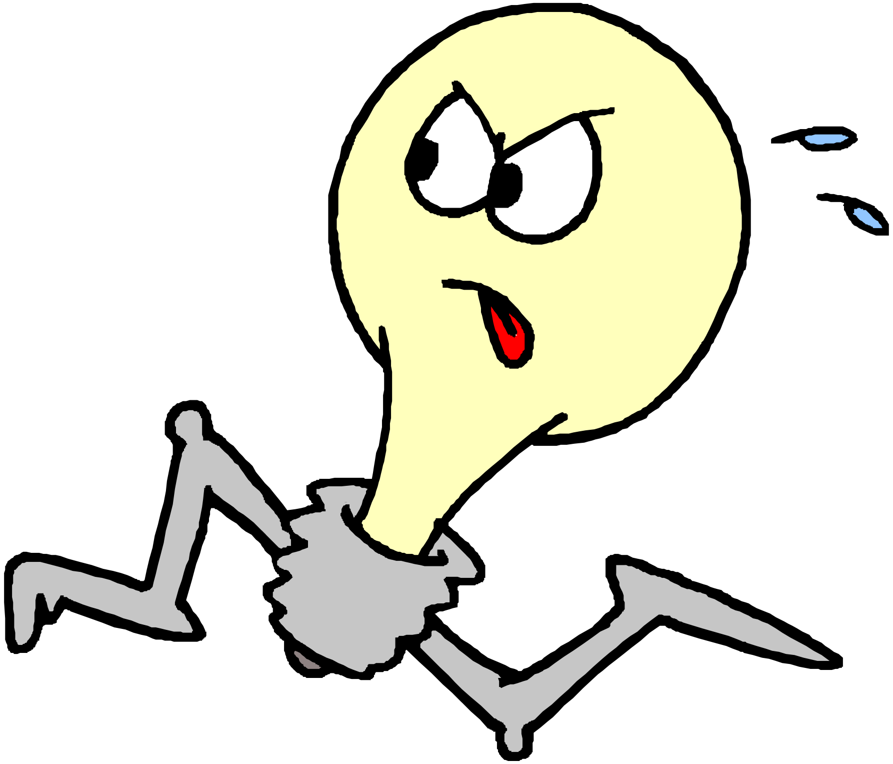
Current

- Is the rate at which electrons flow through a conductor
- It is determined by measuring the amount of electrons flowing past a single point in one second
- I (ampere or amp)

Resistance

- This is the opposition to current flow.
- Similar to a friction force
- Measured in ohms Ω
- Heat generated is a function of resistance
- Every conductor offers resistance

Power

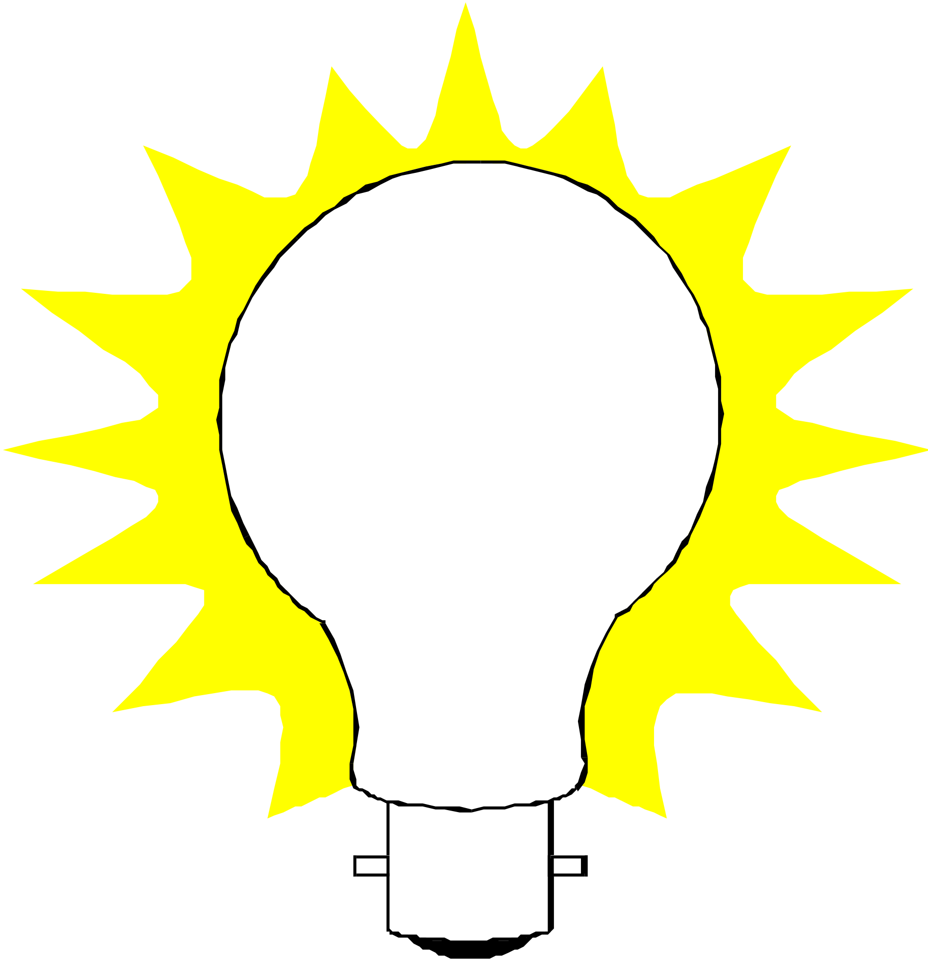


- The rate at which work is done, energy emitted or transferred per unit of time
- Measured in Watts

Understanding Power

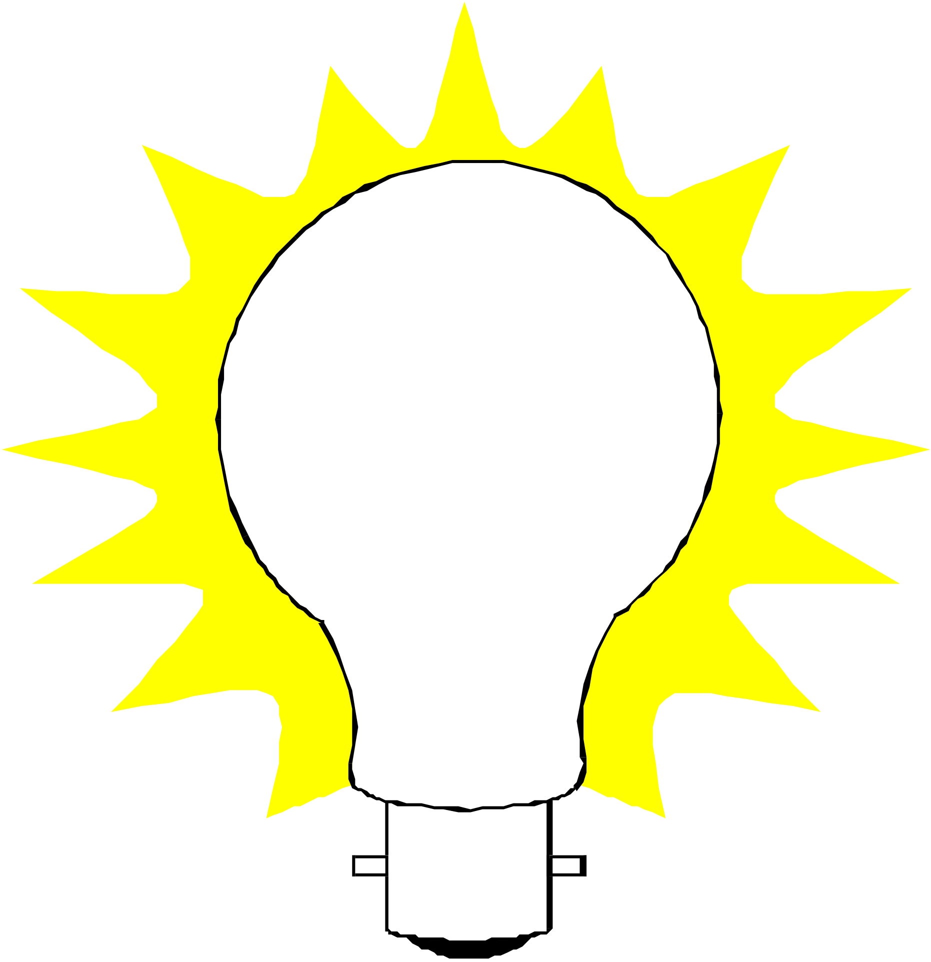
- 150 Watt light bulb
- 180 Watt electric blanket
- After 30 minutes, which one will be hotter?

Understanding Power



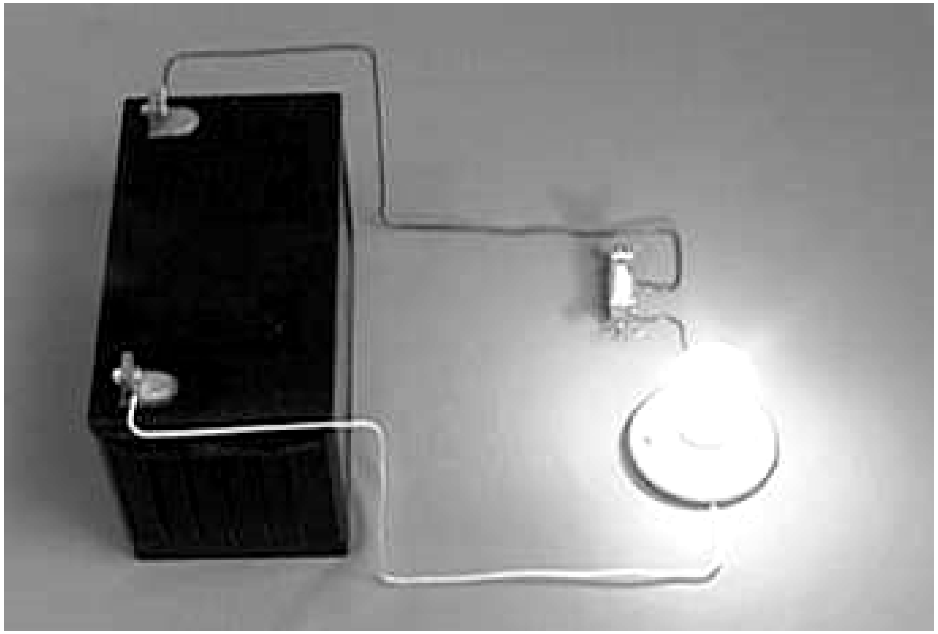
- 100 W light bulb
  - –Turn it on for one second
  - –Touch it
  - –No problem

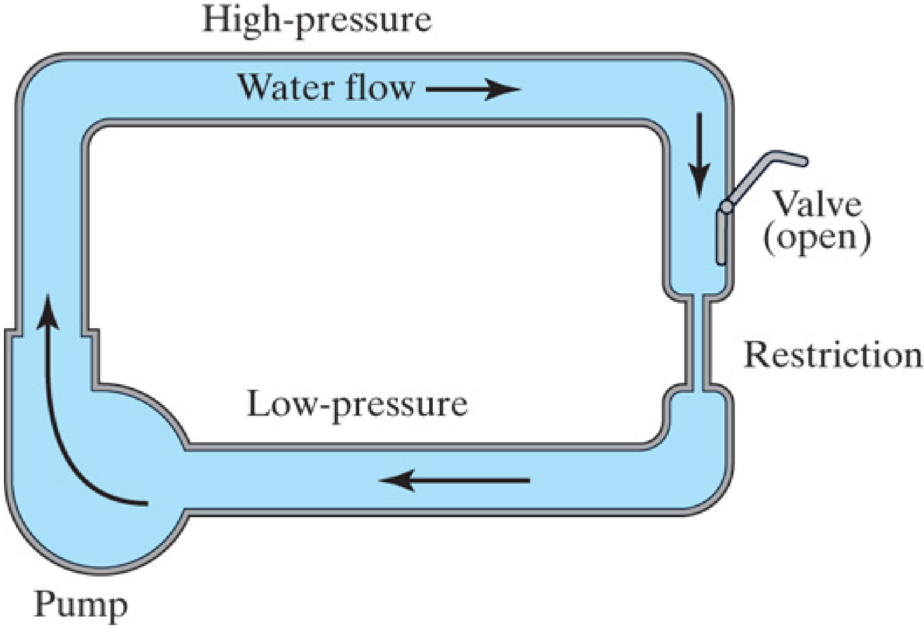
Understanding Power



- 100 W light bulb
  - Turn it on for an hour
  - Touch it
  - OUCH!!!

Electrical and Mechanical Equivalence





Electrical and Mechanical Equivalence

HYDRAULIC	ELECTRICAL
Water/Fluid	Electrons
Pump	Generator
Pressure	Voltage
PSI	Volts
Flow	Current
GPM	Amperes
Friction loss	Resistance

Ohm’s Law and Joule’s Law

Current

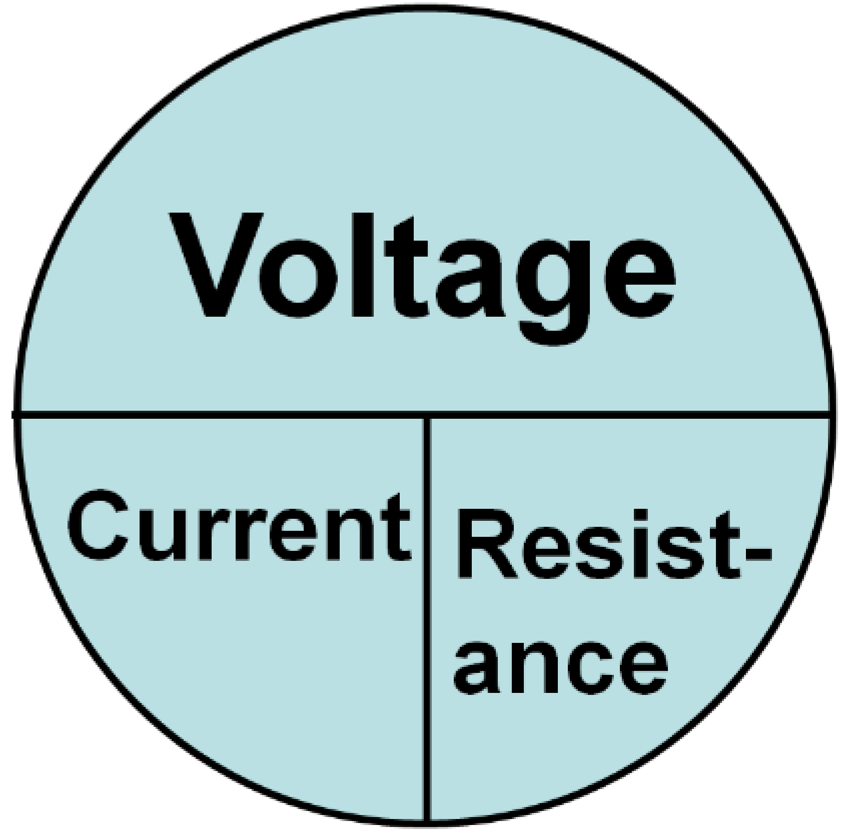
- More Current means:
  - Bigger conductors
  - More HEAT
  - More resistive loss
  - Less efficiency
  - **If you double the current, you quadruple the amount of heat**

- Less Current means:
  - Smaller conductors
  - Less HEAT
  - Less resistive loss
  - More efficiency
  - **If you cut the heat in half, you generate ¼ the amount of heat**

- In terms of running an electrical system – current is like your golf score: LESS IS MORE!!

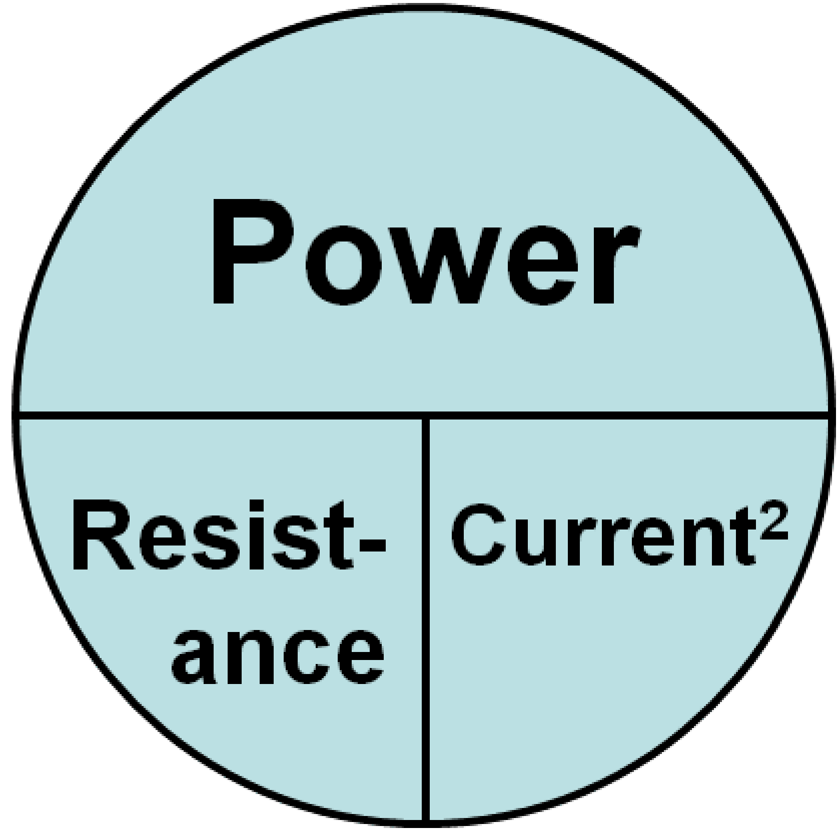
Ohm's Law

- Under constant voltage, what does the current do as the resistance approaches:
  - 0?
  - Something very big?



Joule's Law

- What does the power do as the resistance / current approaches:
  - 0?
  - Something very big?



Joule's Law / Ohm's Law Combined Summary

- As resistance goes down the current goes up.
- As the resistance approaches ZERO the current goes through the roof!!
- As the current goes through the roof the heat goes to the moon!!
- Ultimately there is enough current to trip a circuit breaker (or open a fuse) and melt metal.

BUREAU OF ALCOHOL, TOBACCO, FIREARMS AND EXPLOSIVES
1972

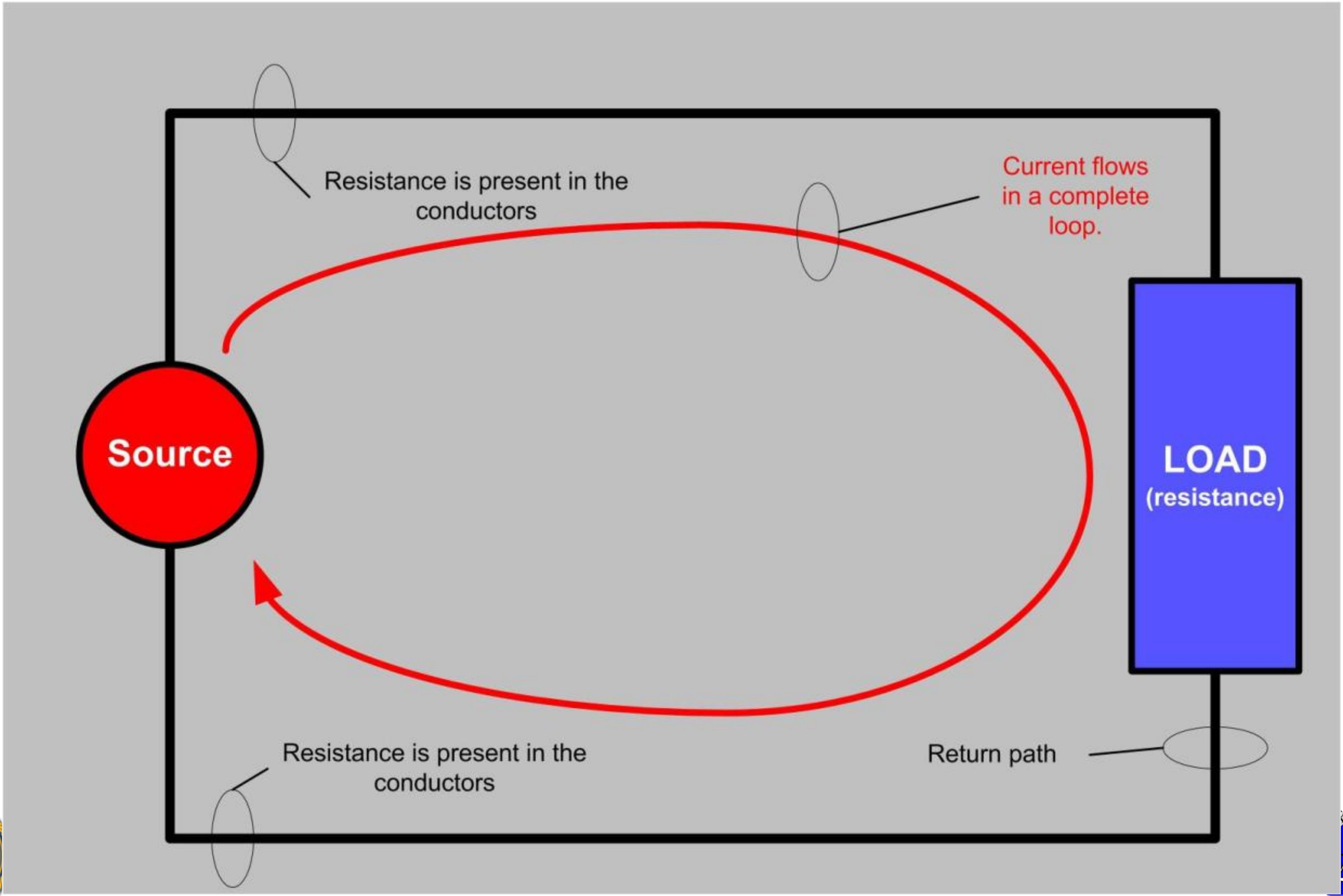
FIRE RESEARCH LABORATORY
ATF

Basic Circuits

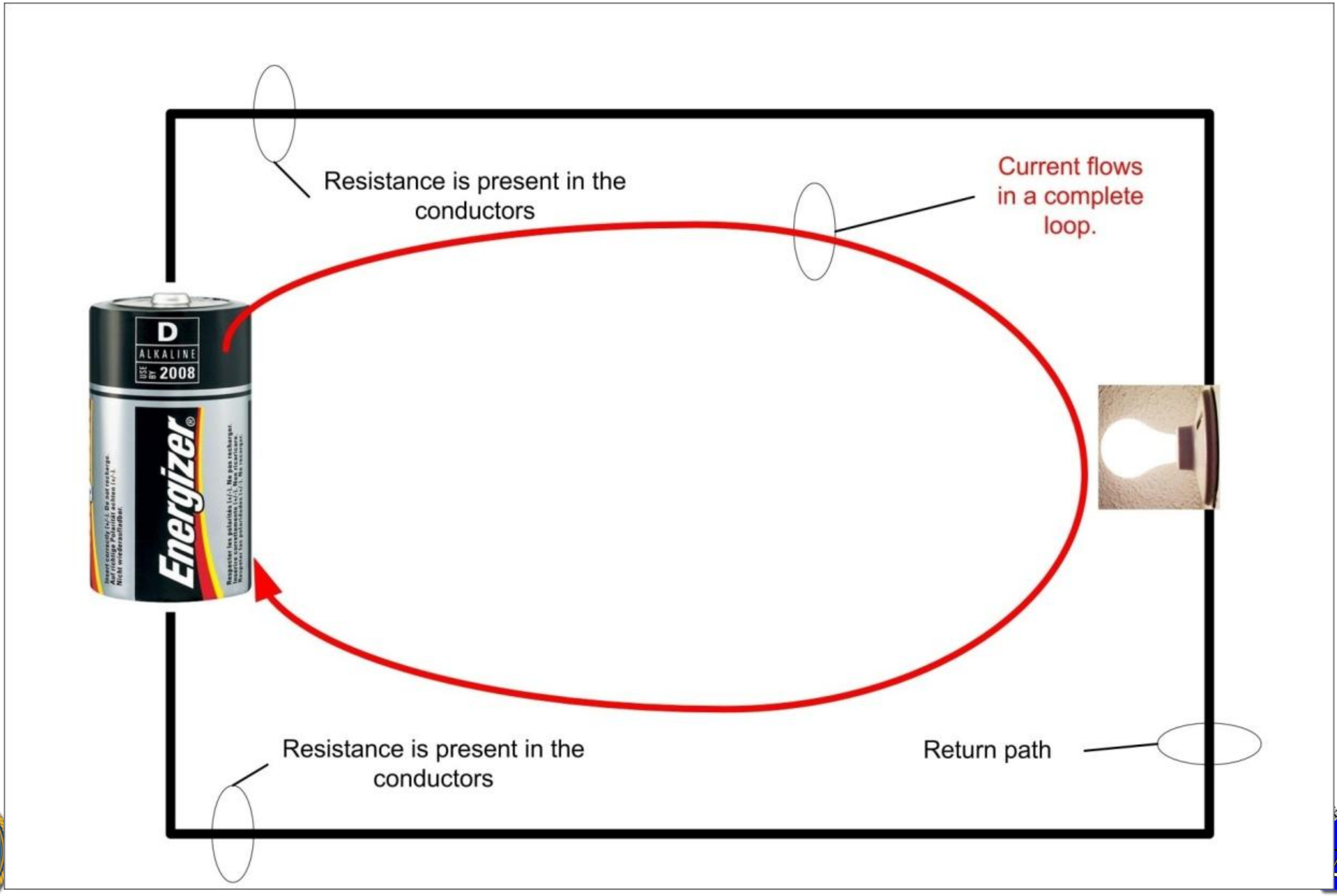
Basic Circuit

- Essential Elements of a circuit
  - Source
    - Generators / Batteries / Panelboards
    - Shoes on dry carpet / Lightning
  - Path
    - Wire
    - Air
    - Water
    - Arm / leg
  - Load
    - Device or group of devices that utilize electrical energy
  - Return Path
    - Allows the current to return to the source

Basic Circuit

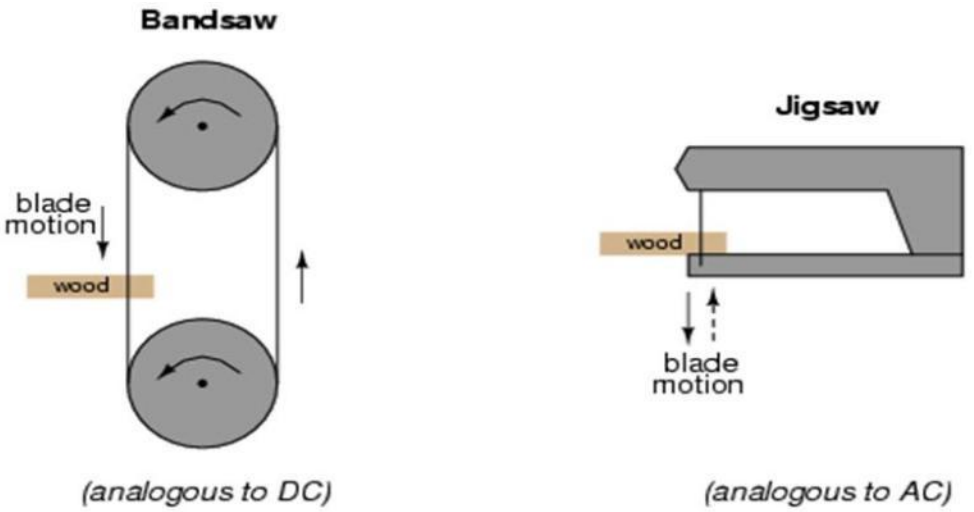


Basic Circuit



AC vs DC

Alternating and Direct Current



- Types of electrical currents:
  - Direct current (DC)
  - Alternating current (AC)

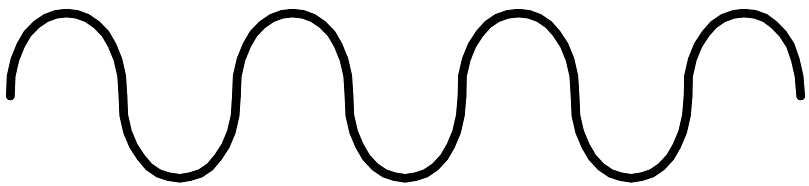
Direct Current

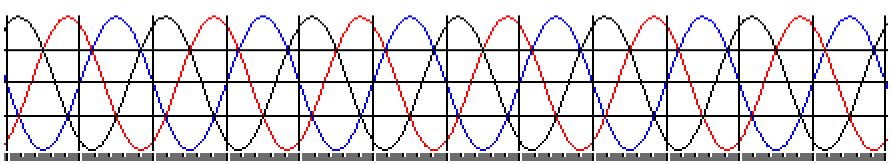
- Mechanically or chemically generated
  - Chemical = batteries or photovoltaic
  - Mechanical = generator
- Electrons flow in one direction only
- Positive and negative terminals on equipment.
  - In through positive, out through the negative
- Most recognized as a battery, found in power supplies, DC generators
- Many industrial applications exist
  - Large industrial requirements may include a motor generator pair
  - Train locomotives are diesel/electric motor generators

Alternating Current

- Mechanically generated
- Electrons reverse flow many times per second (frequency)
- Ungrounded (hot) and grounded (neutral) terminals on equipment

AC Frequency

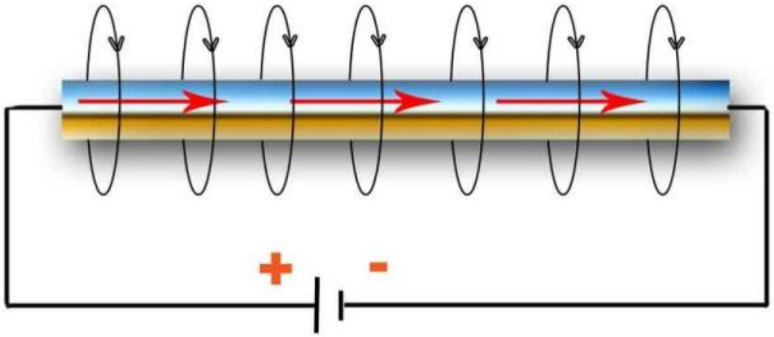




- The number of times the flow of electricity reverses itself in the span of one second
- Measured in Hertz (Hz)
- In US frequency is most often 60 Hz
- Foreign countries use 50 Hz systems
- Some aviation and shipboard systems will use 400 Hz

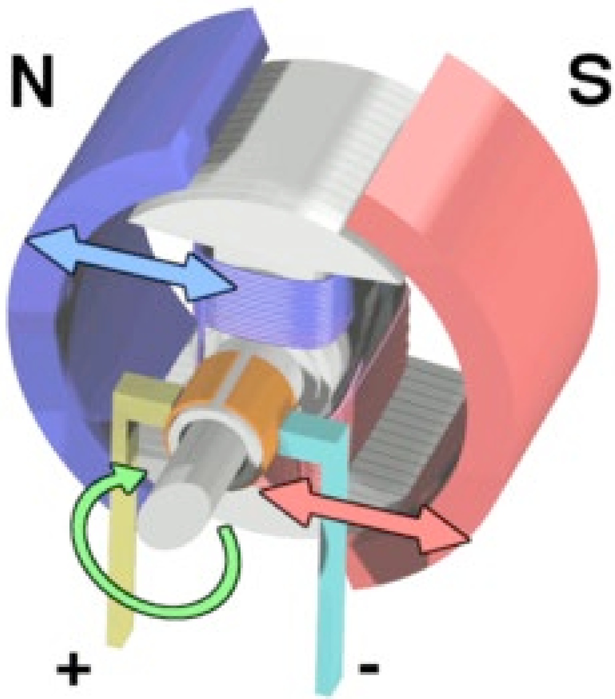
Magnetism

Magnetism



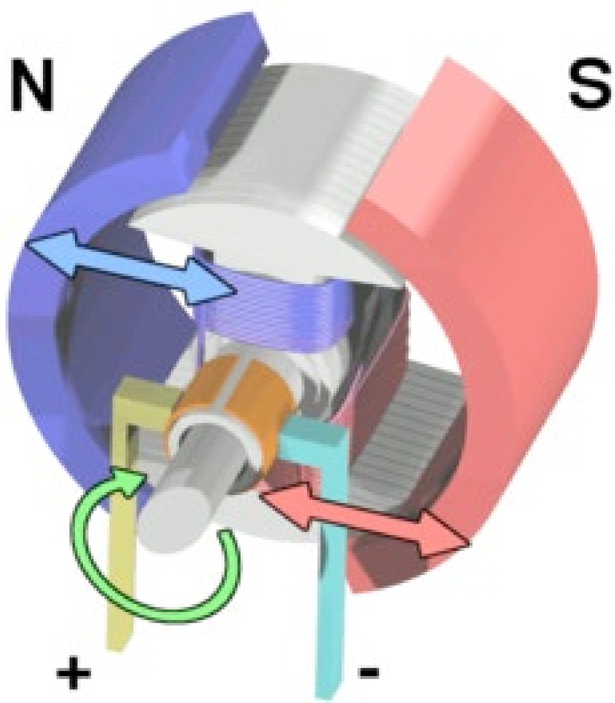
- When an electric current passes through a wire a magnetic field is formed
- The direction of the magnetic field is dependent upon the direction of electron flow
- The intensity of the magnetic field is proportional to the current flowing through the conductor

MAGNETIC FIELD



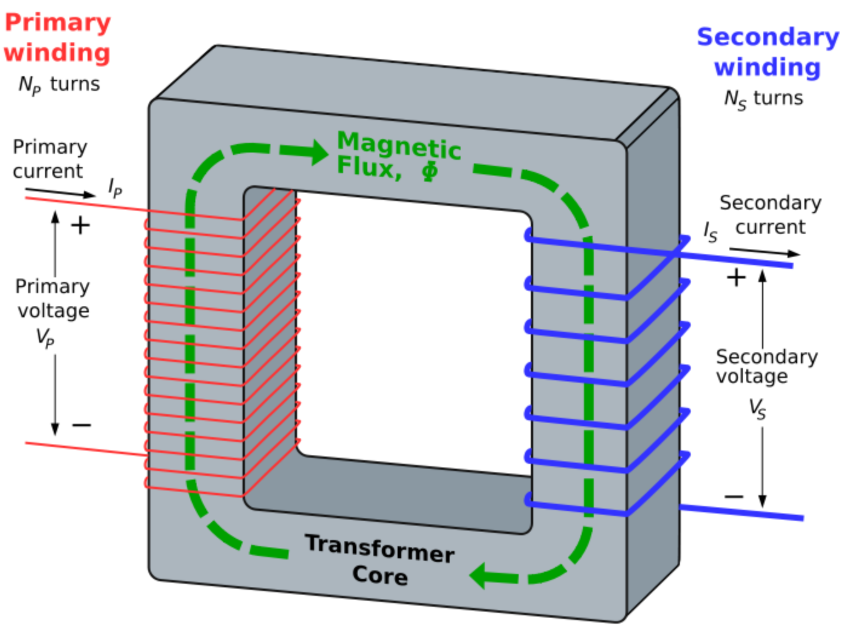
- When current flows through a conductor a magnetic field is generated…this is the basic principal of a motor.

MAGNETIC FIELD



- When a conductor is moved through a magnetic field, voltage is generated…this is the basic principal of a generator.

MAGNETIC FIELD

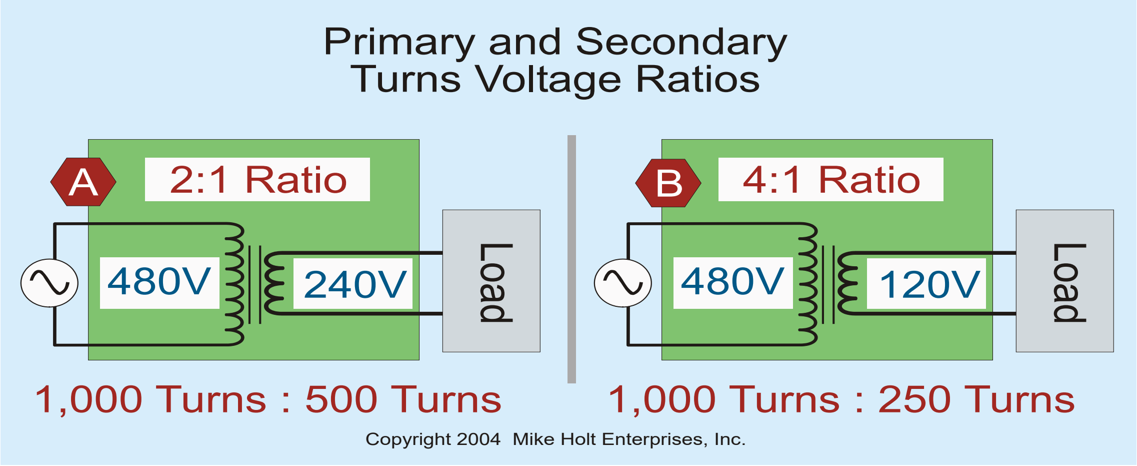


- Both of these principals are used to form a transformer.

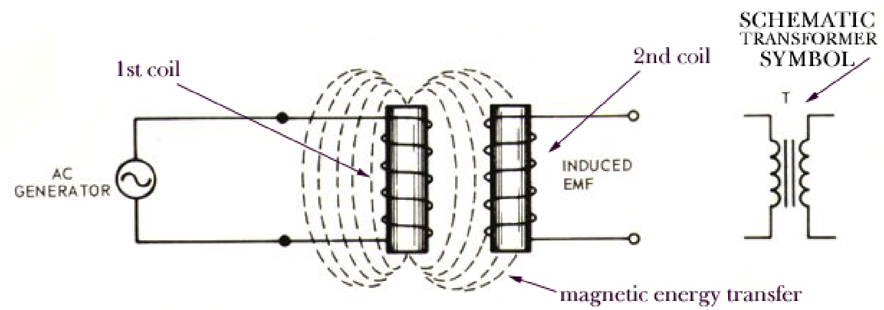
Transformers

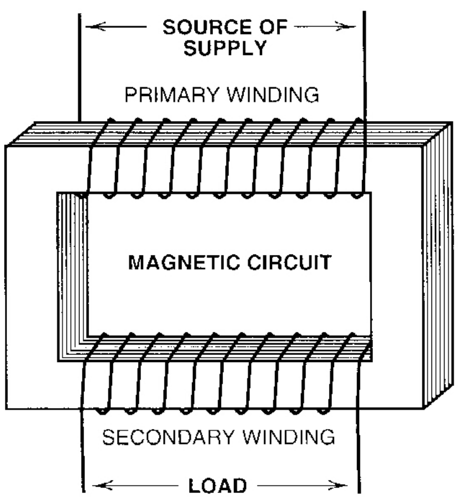
TRANSFORMERS

- 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.



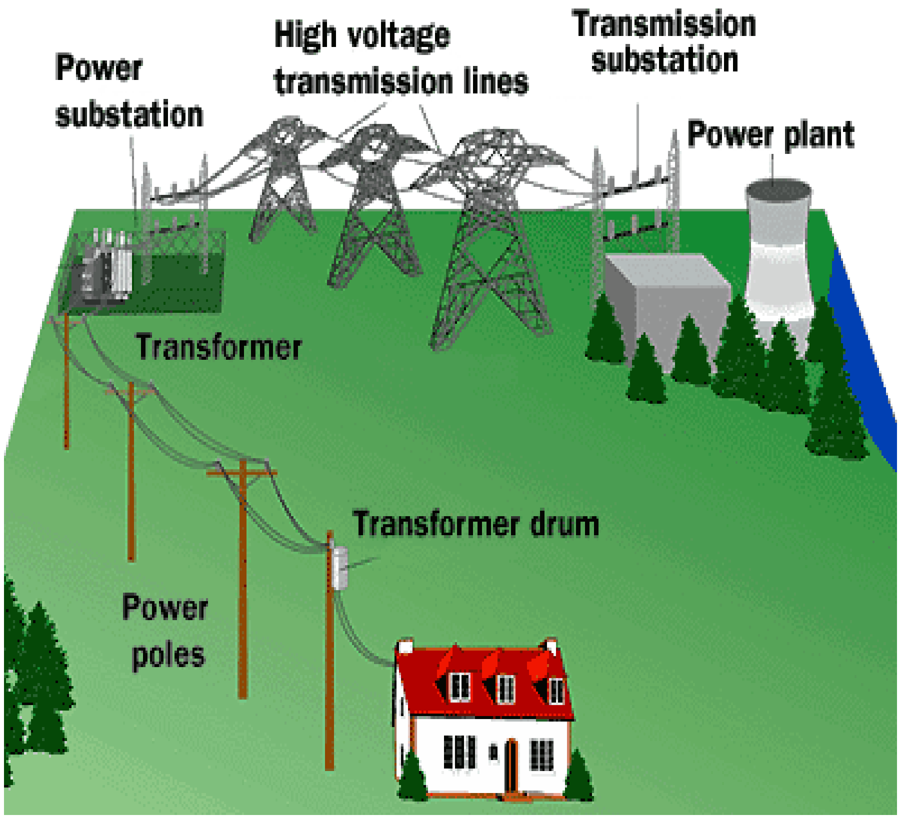
Ideal Transformer





- Power in = Power out
- Output voltage and current is based on the ratio of the coil windings
- Voltage ↑ Current ↓
- Voltage ↓ Current ↑

Why is this a Big Deal?



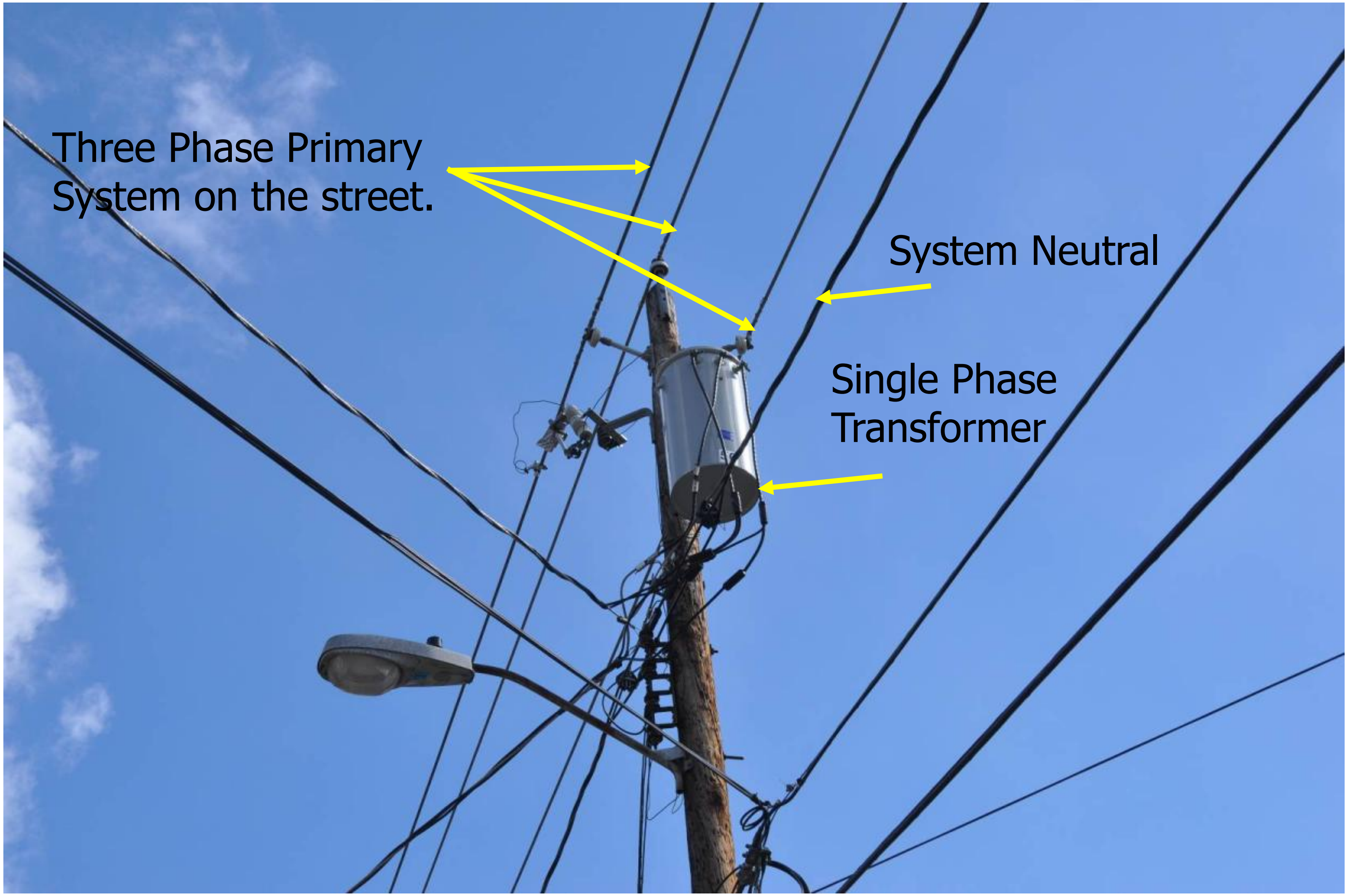
- Transformers allow generated electrical power to be transmitted at high voltage over great distance and then “stepped down” to an individual service

BUREAU OF ALCOHOL, TOBACCO, FIREARMS AND EXPLOSIVES
1972

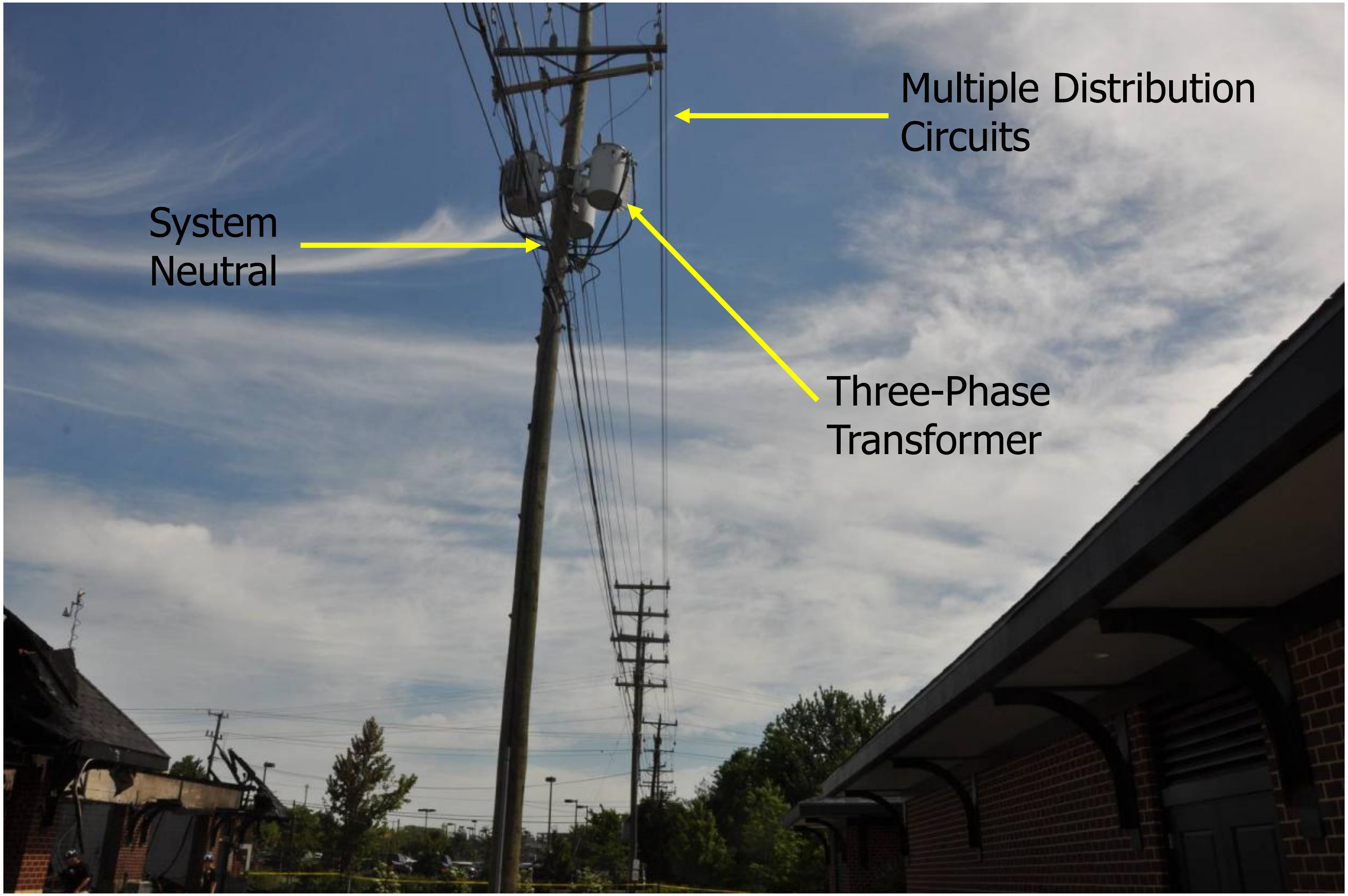
FIRE RESEARCH LABORATORY
ATF

Electrical Service

Primary Distribution System



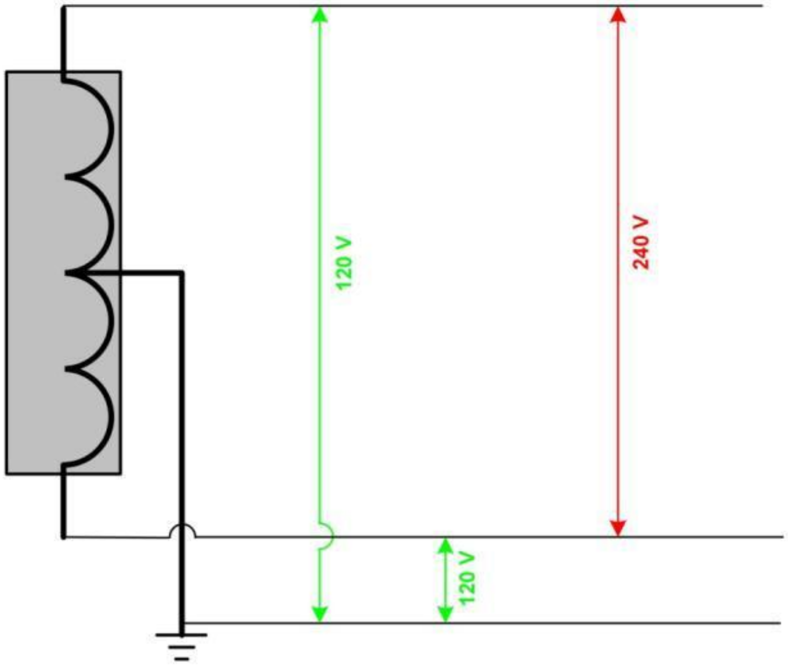
Primary Distribution System



Single Phase Service

- Single Phase 120 / 240 Volt, 3 wire system
- Provides residential and light commercial service
- Note the three lugs on the transformer

120 / 240 V - Single Phase 3 wire (Edison System)

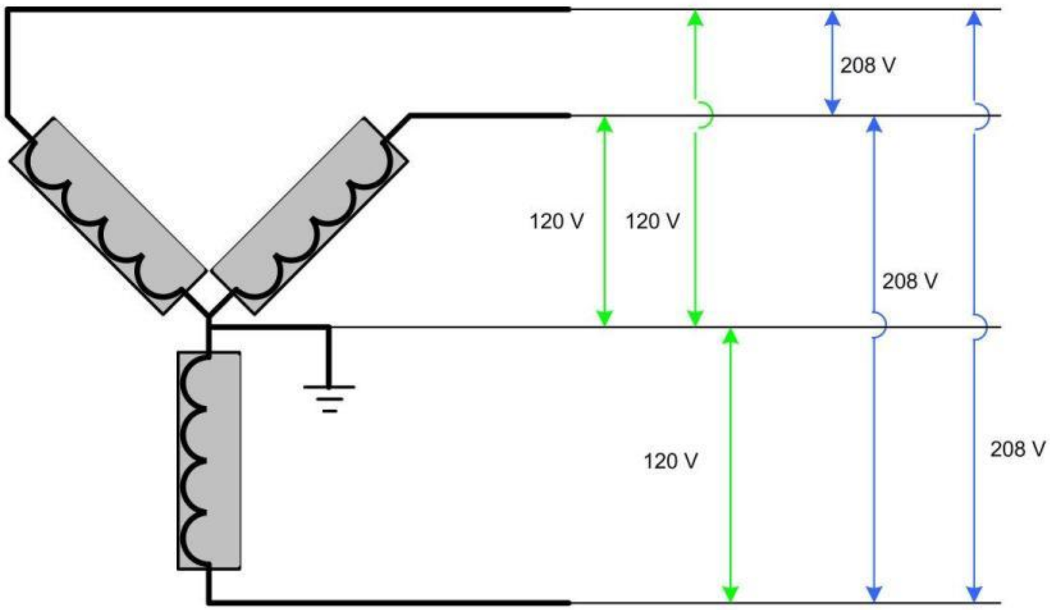


Three Phase Service Grounded Wye

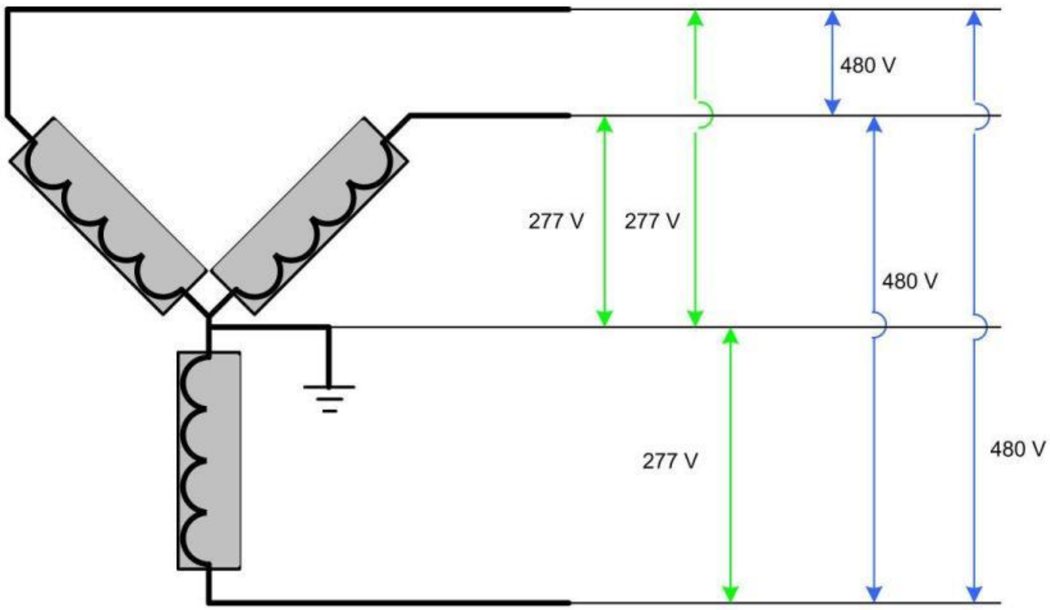
- Three phase 120/208 volt or 277/480 volt three phase, four wire service
- Generally provides service for commercial and manufacturing facilities
- Note: each transformer has one lug tied to the system neutral (common neutral)

Grounded Wye

Grounded Wye
120 / 208 Volt System



Grounded Wye
277 / 480 Volt System



Grounded Wye

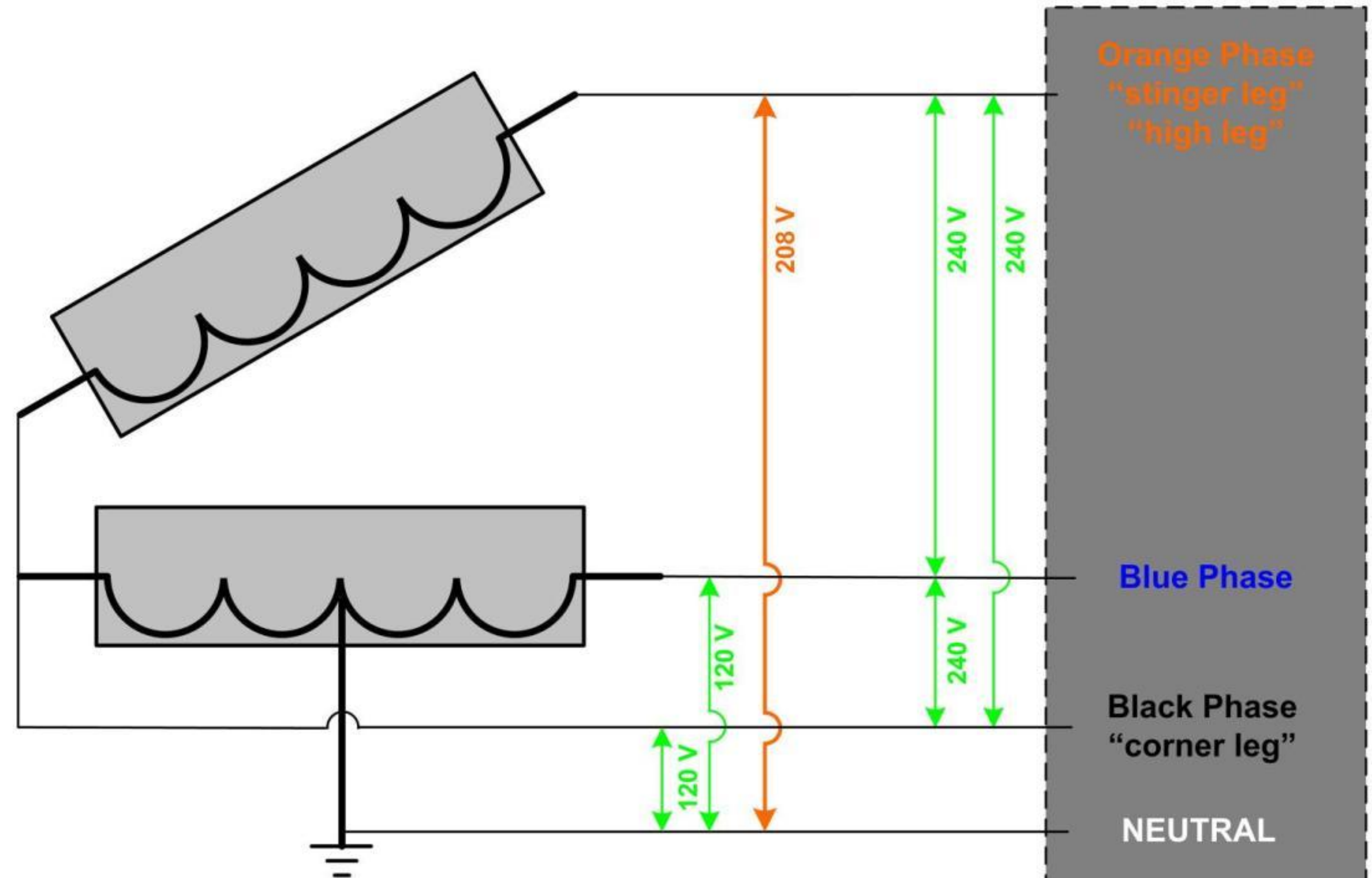
- 277 / 480 V systems still need to provide 120 / 208 volt circuits for receptacles, lighting, etc.
- Look for small 277 / 480 – 120 / 208 three-phase transformers
- In some cases, one transformer will exist with the service entrance equipment – this means the building has TWO distribution systems

Three Phase Service Open Delta

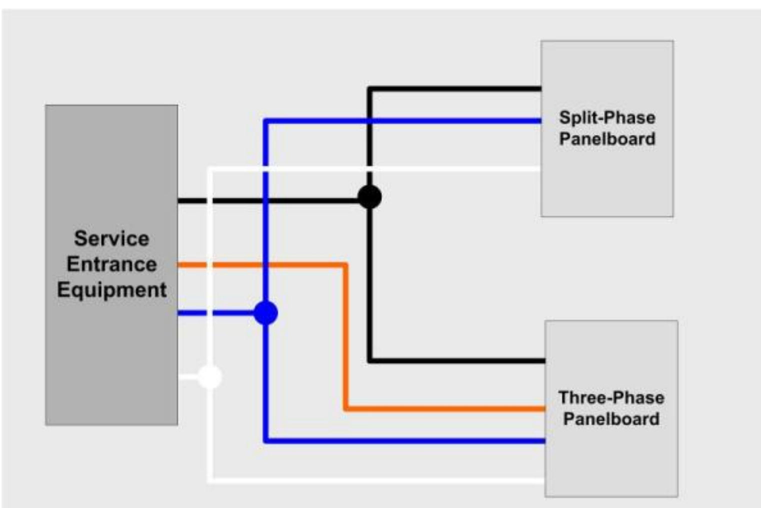
- Three phase 120/240/208 volt, 4 wire system
- The 208 volts to ground leg is known as a "high leg" or a "stinger leg"
- Provides three phase service with only two transformers
- Note the tie between the two transformers
- Note that one transformer has a grounded center tap that is just like an Edison Configuration
  - Look for other services to be tied to this transformer

Open Delta

Open Delta
120 / 208 /240 V System



Open Delta

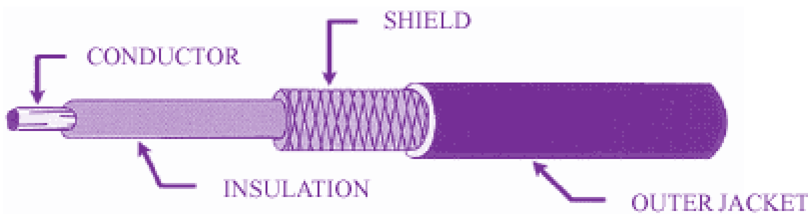


- Look for two panelboards
- One will be three phase
- One will be "split phase"
  - 120 / 240 V
- The "stinger leg" will only be present in the three phase panelboard.
  - The stinger leg must be installed in the center bus connection

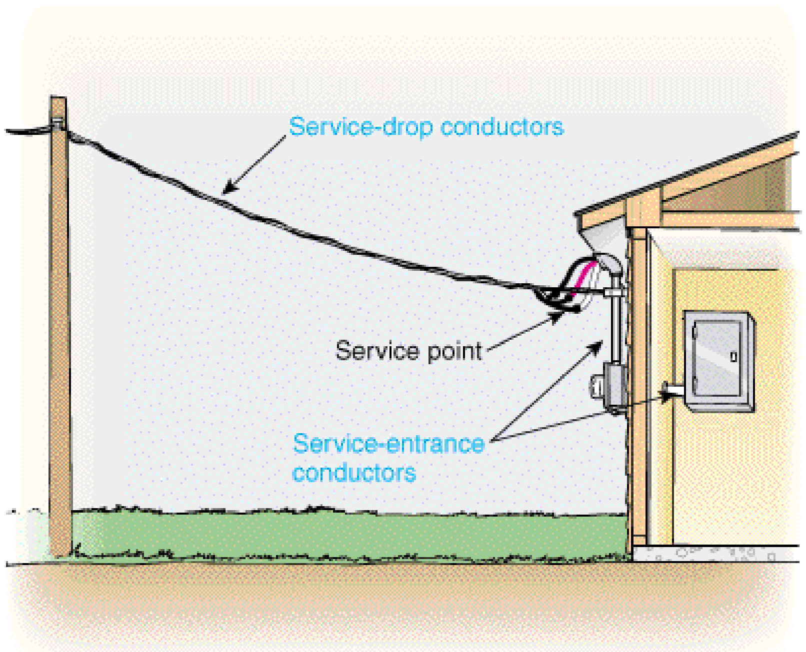
Service via Three-Phase Transformer

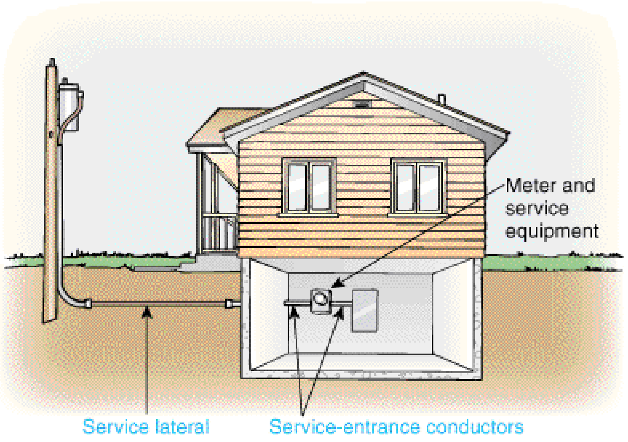
- Feed from primary is often HV Coaxial Shielded cable.
- Coaxial shield carries the ground.
  - Looks like a big CATV cable
- With shielded HV cable, there will only be three wires coming from the primary system.

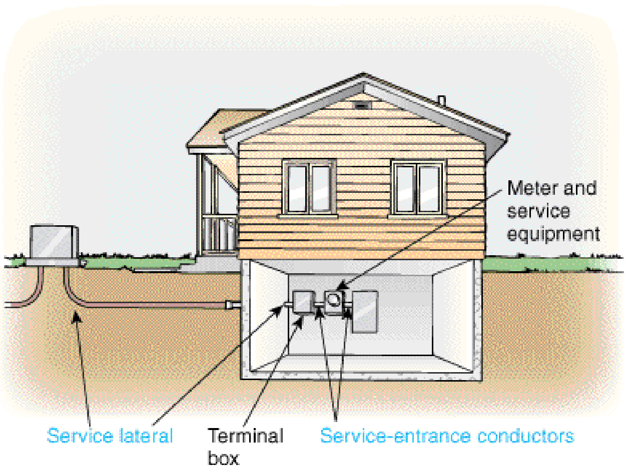
Shielded HV Cable



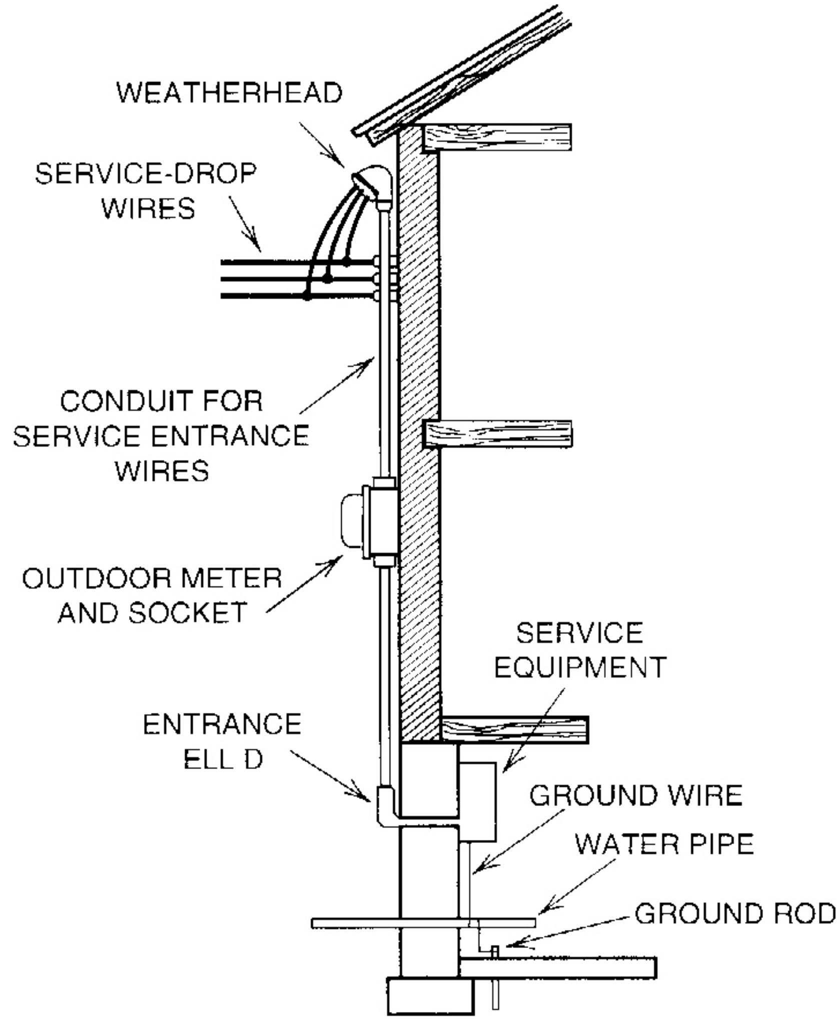
Service Entrance



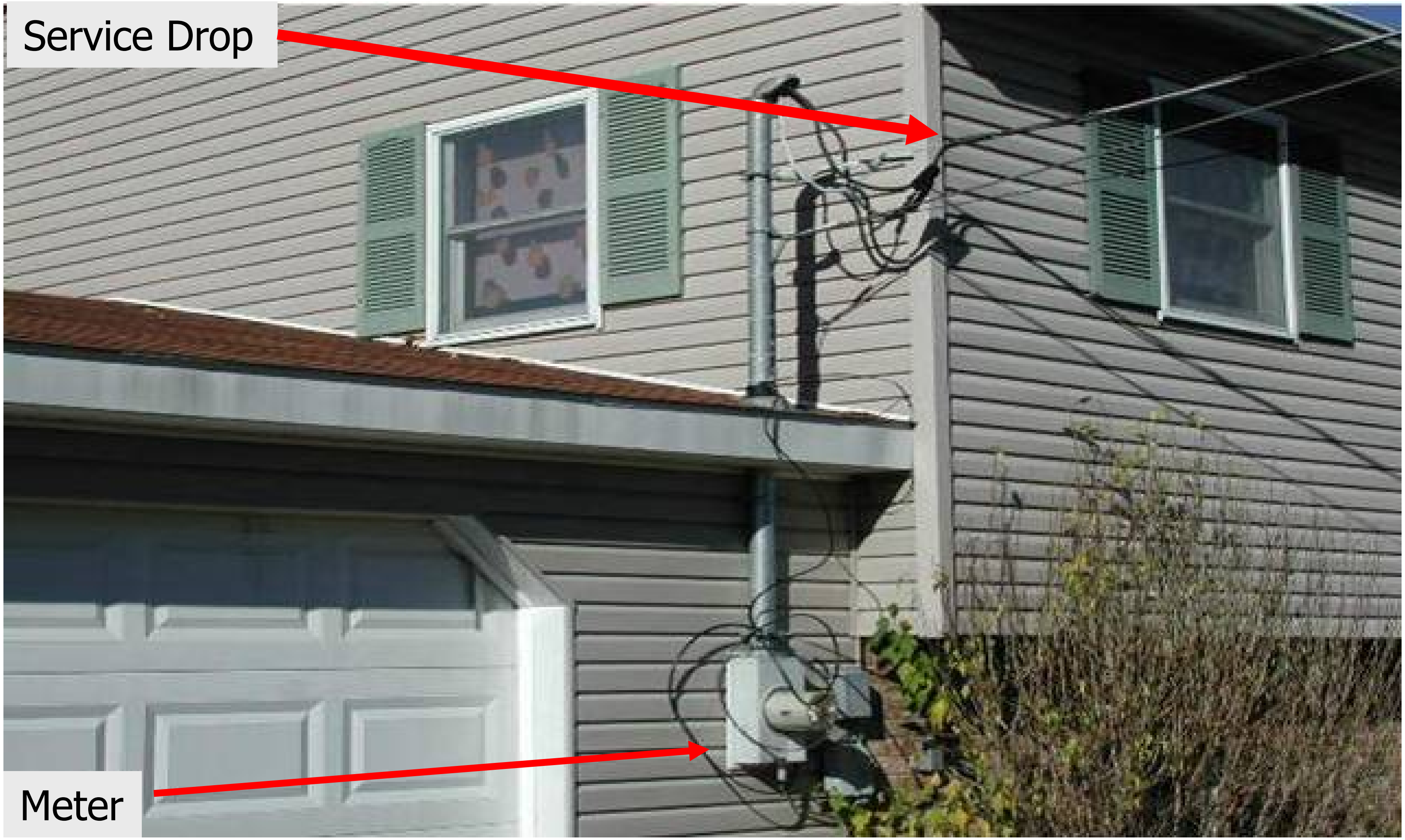




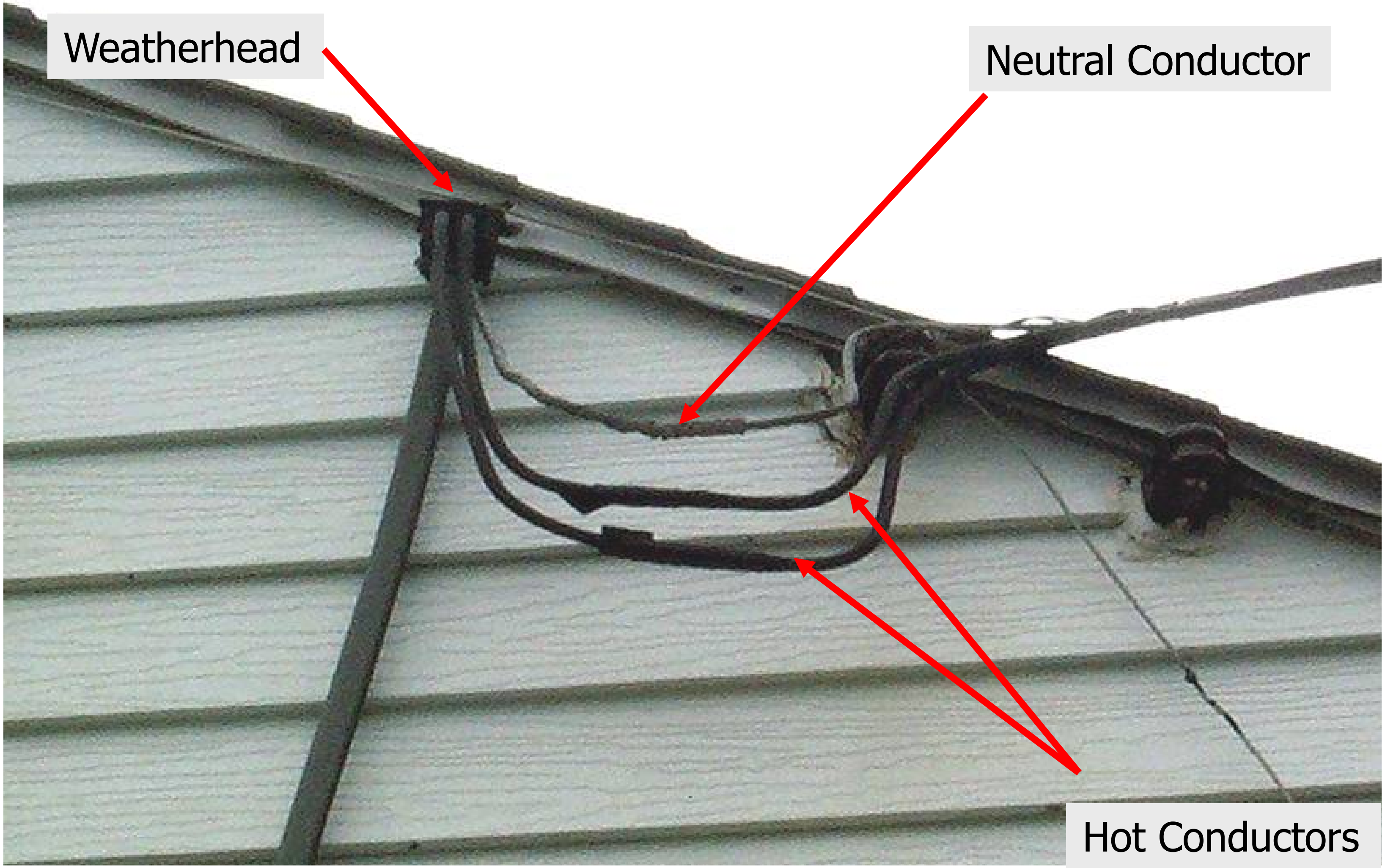
Service Entrance Terminology



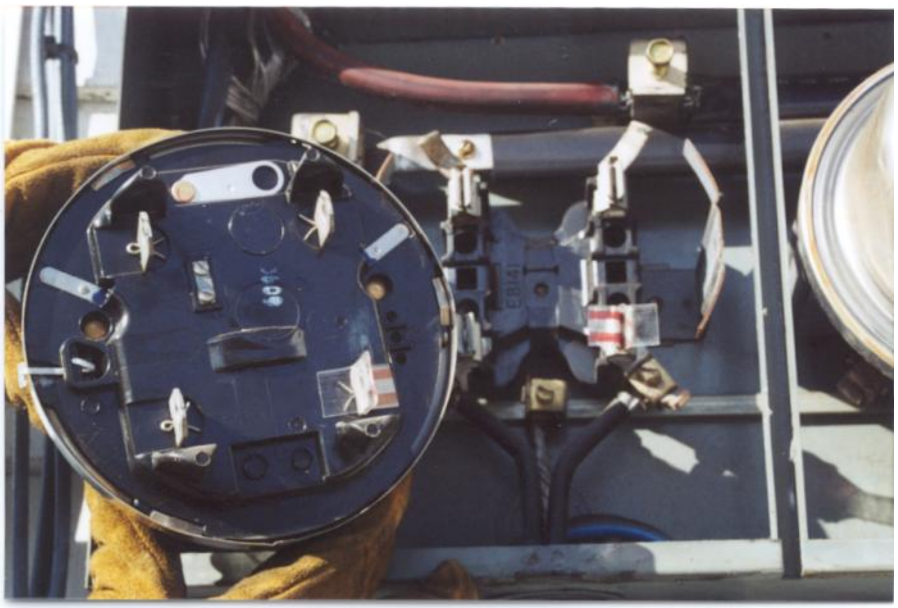
Service Entrance Terminology



Service Entrance Terminology



Service Entrance



- Plug in Meter
- Normally associated with a 200 Amp service or less
- Removing the meter de-energizes the structure

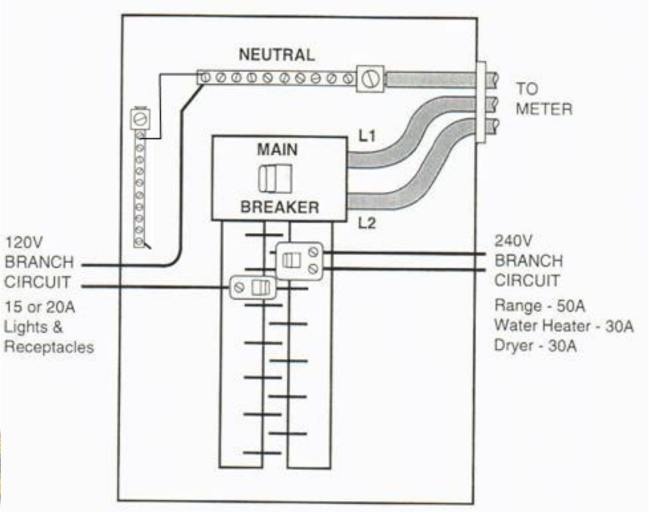
Service Entrance

- Exposed current transformer (CT) metering
- Used when service is greater than 400 amps
- WARNING: REMOVING THIS TYPE OF METER DOES NOT DISCONNECT POWER

Service Entrance

- Enclosed CT metering
- Used in services greater than 400 amps
- WARNING: REMOVING THIS TYPE OF METER DOES NOT DISCONNECT POWER
- Exposed or Enclosed CT metering can be found in large residential structures, commercial, and industrial applications

Service Entrance Panelboards

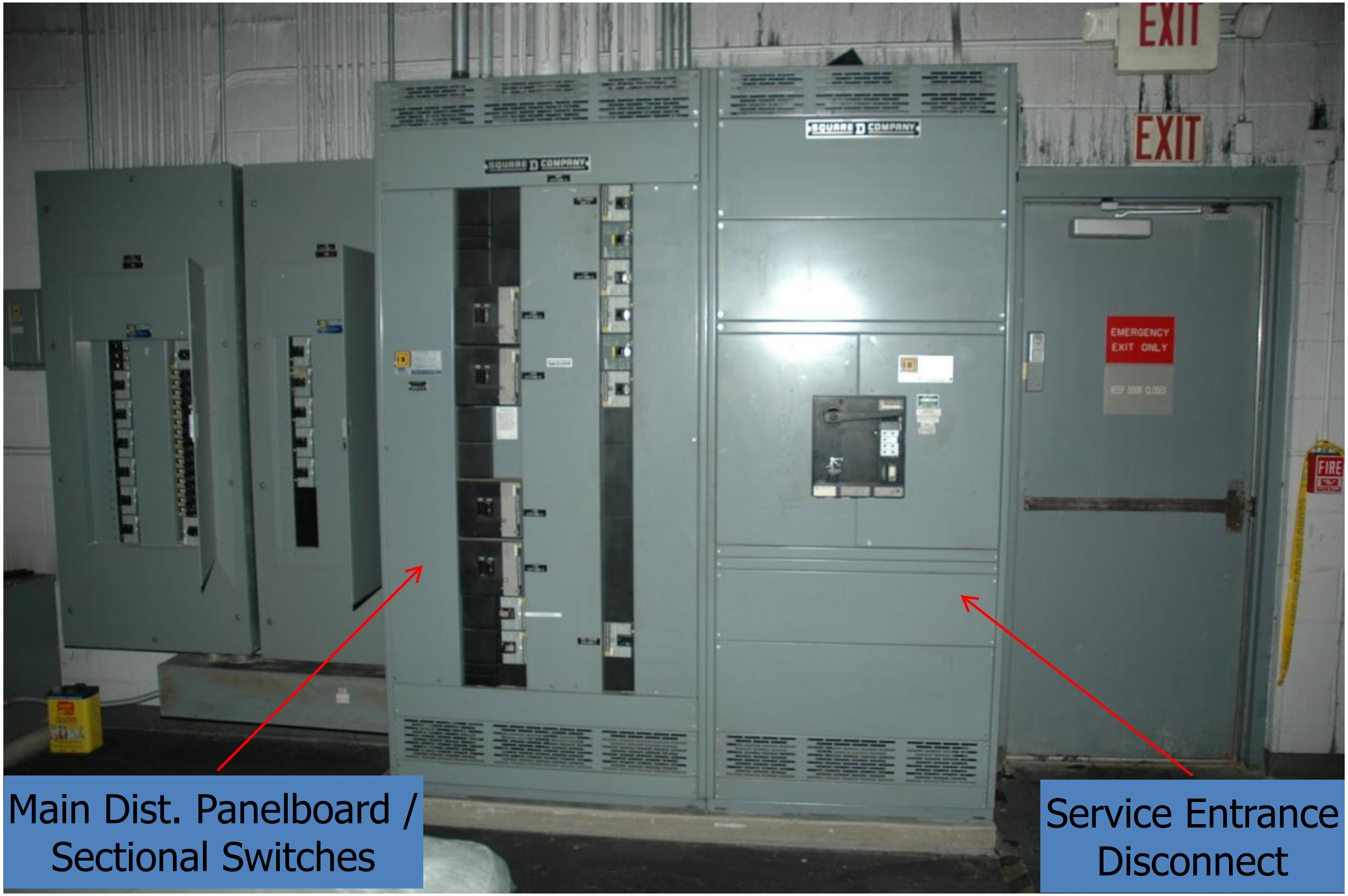


- Provide over current protection for building and branch circuits
- Neutral and grounding conductors are tied together in the panelboard

Old Service Entrance Equipment

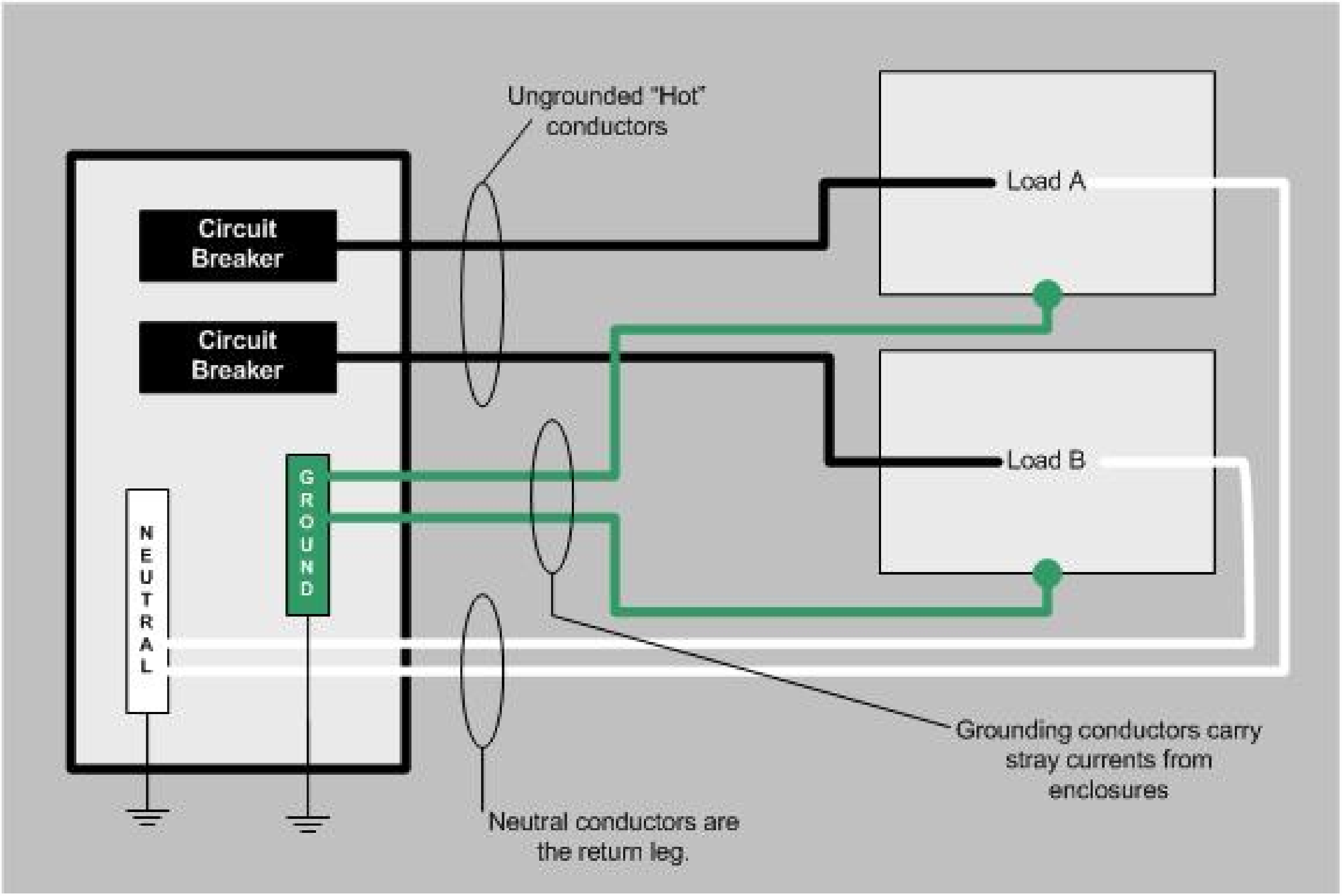
Branch Circuit

Branch Circuit Configuration

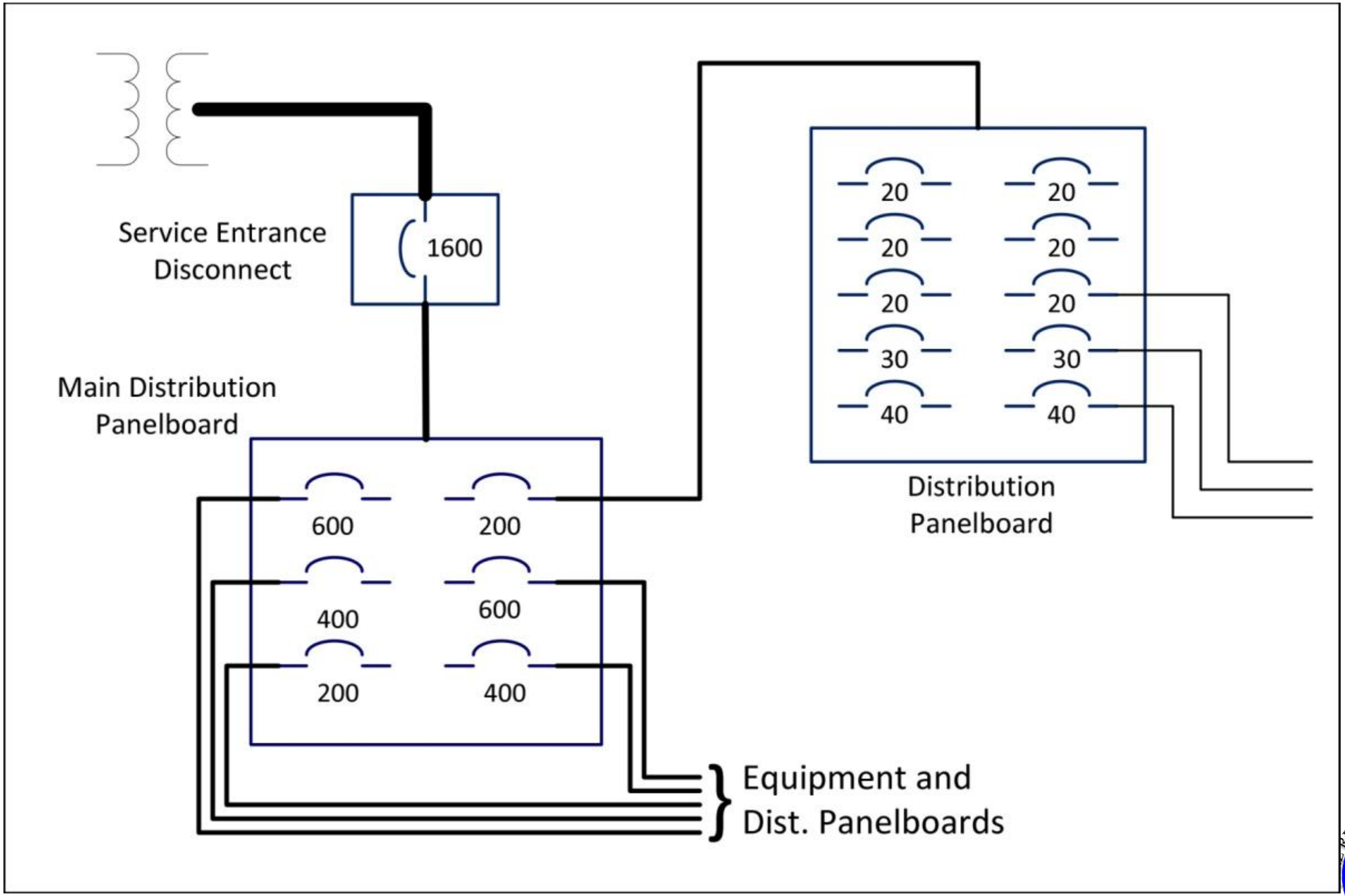


Branch Circuit Configuration

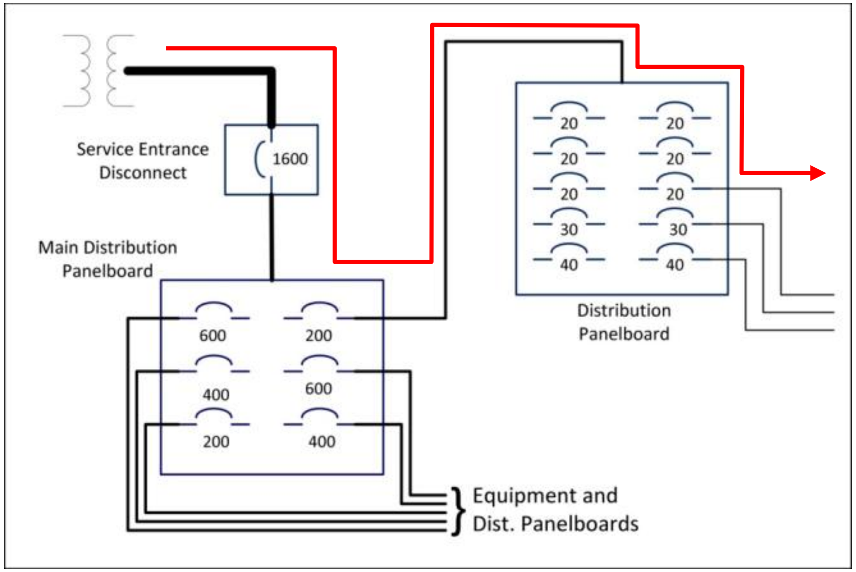
Simple Branch Circuit



Branch Circuit Configuration

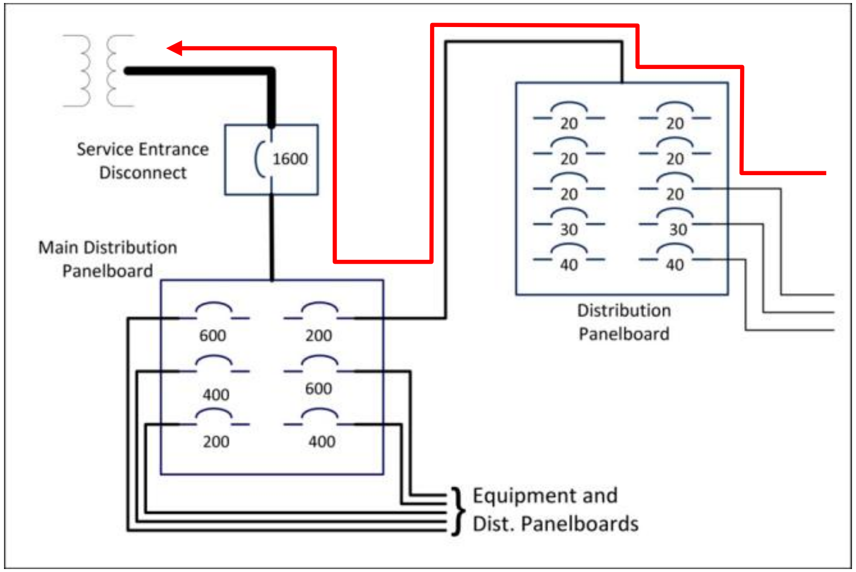


Branch Circuit Configuration Downstream



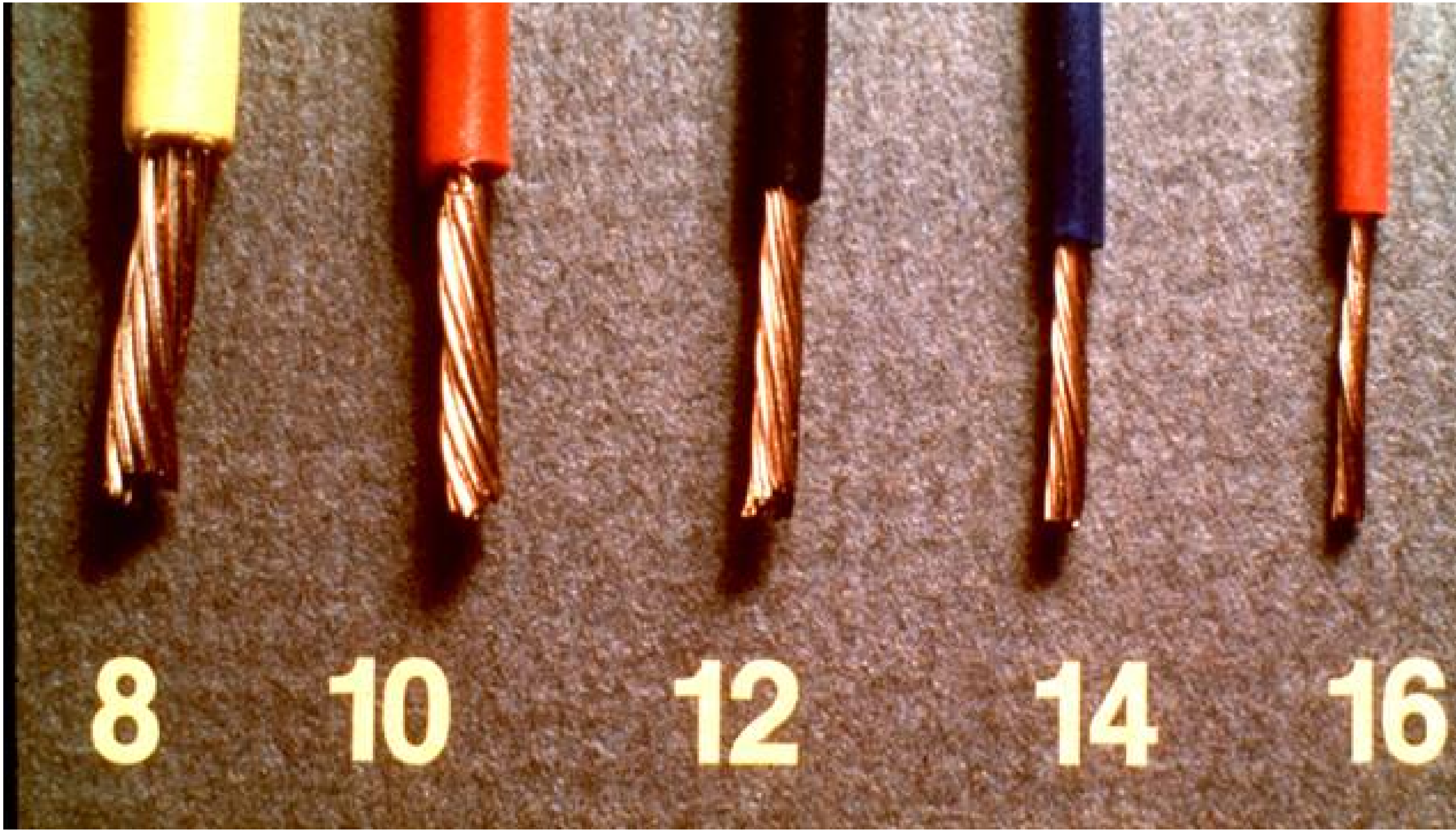
- The service entrance disconnect is DOWNSTREAM from the transformer.
- The main distribution panelboard is DOWNSTREAM from the service entrance disconnect.
- The branch circuit loads are DOWNSTREAM from the distribution panelboard.

Branch Circuit Configuration Upstream

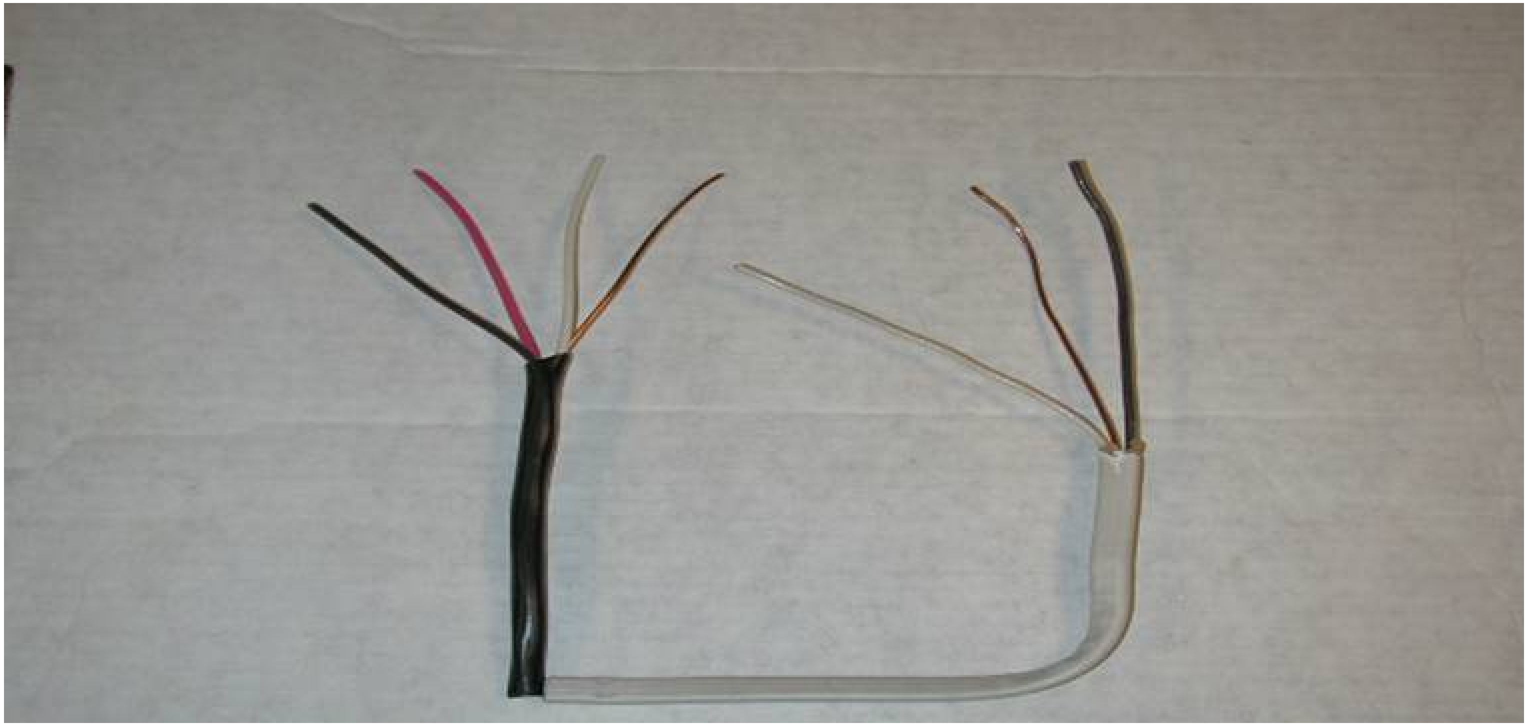


- The transformer is upstream from the service entrance disconnect.
- The main distribution panelboard is upstream from the distribution panelboard.

Wiring

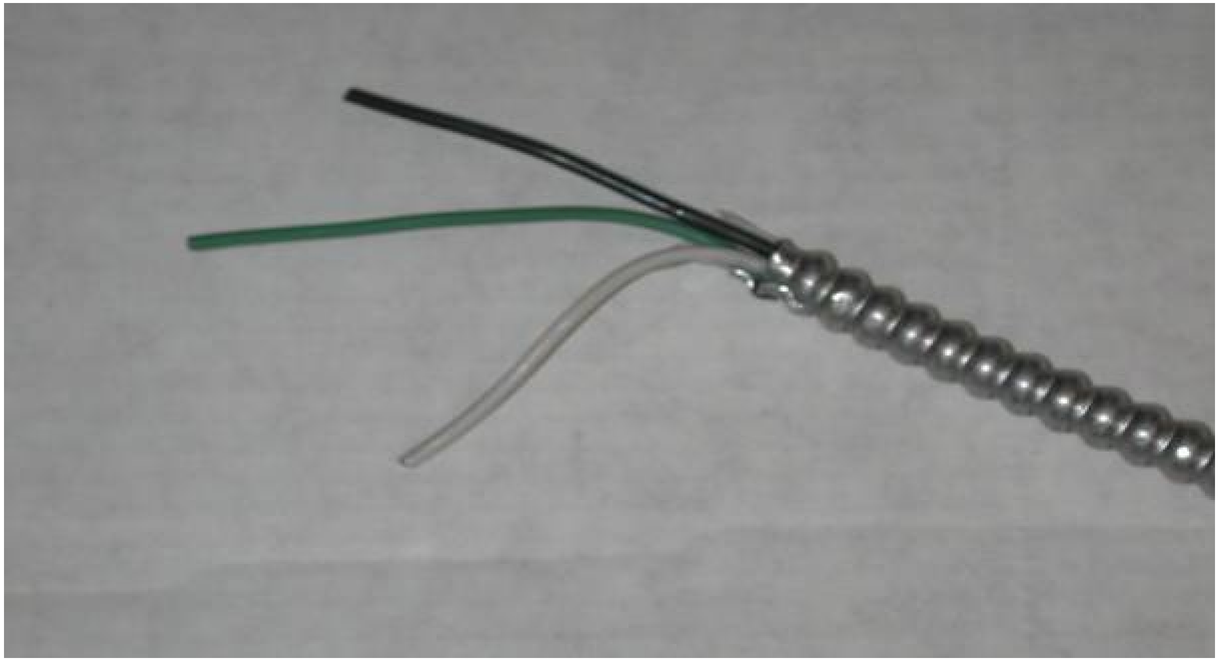


Non Metallic Sheathed Cable

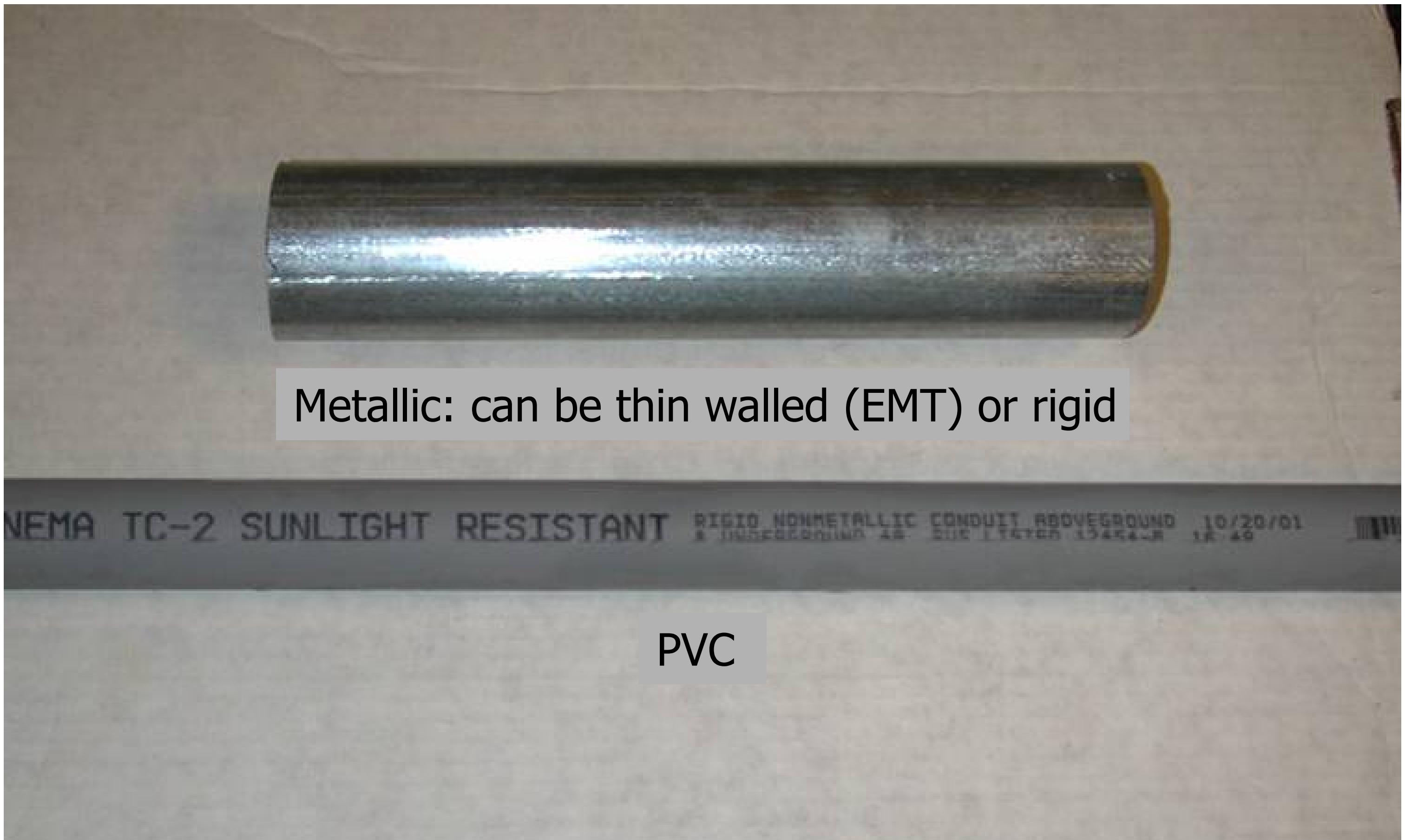


Non Metallic Sheathed Cable

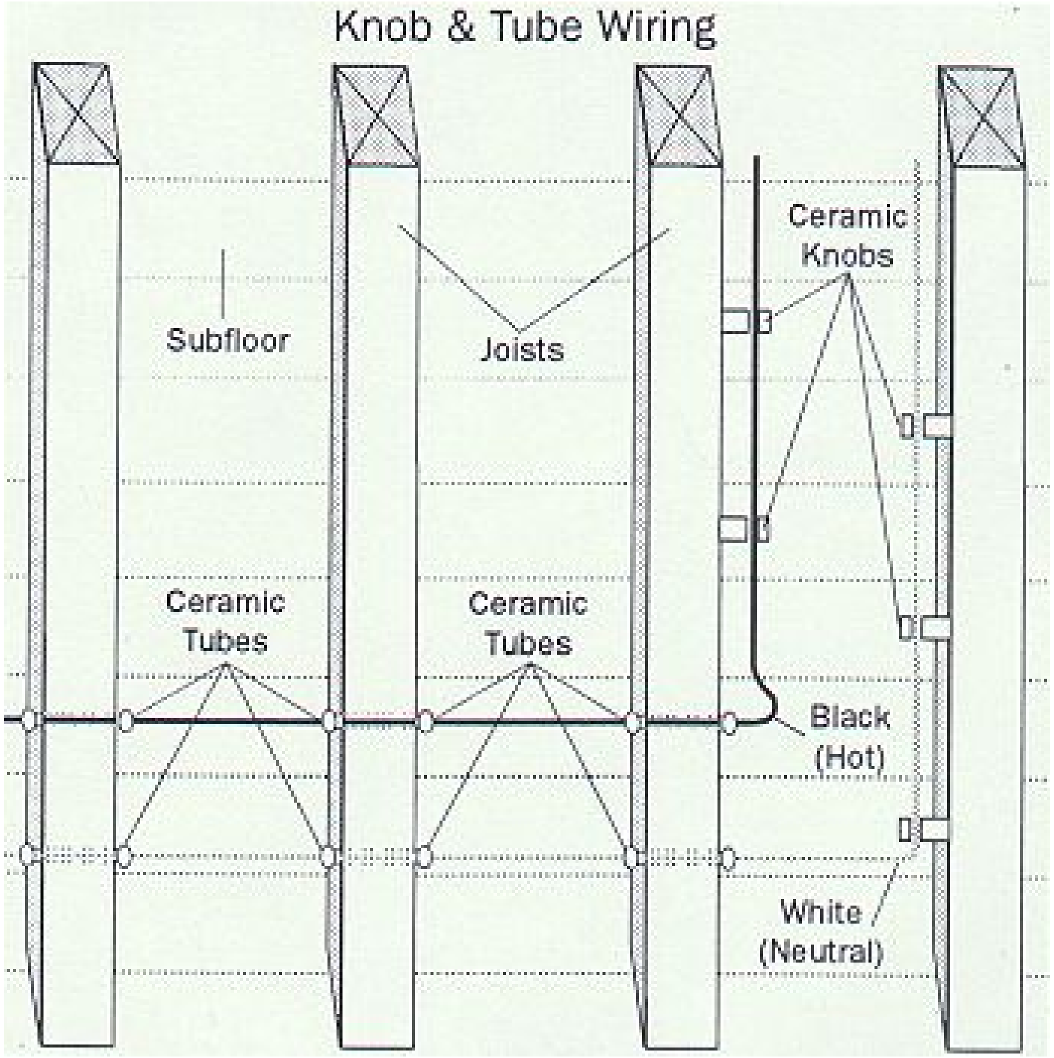
Metallic Sheathed Cable



Conduit


Metallic: can be thin walled (EMT) or rigid
NEMA TC-2 SUNLIGHT RESISTANT RIGID NONMETALLIC CONDUIT ABOVEGROUND 10/20/01
PVC

Knob and Tube



Knob and Tube

FIRE RESEARCH LABORATORY ATF

Knob and Tube

Knob and Tube

Circuit Breakers

Thermal-Magnetic Circuit Breakers

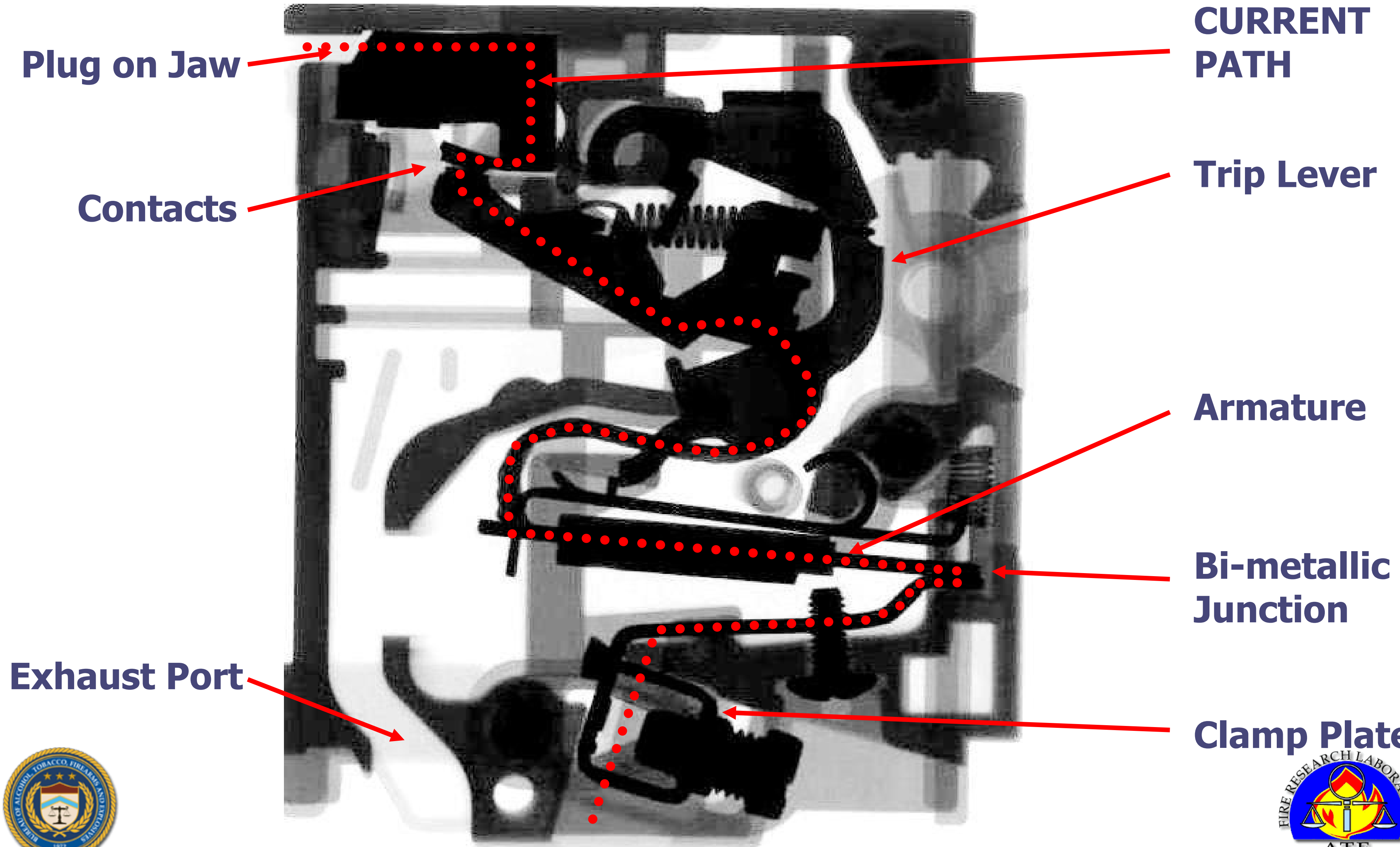
- Thermal-magnetic circuit breakers are designed with two modes of circuit protection:
  - over-current protection
  - short-circuit protection

- Over-current protection is provided by a thermal trip element.
  - Current flowing through a circuit breaker generates heat in the vicinity of the thermal sensor: a bi-metallic strip.

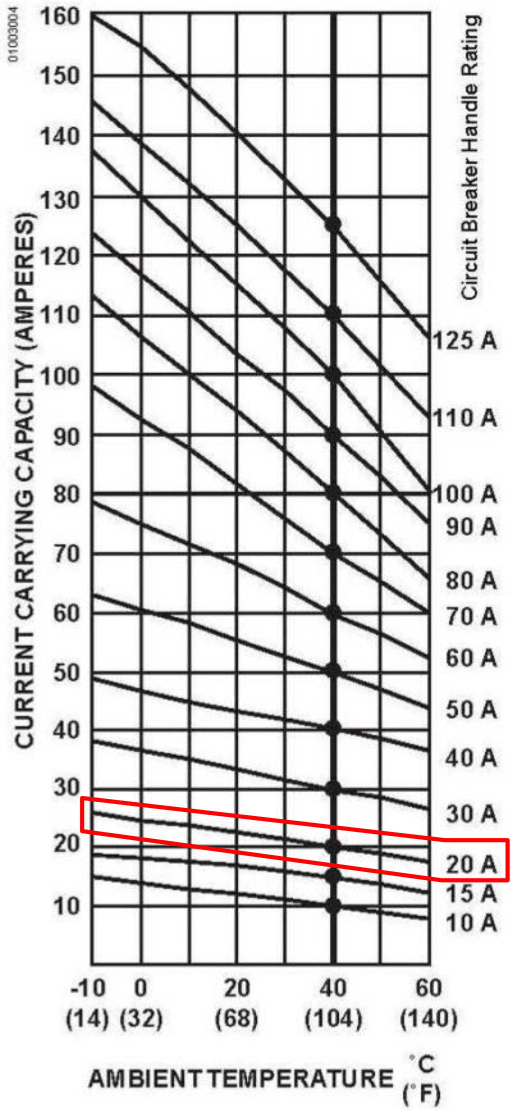
- Short Circuit protection is provided by a magnetic trip element.
  - electromagnetic element

- Total response time includes opening the circuit breaker and cooling the arc generated by the opening contacts.

Components


Plug on Jaw
Contacts
Exhaust Port
CURRENT PATH
Trip Lever
Armature
Bi-metallic Junction
Clamp Plate

Thermal Response

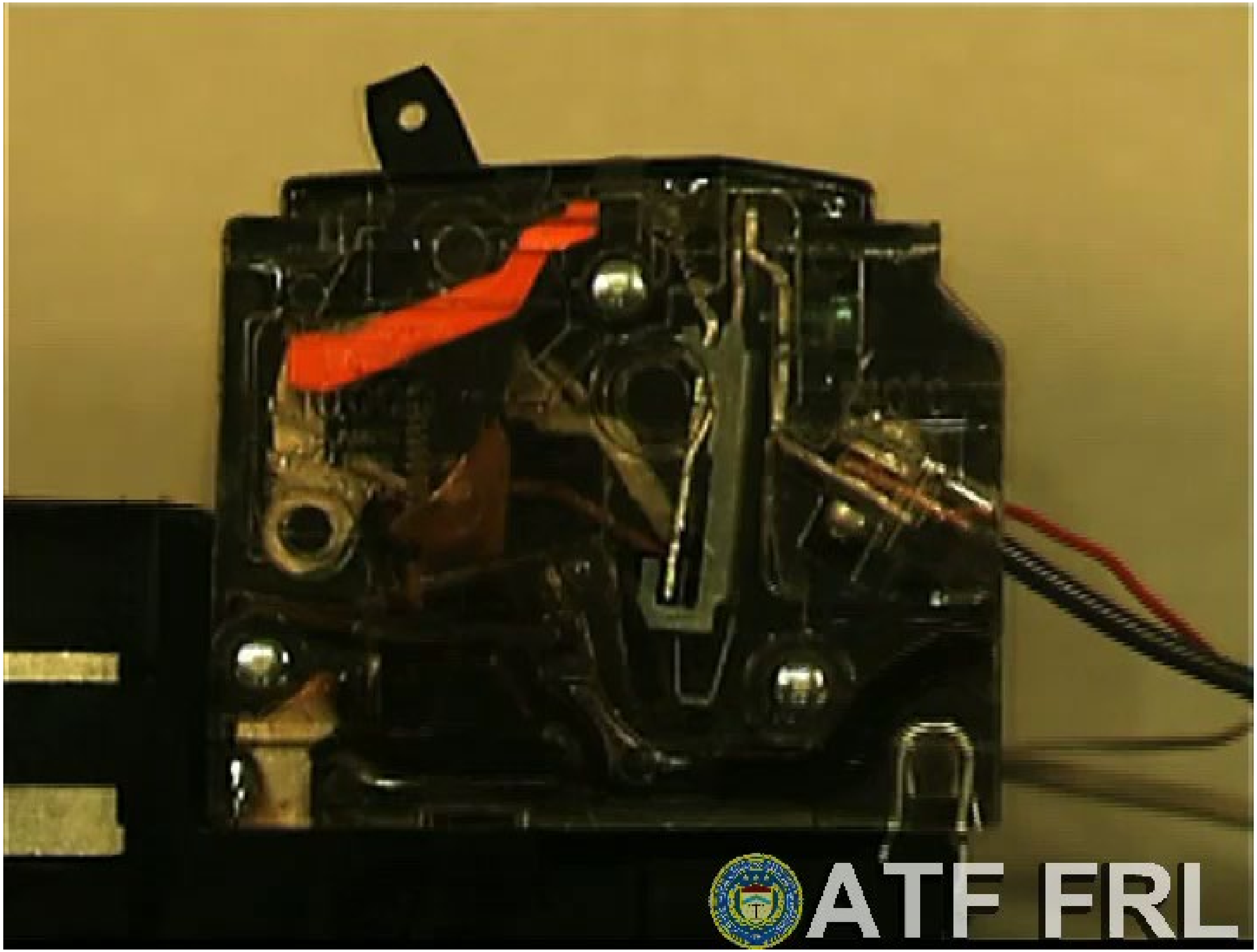


- Most common circuit breakers are tested and obtain their rating with an ambient temperature of 40°C (~104°F) [UL Standard]

- Ambient temperature impacts the circuit breaker's thermal / overcurrent trip characteristics
  - Temperature increase causes the circuit breaker to trip at a current less than rated
  - Temperature decrease causes the circuit breaker to trip at a current greater than rated

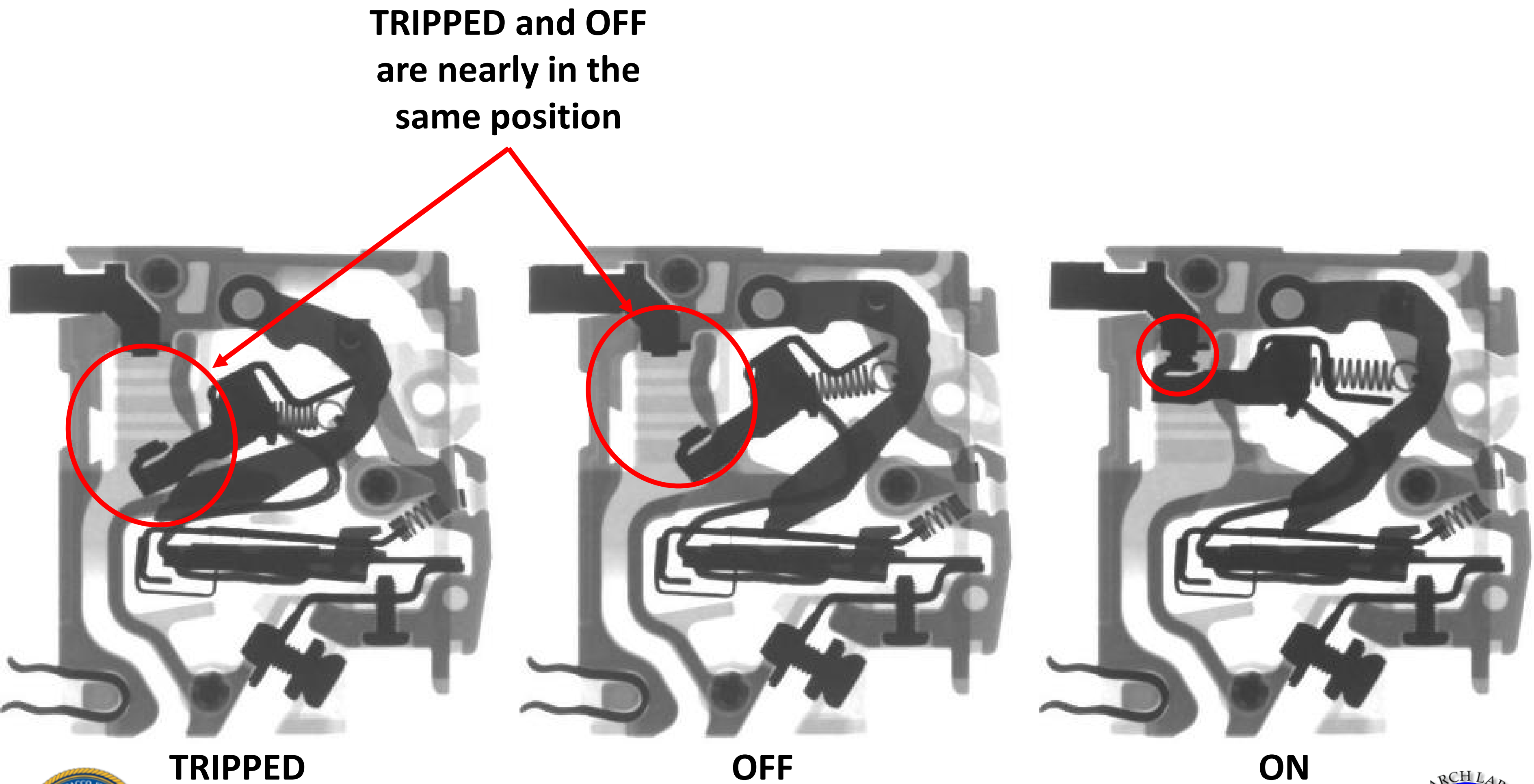
  - For a 20 Amp circuit breaker:
    - ~17.5 Amp at 60°C
    - ~27.5 Amp at -10°C

Circuit Breaker Operation



Status of a Circuit Breaker

Contact Position – are you ON or not?

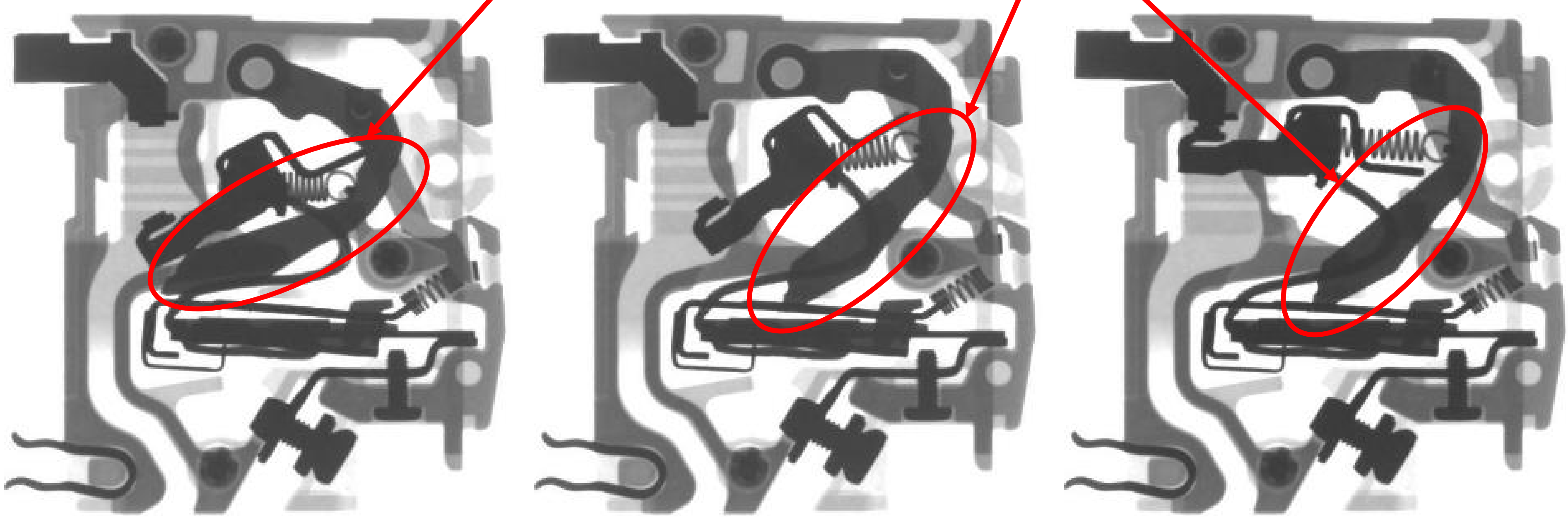


Status of a Circuit Breaker

Trip Lever Position – if you are NOT ON, what are you?

TRIPPED is moved close to the back of the contact assembly

ON and OFF are nearly in the same position



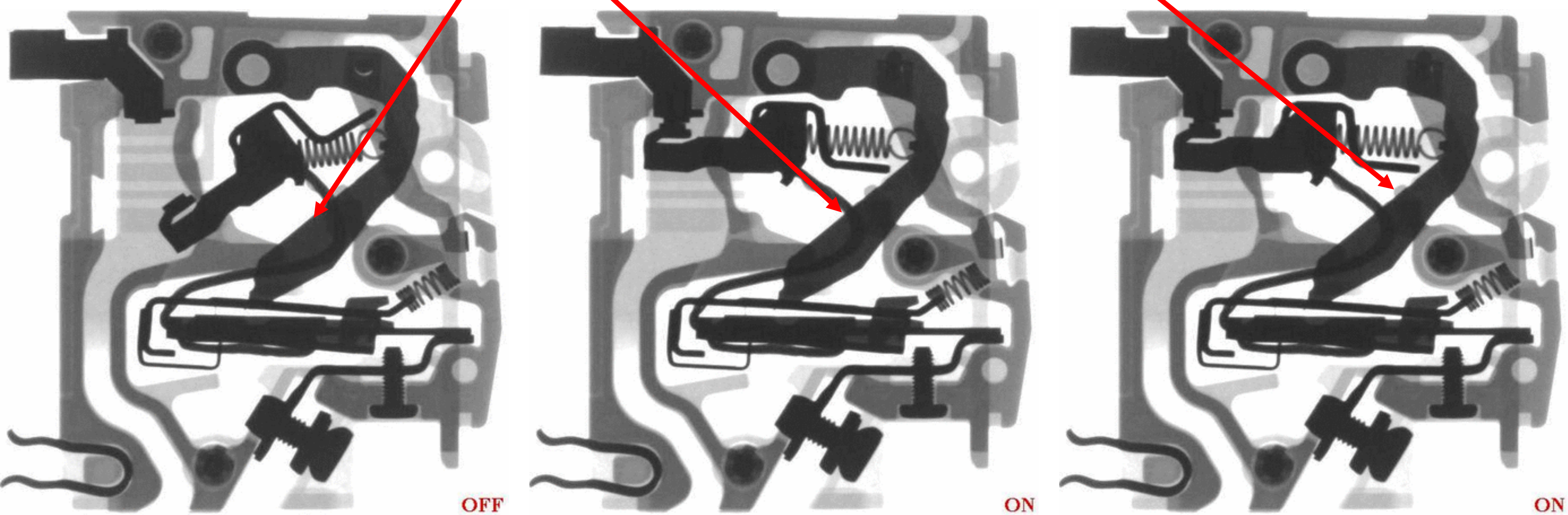
TRIPPED **OFF** **ON**

Status of a Circuit Breaker

Trip Lever Position

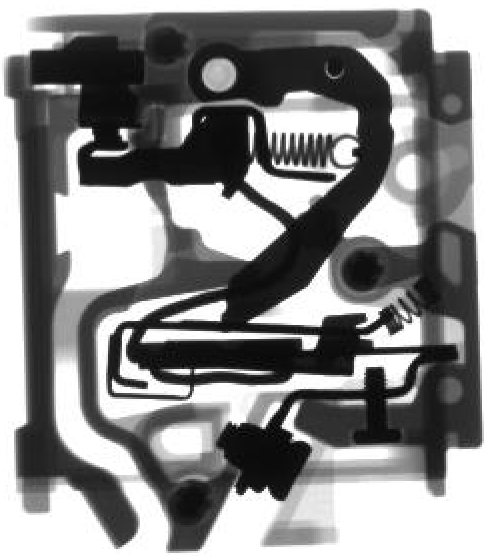
Movement in
the Trip Lever
when TRIPPING

ON and OFF
are nearly in the
same position

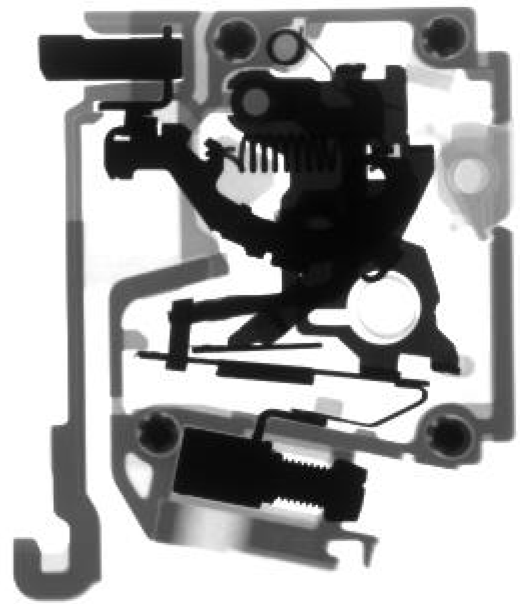


ON

Square D



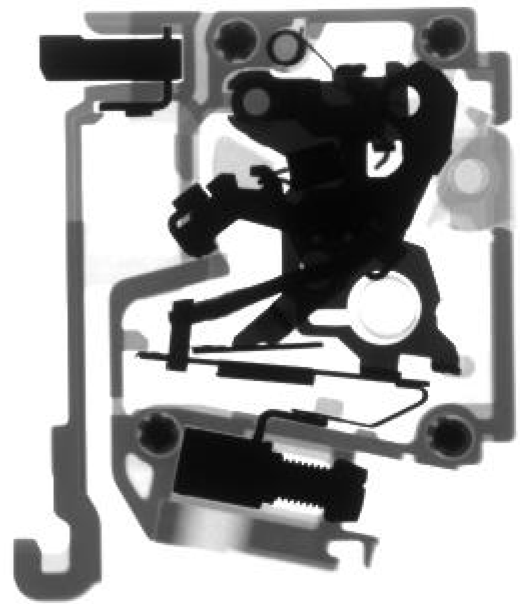
Cutler Hammer



OFF

Square D

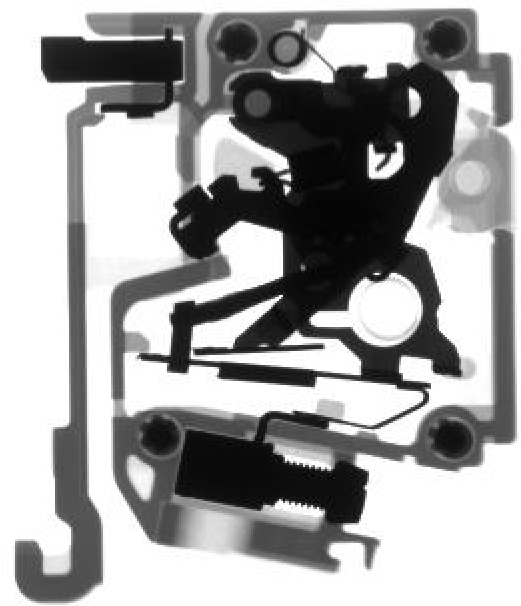
Cutler Hammer



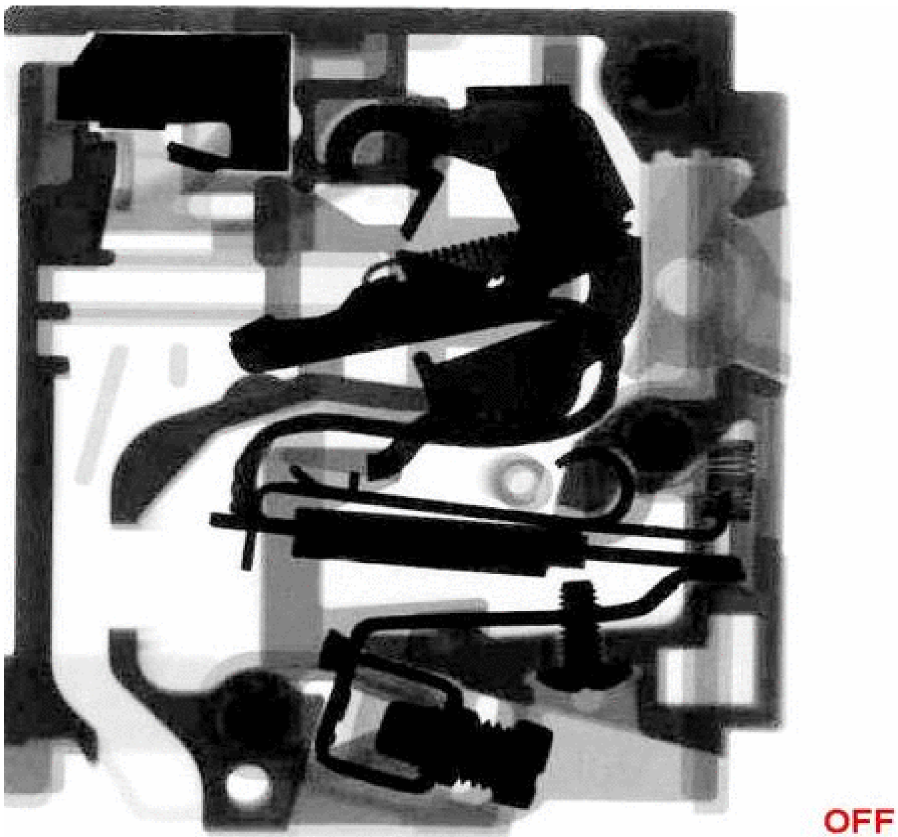
TRIPPED

Square D

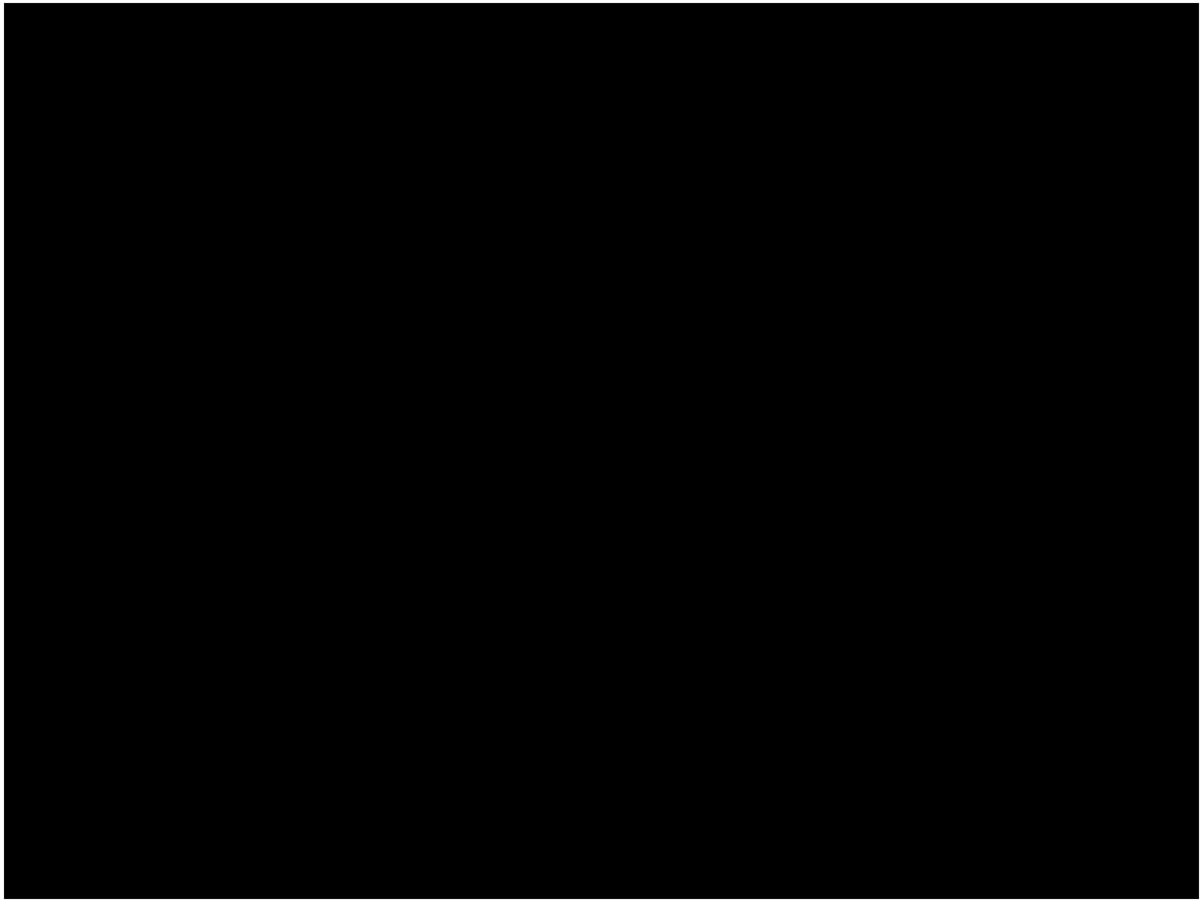
Cutler Hammer



Tripped Circuit Breakers



- Note that the trip lever is in the same position when the circuit breaker is on and off
- This means that a circuit breaker in the off position can be influenced and tripped by external heat
- Heat sources can come from a fire or adjacent circuit breakers heating from overcurrent / venting
- A forensic examination cannot differentiate between a thermal and magnetic trip



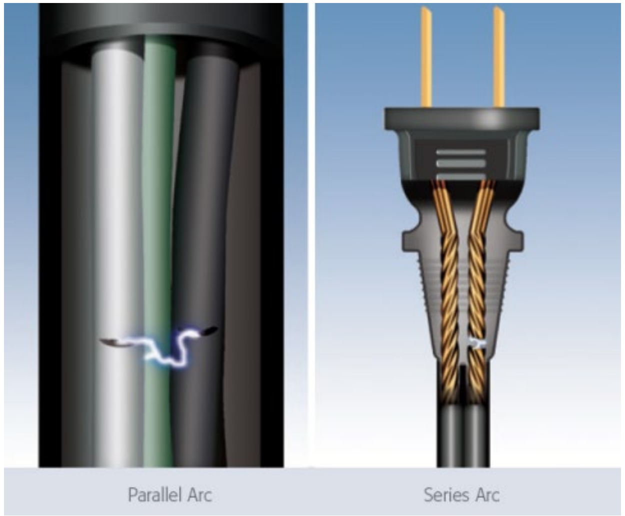
BUREAU OF ALCOHOL, TOBACCO, FIREARMS AND EXPLOSIVES 1972

FIRE RESEARCH LABORATORY ATF

Tripped Circuit Breakers

- A panelboard that has been impinged by flame will generally have all of the circuit breakers tripped
- Only check the circuit breaker by turning it ON
  - If you are not sure which direction is on – leave it alone

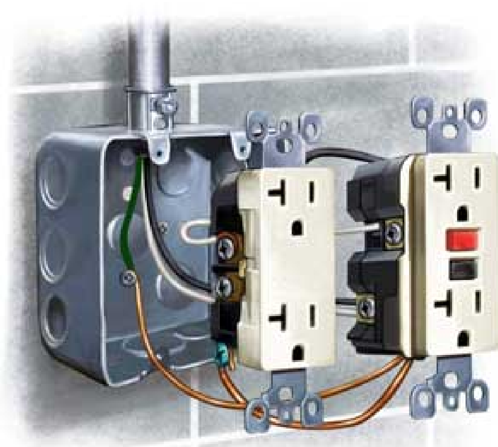
Arc Fault Circuit Breakers



- Combination AFCI circuit breakers sense and respond to both parallel and series arcing incidents
  - Series arc: arcing in series with one of the conductors
  - Parallel arc: line to line, line to Neutral, line to ground

- In short, it is a thermal magnetic circuit breaker with a computer to sense the arc activity

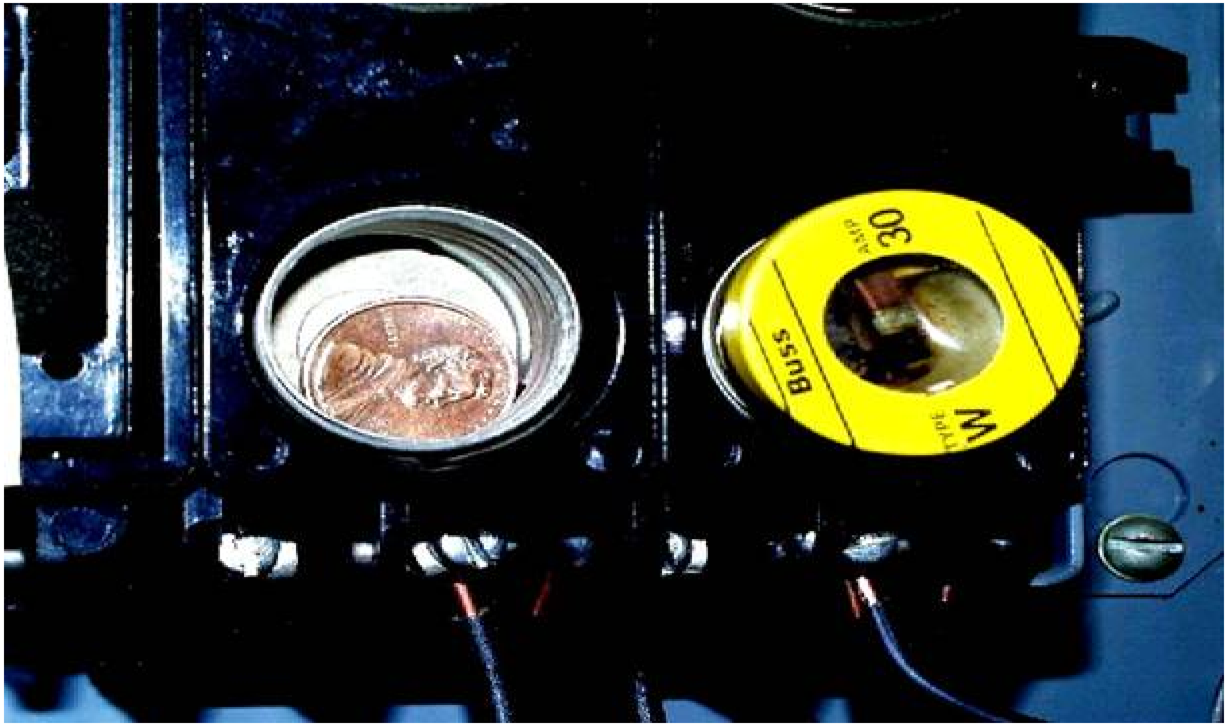
Ground Fault Circuit Breakers and Outlets



- A small coil observes current on the hot and neutral legs

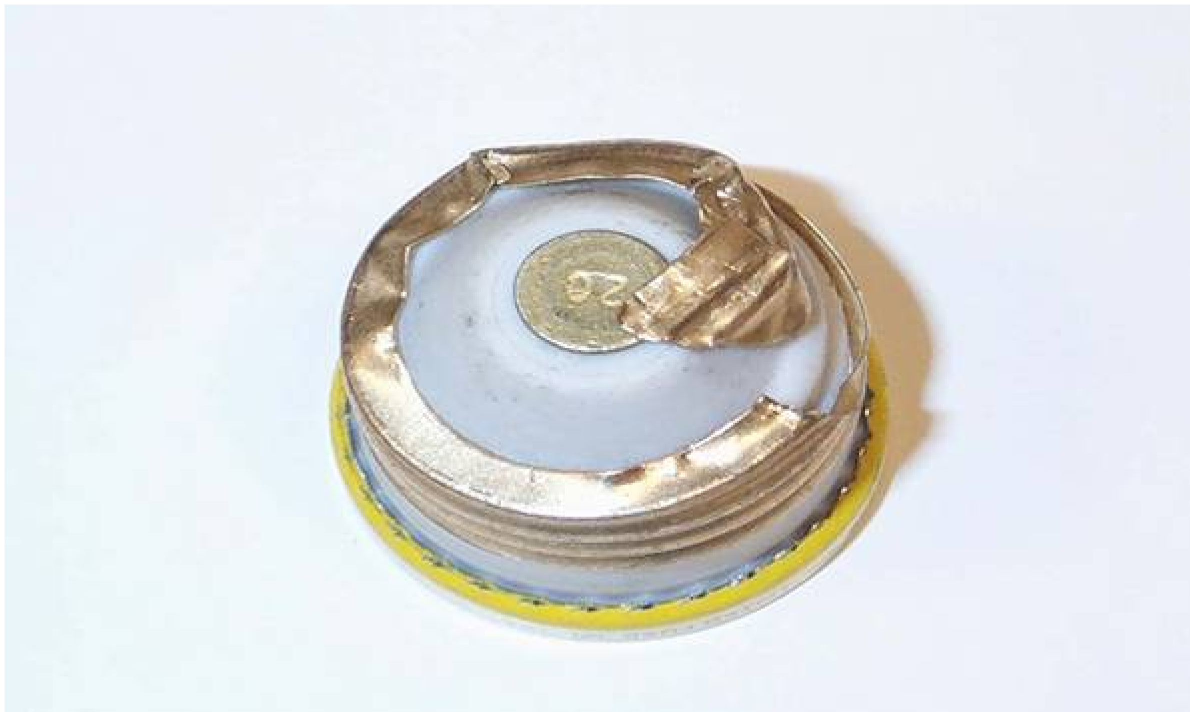
- If a difference of more than 5 ma is observed, the outlet or circuit breaker are tripped

Evidence of Tampering

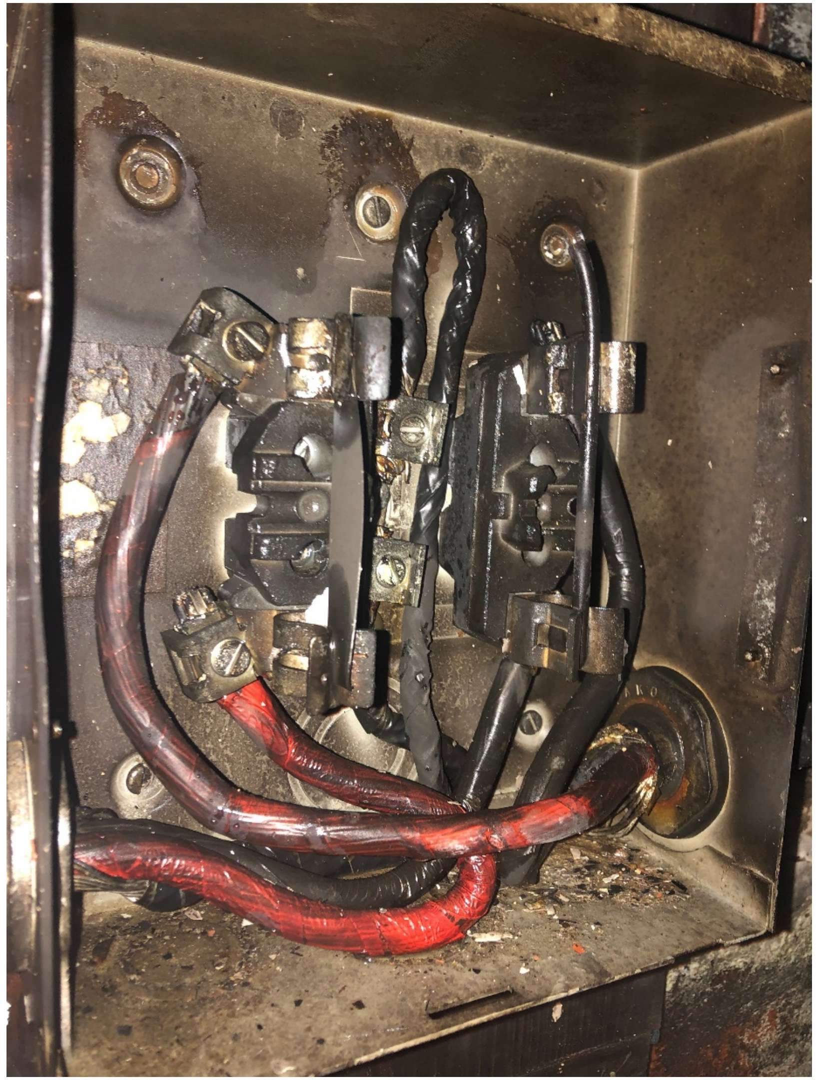


Evidence of Tampering

Evidence of Tampering



Baltimore City Meter Bypass



Five Forms of Electrical Heating

- Arcing
- Sparking
- Resistance
- Static electric discharge
- Lightning

Arcing

- Caused by electricity traveling through an air space from one conducting point to another
- Temperature can exceed 2000 degrees Fahrenheit
- Often of short duration
- Can be continual or intermittent

Arcing

Arcing

Sparking

- Produced by conversion of metals to vapors and liquids from exposure to intense heat
- Can occur only once
- Metal is displaced from origin
- Does not create a sustained heating effect
- Extremely dangerous in flammable atmospheres

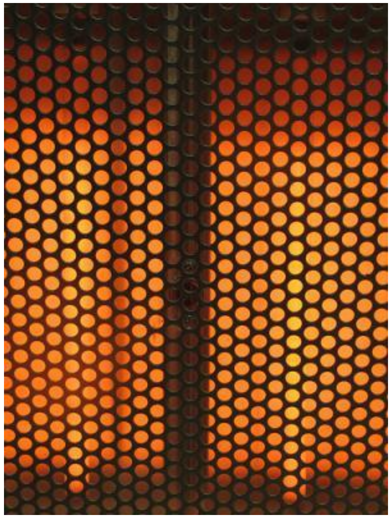
Sparking

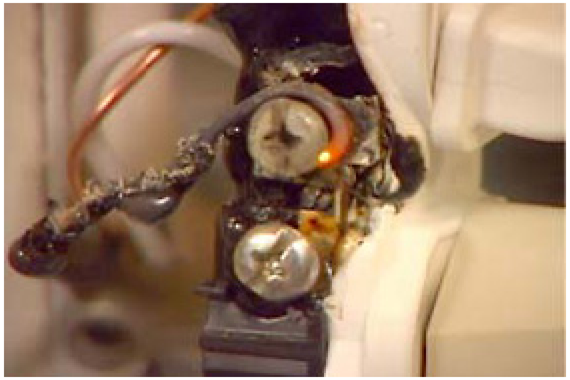
Arcing & Sparking

Arcing & Sparking

BUREAU OF ALCOHOL, TOBACCO, FIREARMS AND EXPLOSIVES
FIRE RESEARCH LABORATORY
ATF

Resistance Heating





- The process by which the passage of an electric current through a conductor releases heat

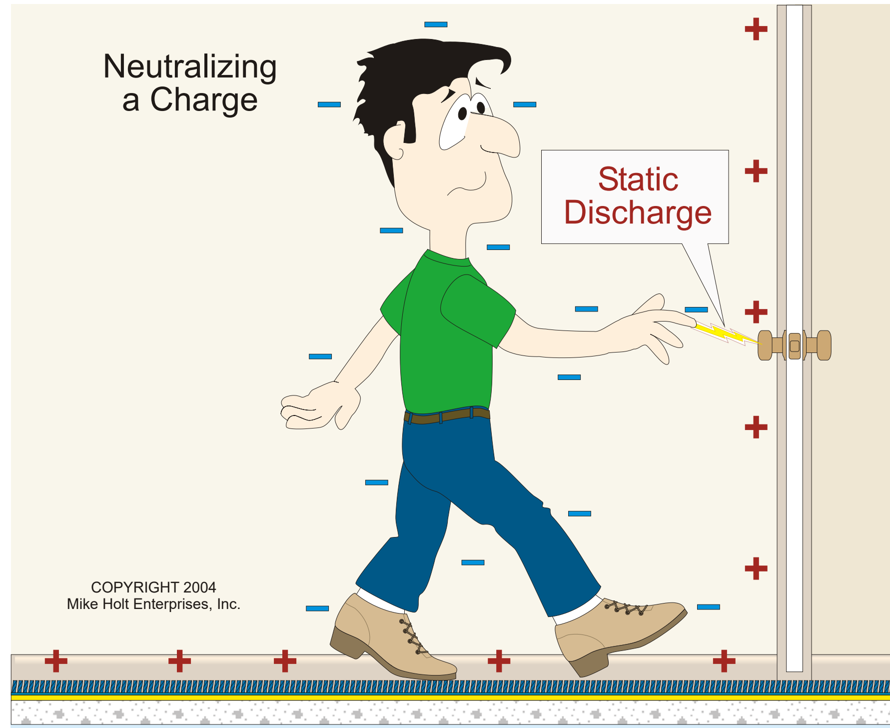
- This can be a desirable effect – or an electrical failure

Electrostatic Discharge

- The sudden and momentary electric current that flows between two objects at different electrical potentials.
- Surfaces with opposite electrical charges come in close proximity or contact and an arc occurs
- Prevented by bonding materials
- Temperature will not ignite liquids or most solids
- Will ignite flammable vapors and combustible dusts.

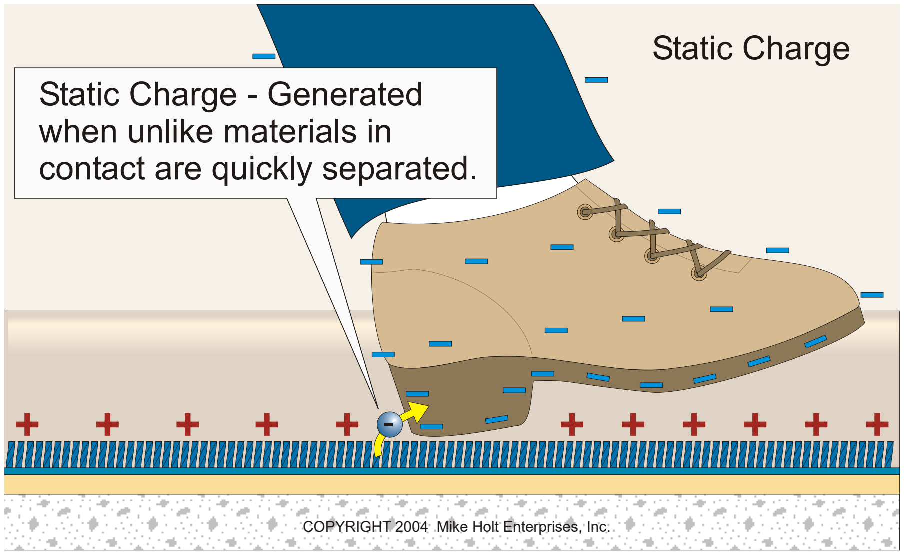
Electrostatic Discharge

- An ESD event is a rapid transfer of charge (electrons) from one object to another in an attempt to become electrically neutral.
- Spark Discharge
  - Between a highly charged object and ground
  - Between a highly charged object and another object with much less charge



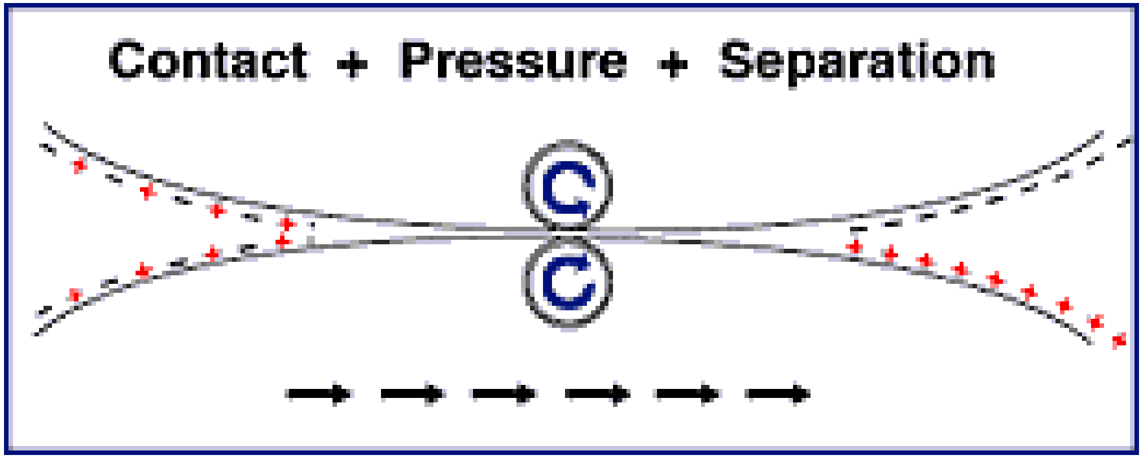
The build up of electrons can be "discharged" when a negatively charged object comes close to a positively charged object.

Charge Separation & Accumulation

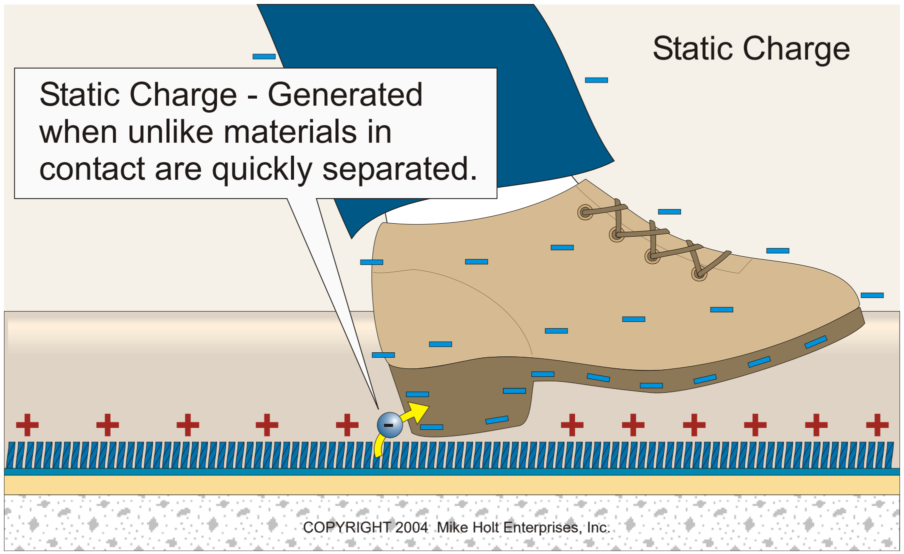


- Electrostatic charge is most commonly accumulated by the contact and separation of two electrically nonconductive materials.
  - This can be:
    - Solid to solid
    - Solid to liquid
    - Liquid to liquid

Charge Separation & Accumulation



Things that Impact Charge Separation & Accumulation



- Surface Area
- Pressure
- Speed
- Humidity
- Contamination
- Materials

Triboelectric Series

POSITIVE
Air
Human Skin
Asbestos
Glass
Mica
Human Hair
Nylon
Wool
Fur
Lead
Silk
Aluminum
Paper
Cotton
Wood
Steel
Sealing wax
Hard rubber
Mylar
Epoxy-glass
Nickel, copper
Brass, Silver
Gold, platinum
Polystyrene foam
Acrylic
Polyester
Celluloid
Orion
Polyurethane foam
Polyethylene
Polypopylene
Polyvinylchloride (PVC)
Silicon
Teflon
NEGATIVE

Triboelectric Series Chart (Ott, 1988)

Air	(+) POSITIVE
Skin (dry)	
Glass	
Human Hair	
Mica	
Nylon	
Wool	
Cat Fur	
Lead	
Silk	
Aluminum	
Paper	
Cotton	
Steel	
Wood	
Lucite	
Amber	
Rubber Balloon	
Hard Rubber	
Mylar®	
Epoxy glass	
Nickel	
Copper	
Silver	
Gold, Platinum	
Polyester	
Polystyrene	
Orlon, Acrylic	
Polyester	
Cellophane Tape	
Polyurethane	
Polyethylene	
Polypropylene	
Polyimide (Kapton ®)	
PVC, Vinyl	
Teflon	
Silicone Rubber	NEGATIVE (-)


02/12/2004 20:20:35
Pump 1 & 2

Lightning

- Naturally and frequently occurring source of powerful electrical energy
- Extreme temps and damage associated with strikes
- Damage prevented with proper grounding techniques
- Damage can be distant of strike location
- Multiple side strikes can leave a confusing scene

FIRE RESEARCH LABORATORY
ATF

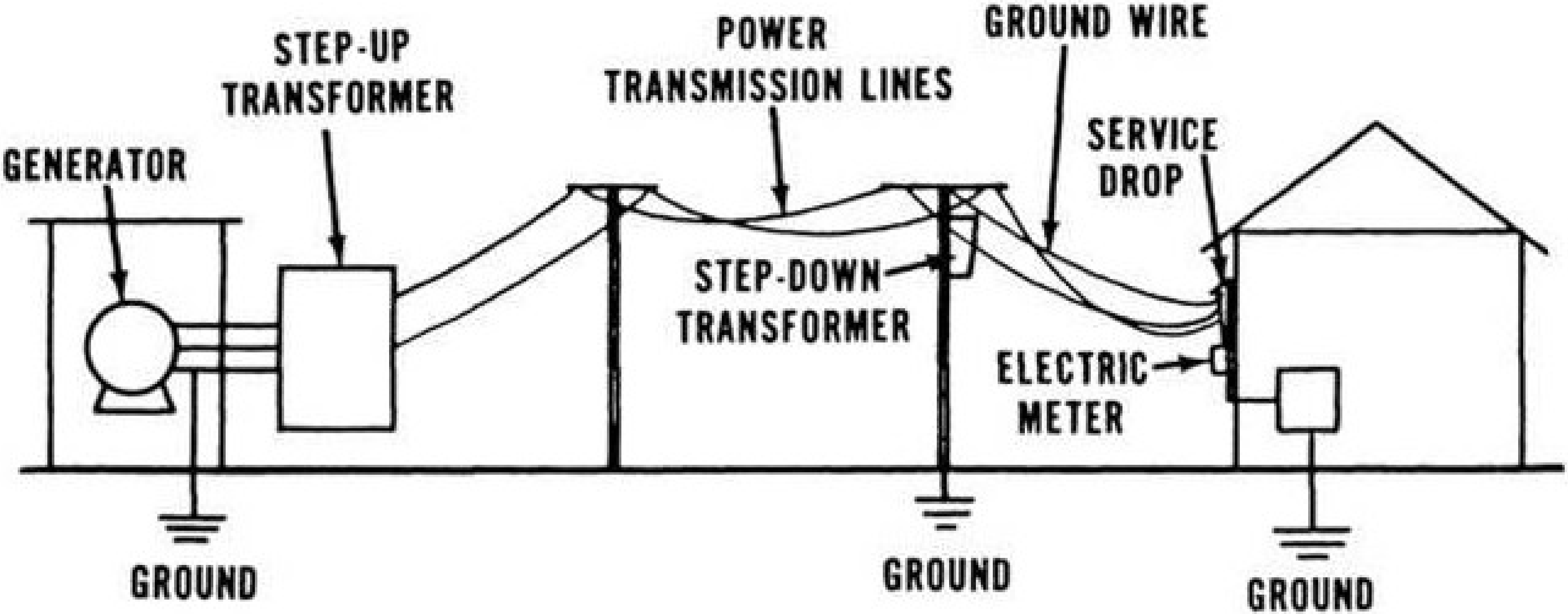
Open (Floating) Neutrals

Open Neutral
(Floating Neutral)

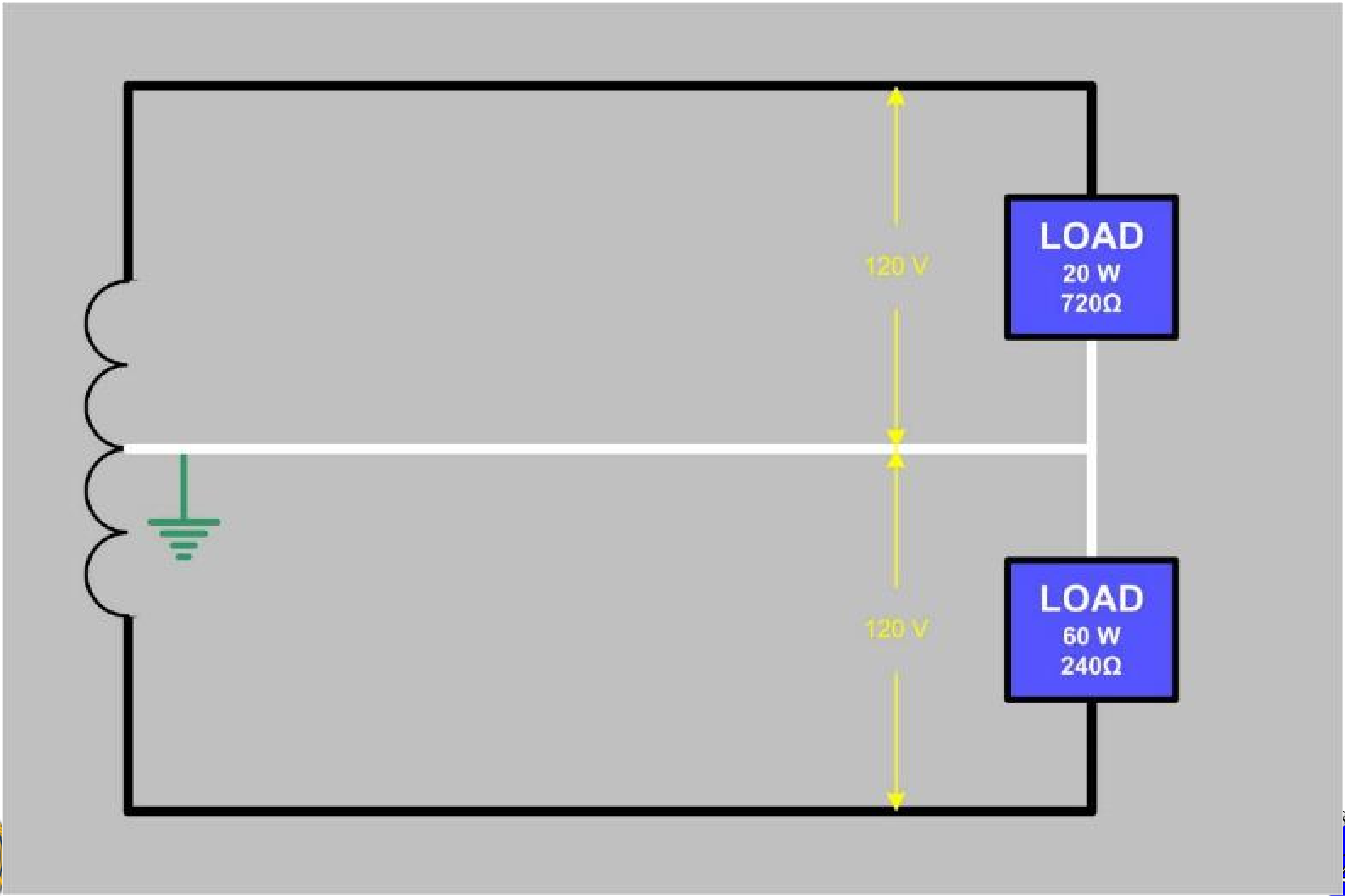
- The neutral serves as a reference to ground in an electrical system.

- It acts as a return path for electric current.

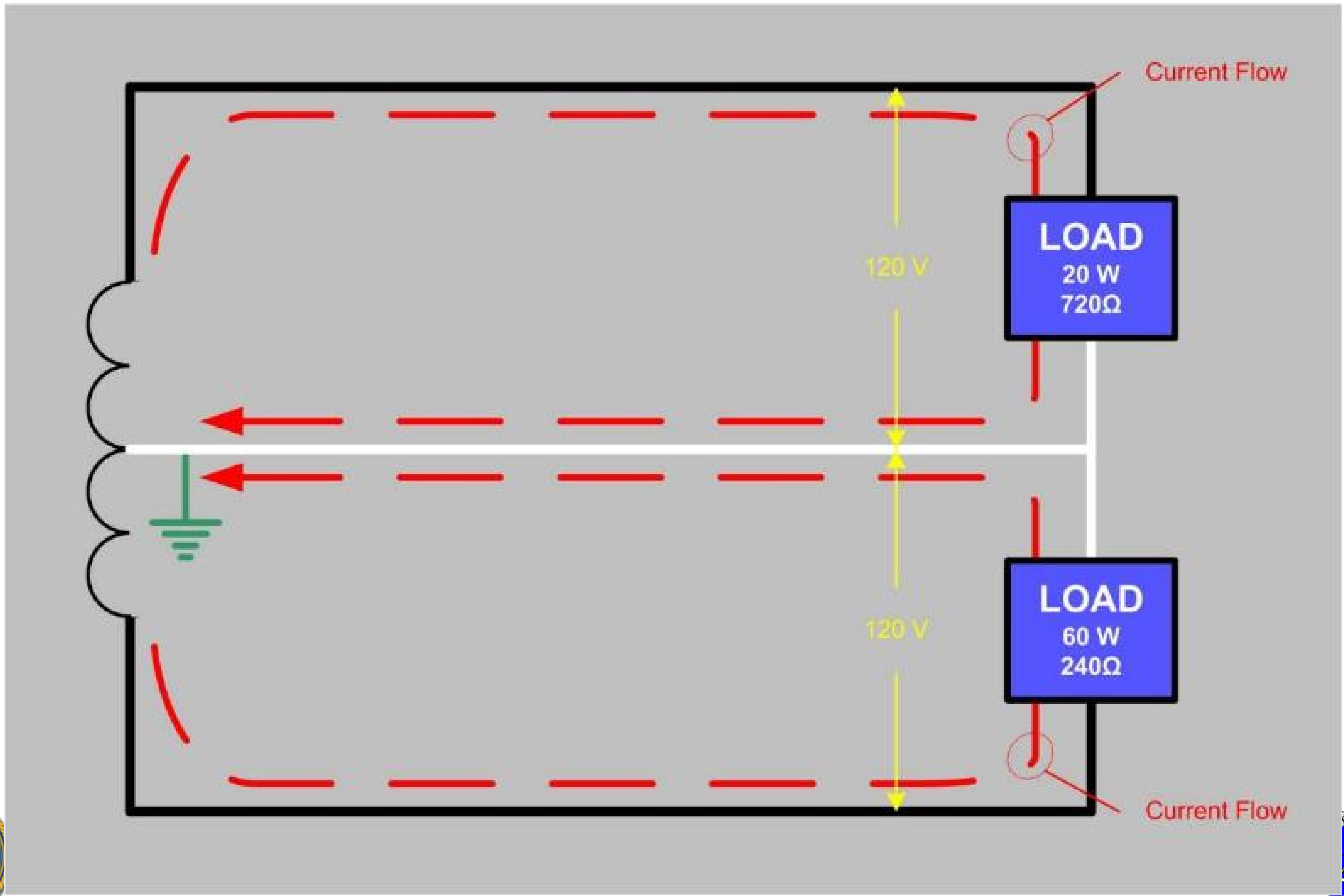
- When the neutral is broken (open/floating), the return current must find another way to get back into the system.


GENERATOR
STEP-UP TRANSFORMER
POWER TRANSMISSION LINES
GROUND WIRE
SERVICE DROP
STEP-DOWN TRANSFORMER
ELECTRIC METER
GROUND
GROUND
GROUND

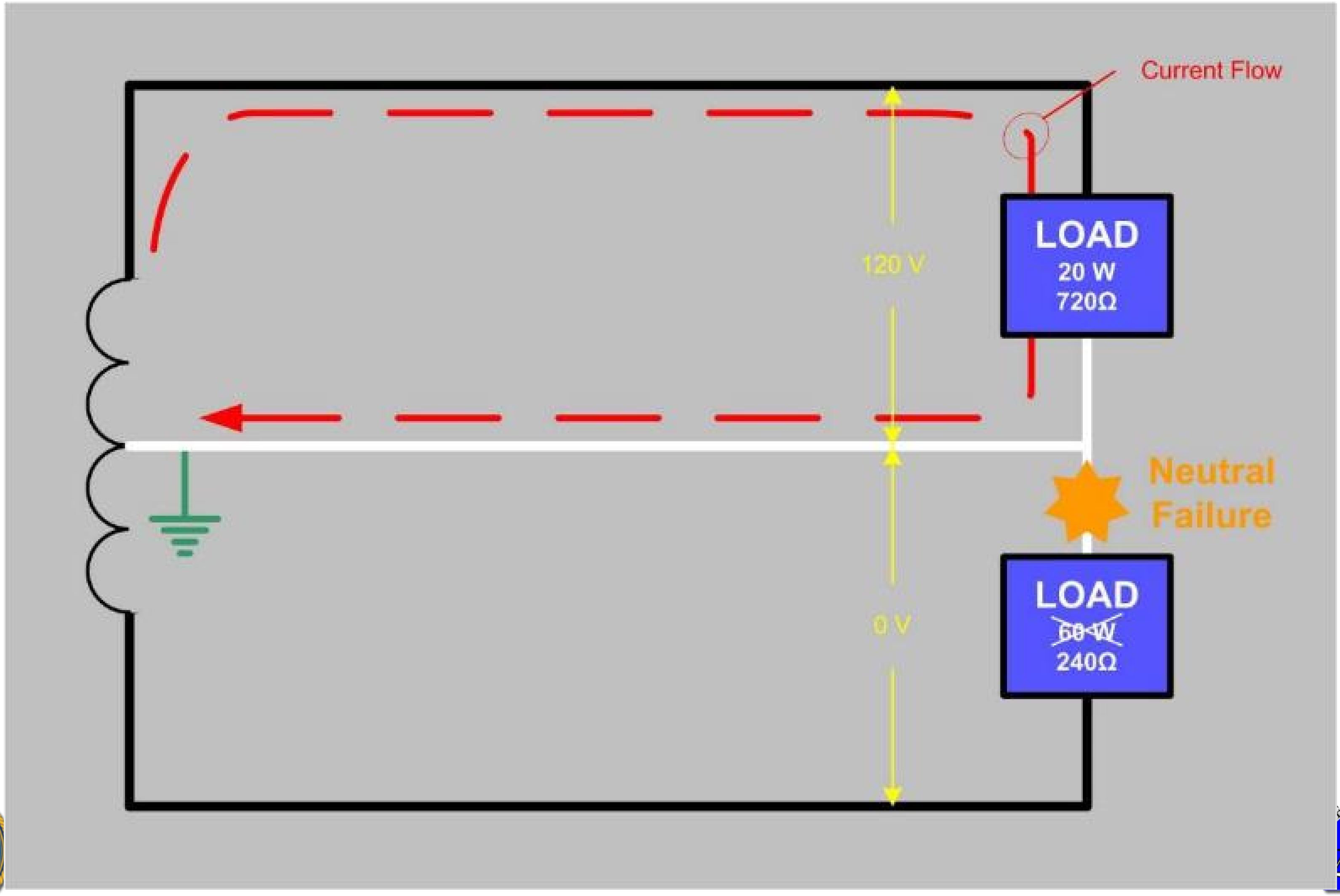
Normal 120 / 240 V System



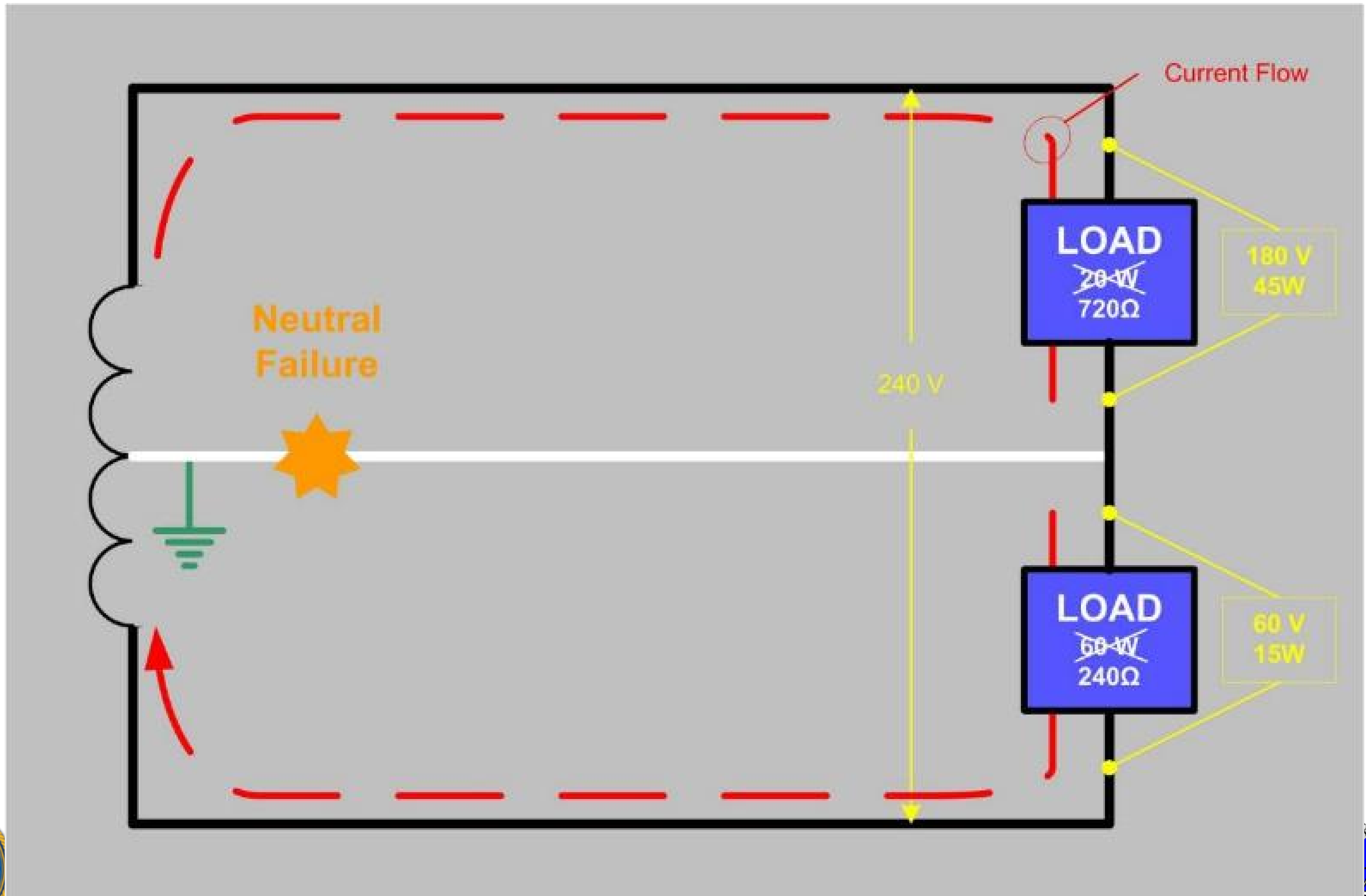
Normal 120 / 240 V System



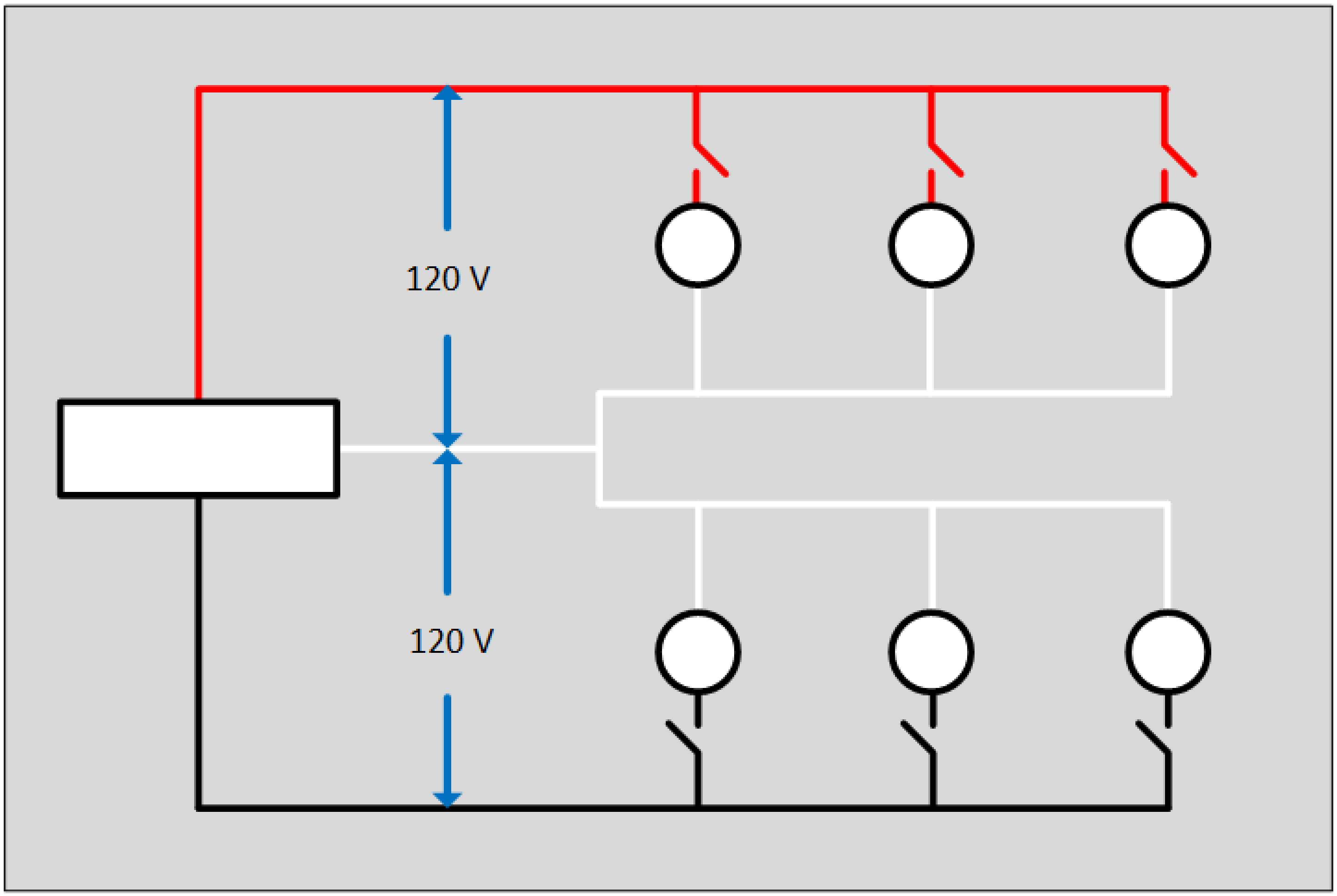
Open Neutral Scenario 1



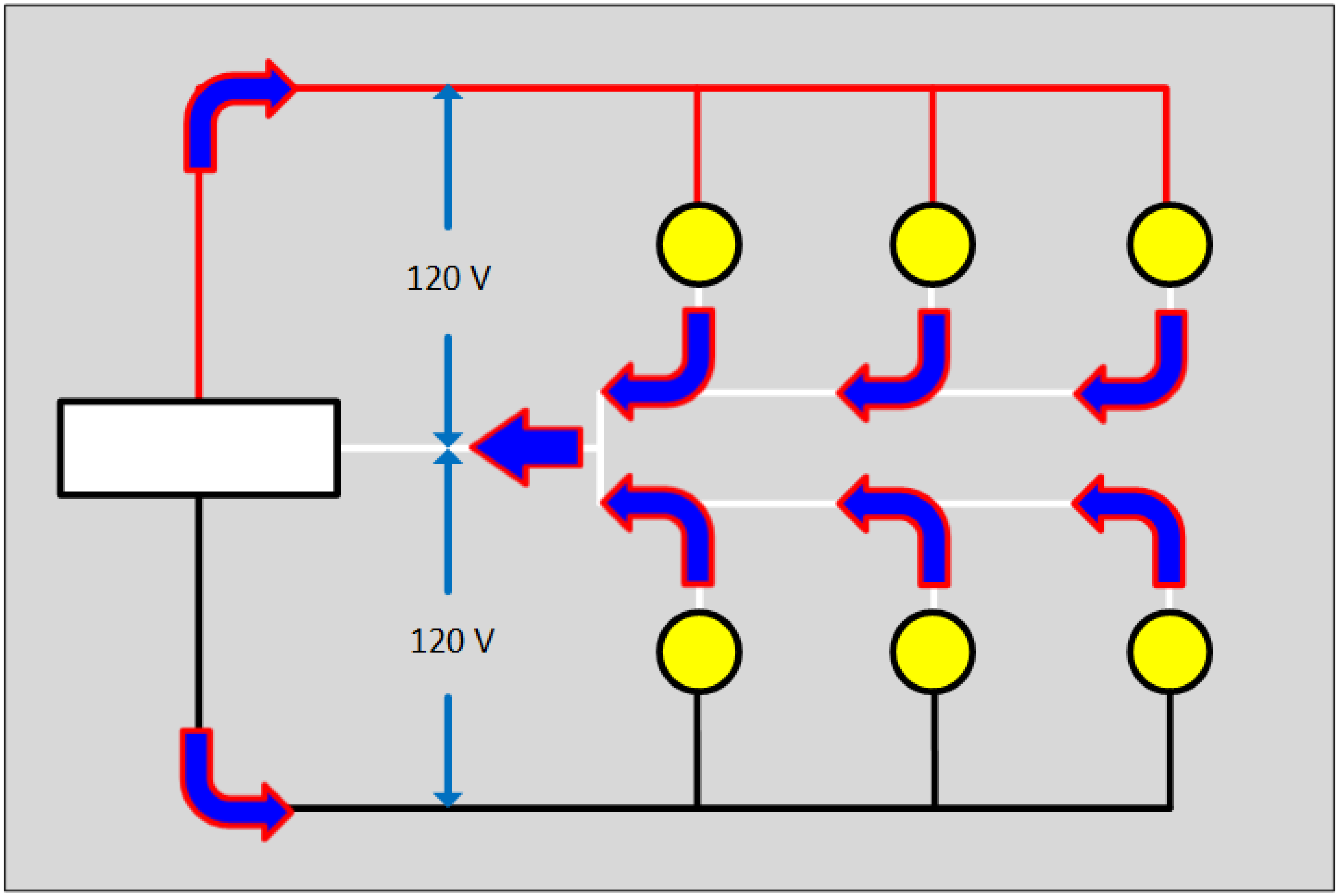
Open Neutral Scenario 2



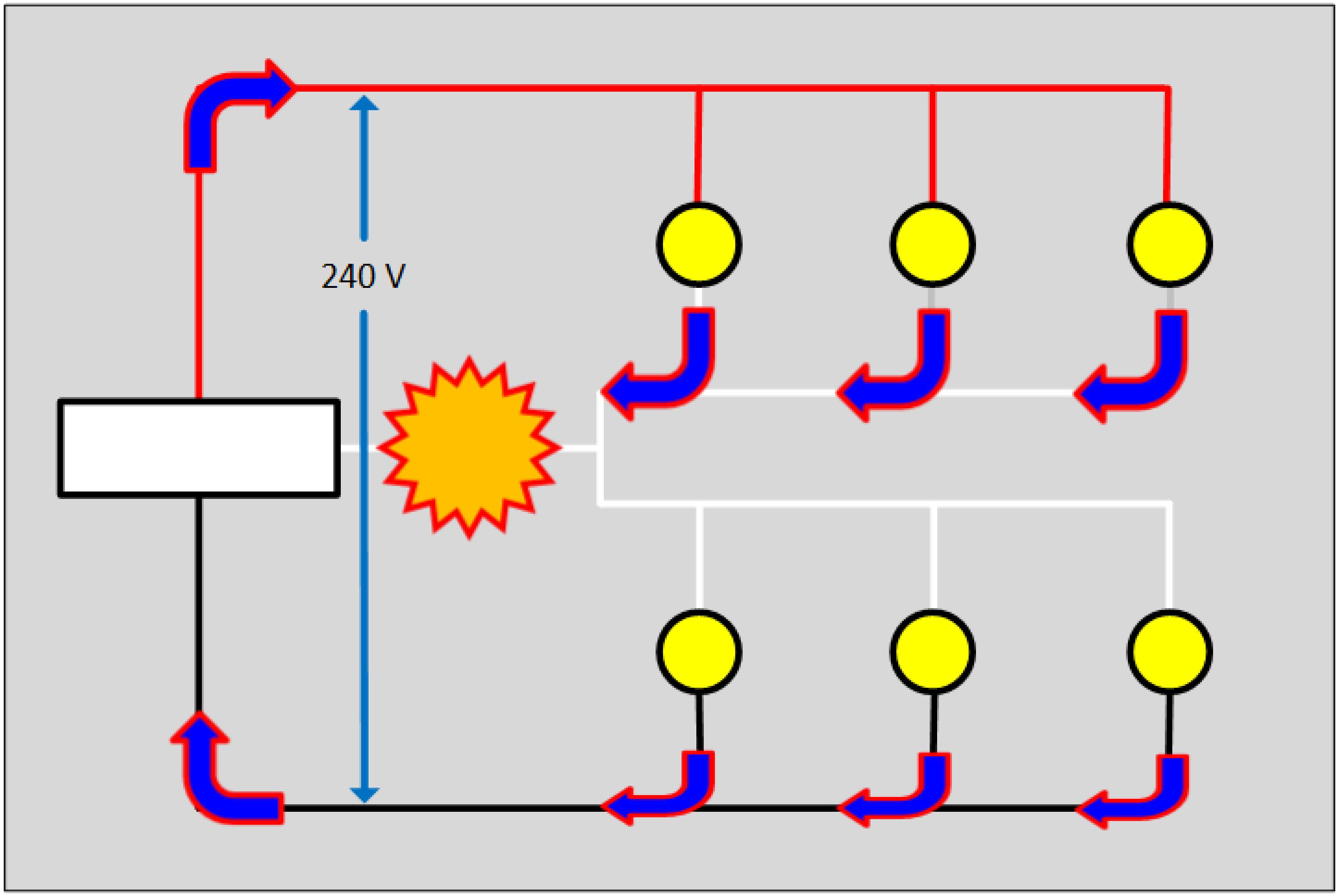
Open Neutral with Multiple Appliances



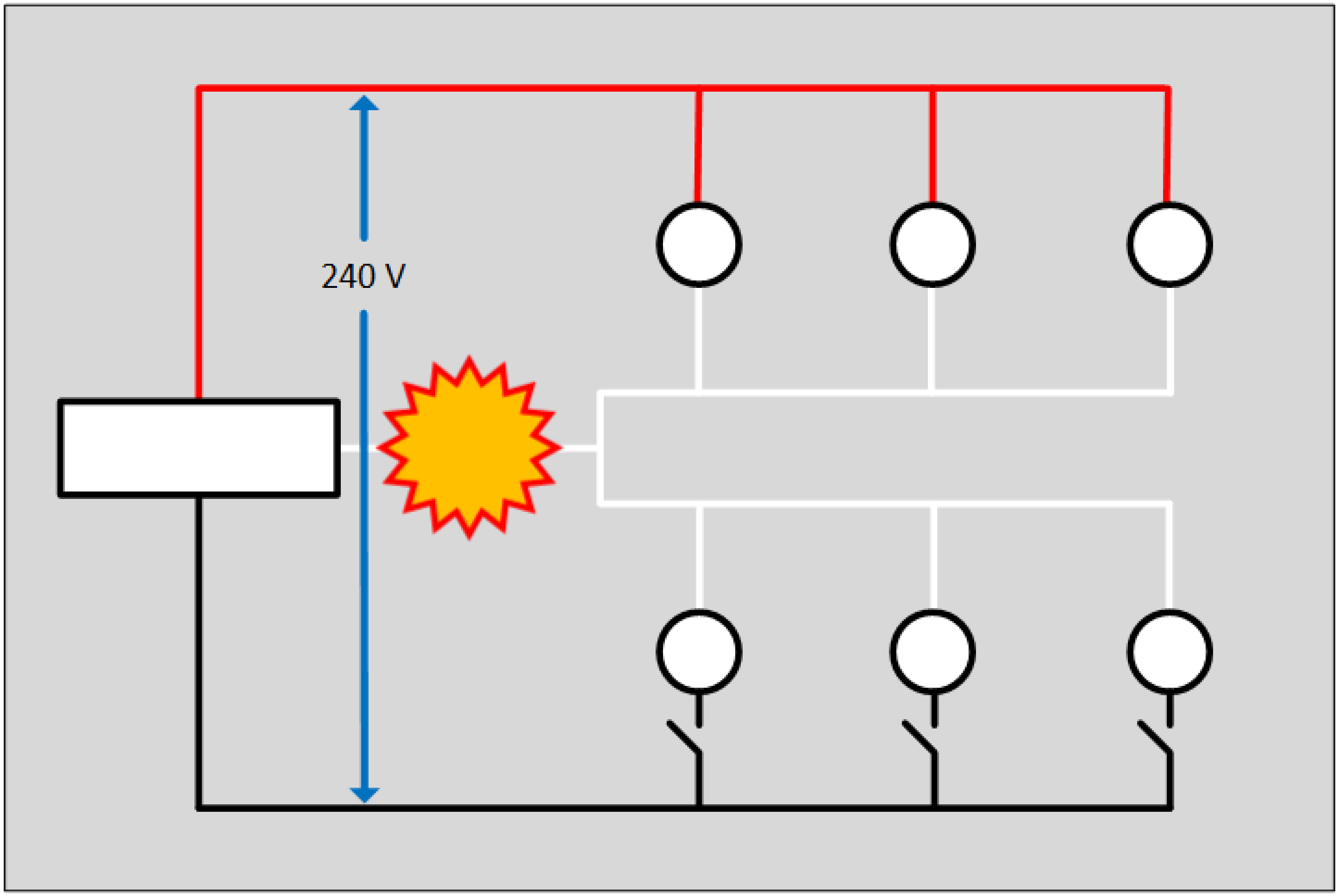
Open Neutral with Multiple Appliances



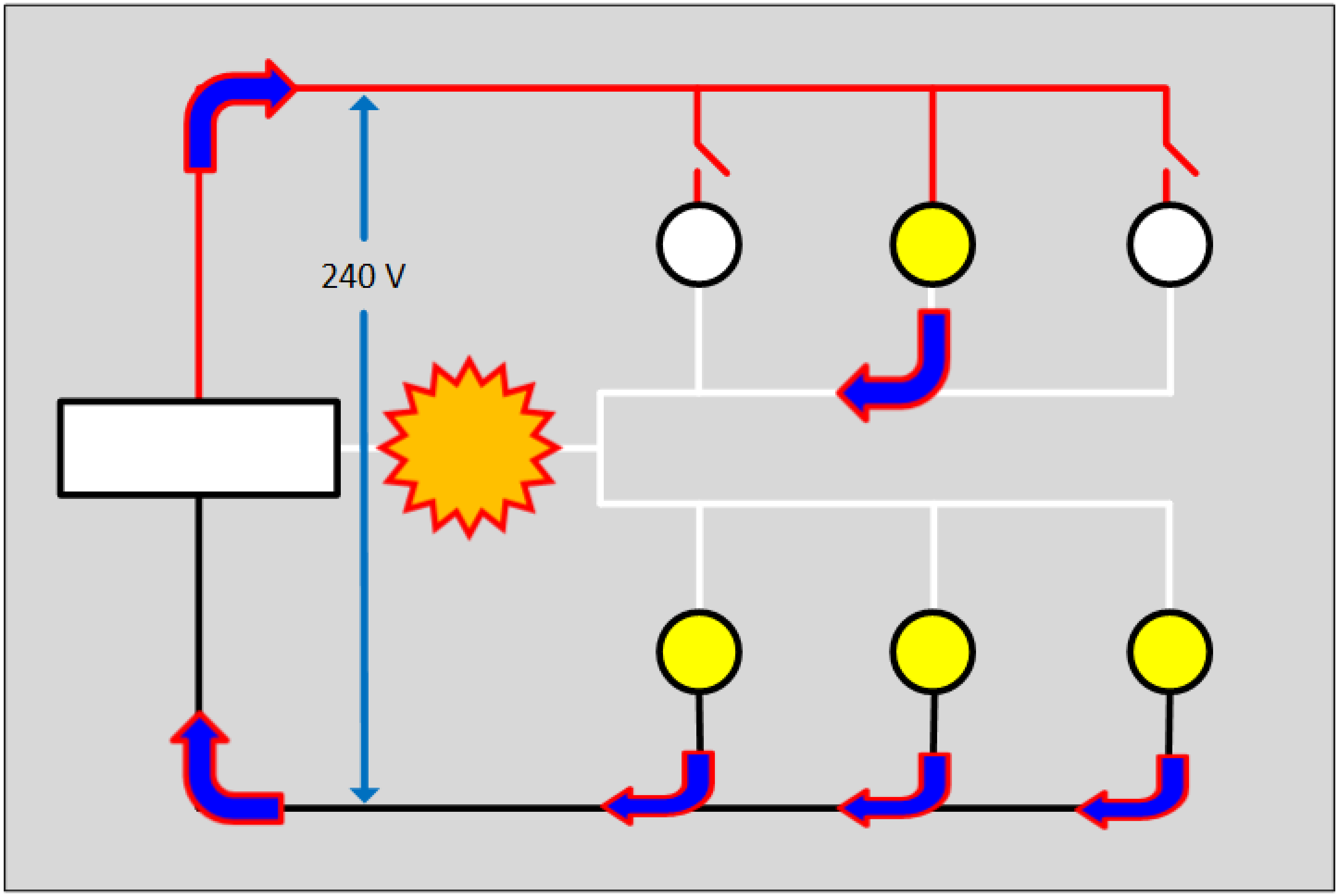
Open Neutral with Multiple Appliances

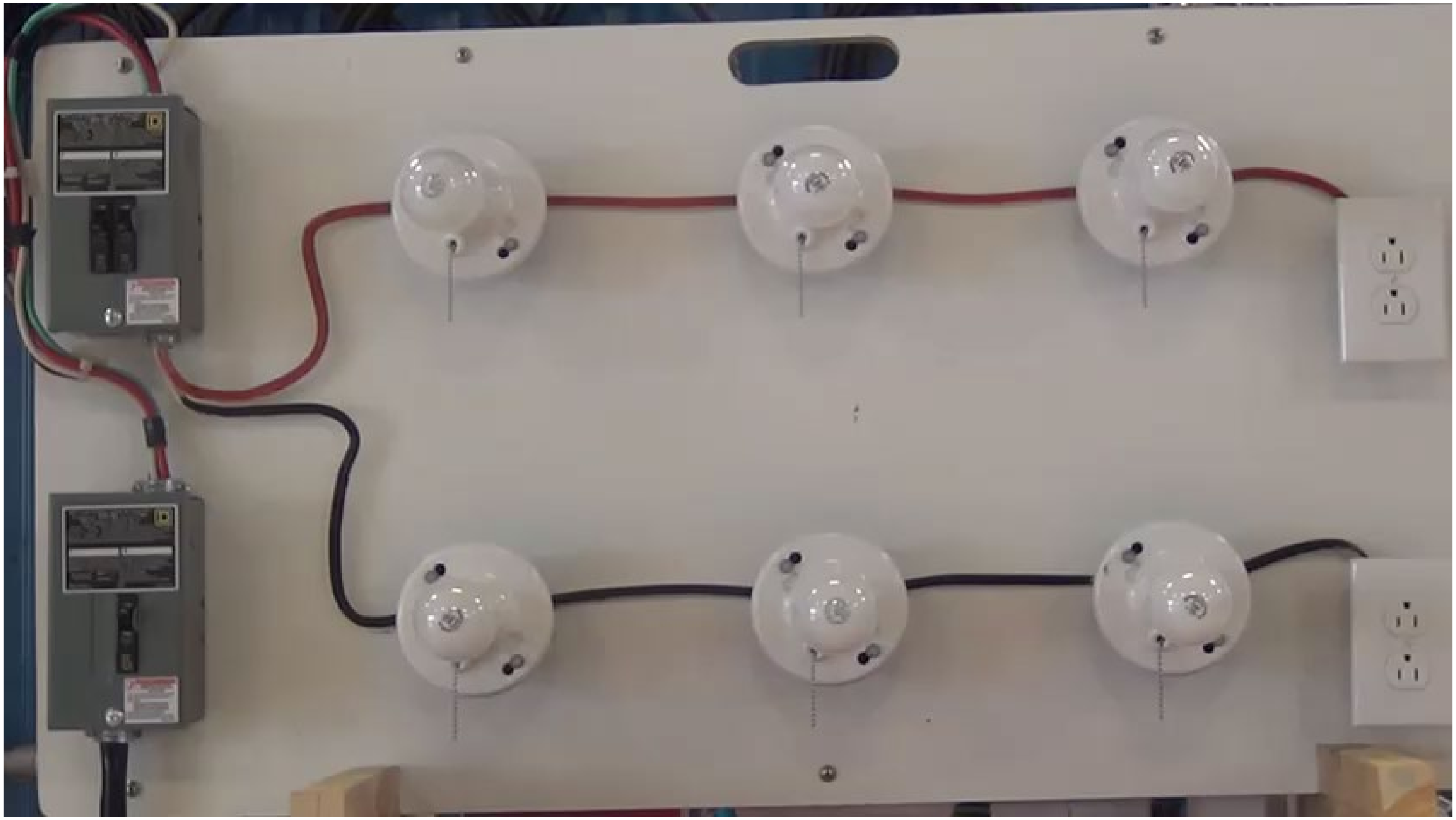


Open Neutral with Multiple Appliances



Open Neutral with Multiple Appliances





Open Neutral

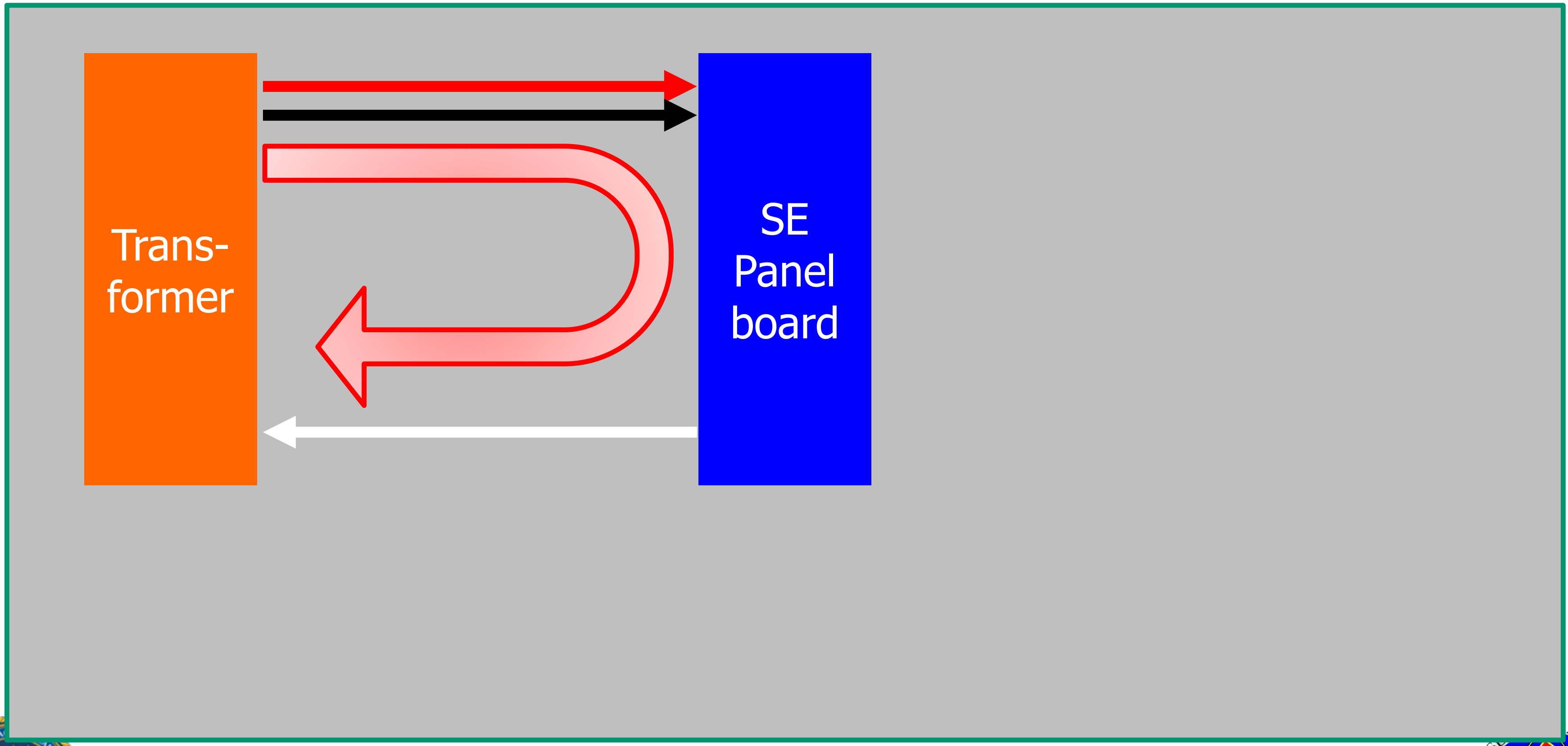
- The higher voltage can overheat or burn out some equipment.
- The lower voltage can damage electronic equipment and some motors.
- Occupants would have seen incandescent lights that were too bright or too dim or appliances that overheated or malfunctioned in some way.

Open Neutral

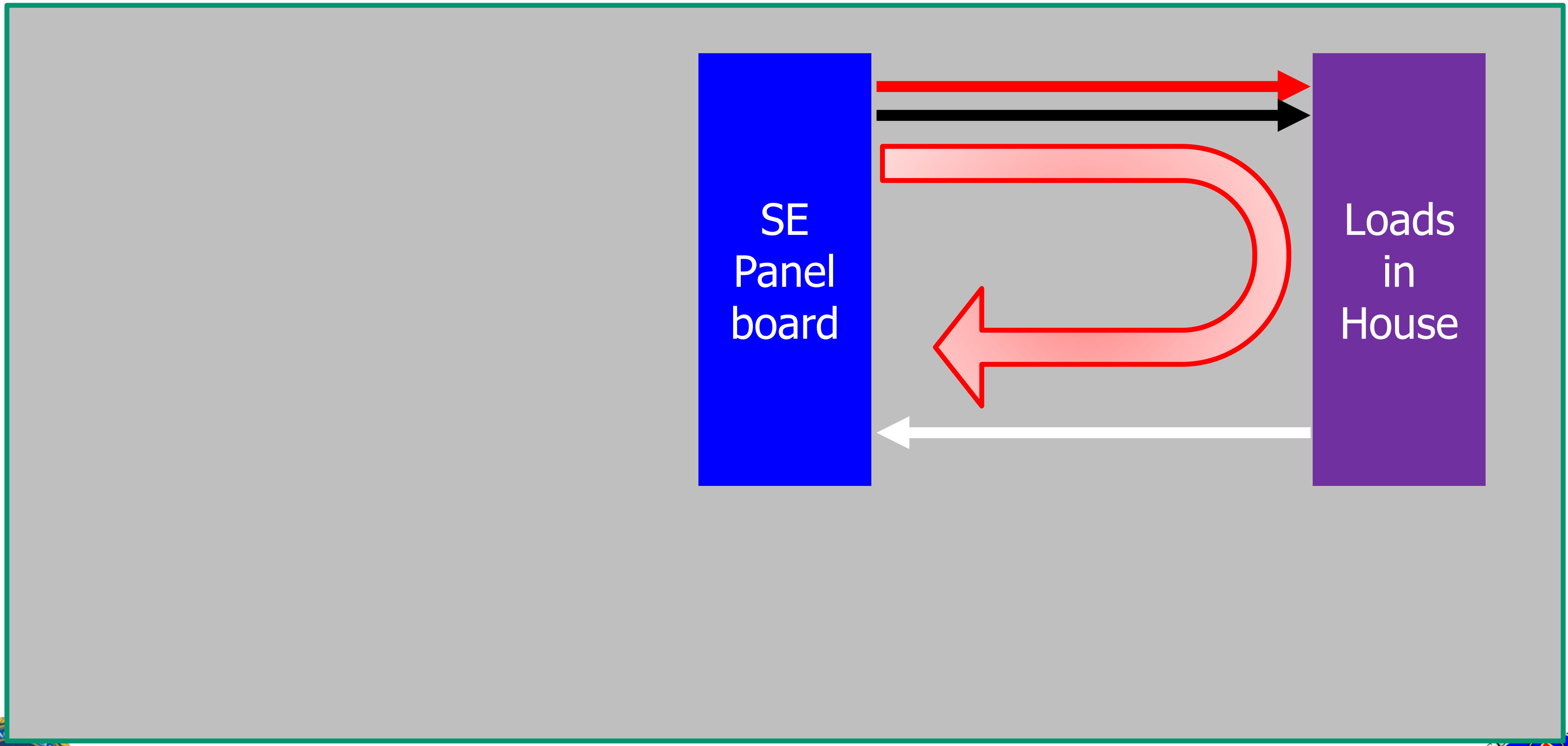
- An open neutral condition is not dependent on proper grounding of the service.

- Removing the grounding electrode does not cause an open neutral. Only a break in the neutral conductor can cause a floating neutral condition to occur.

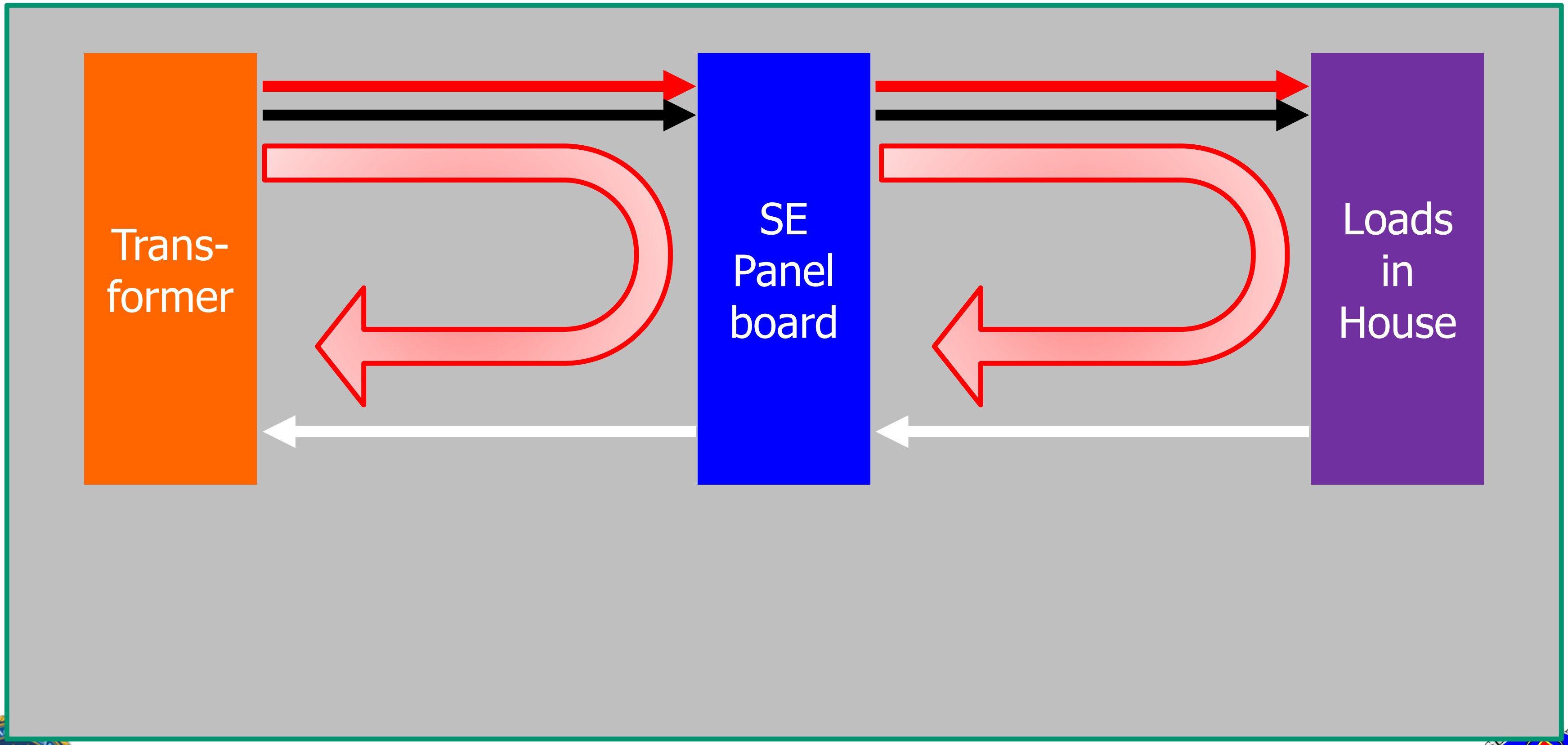
Residential Structure



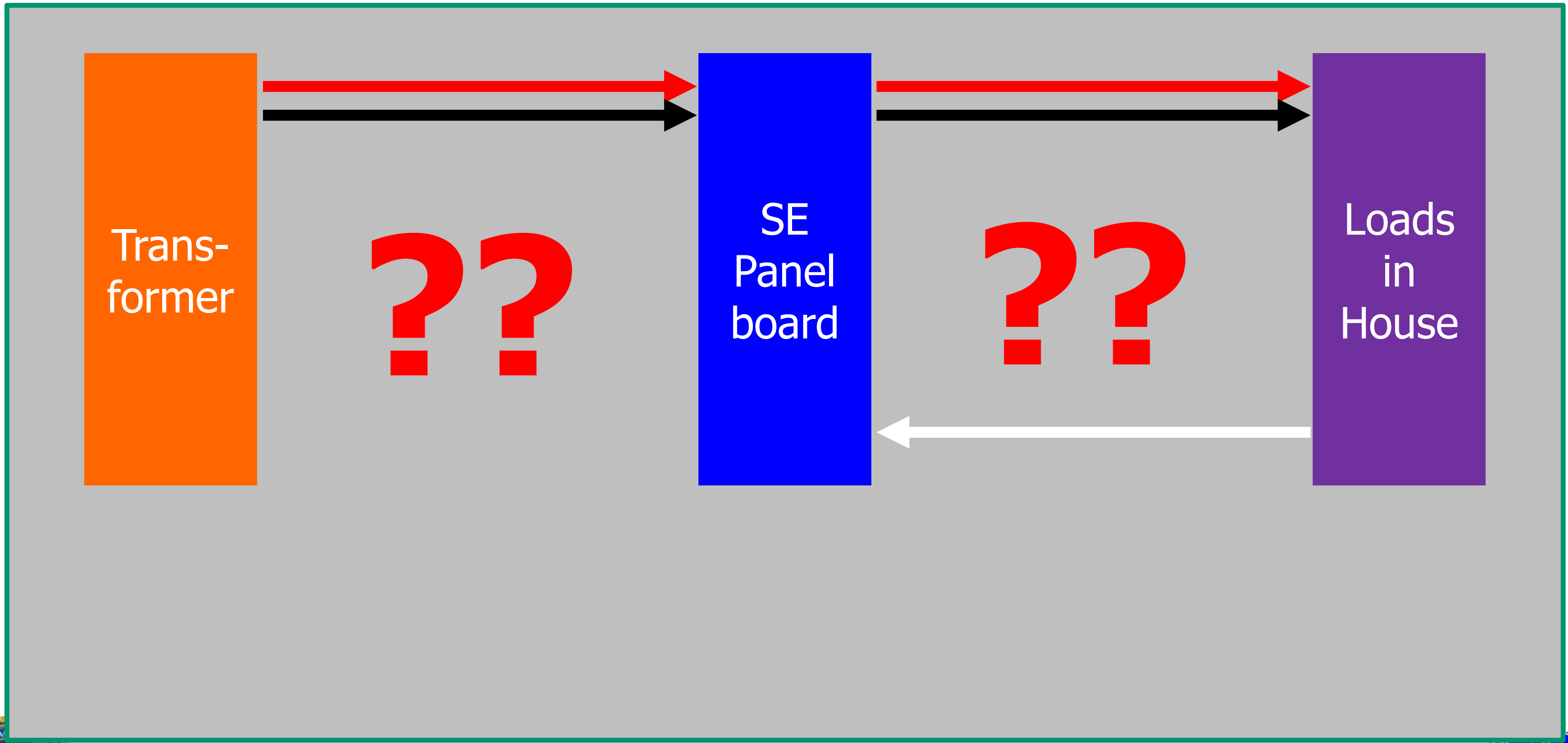
Residential Structure



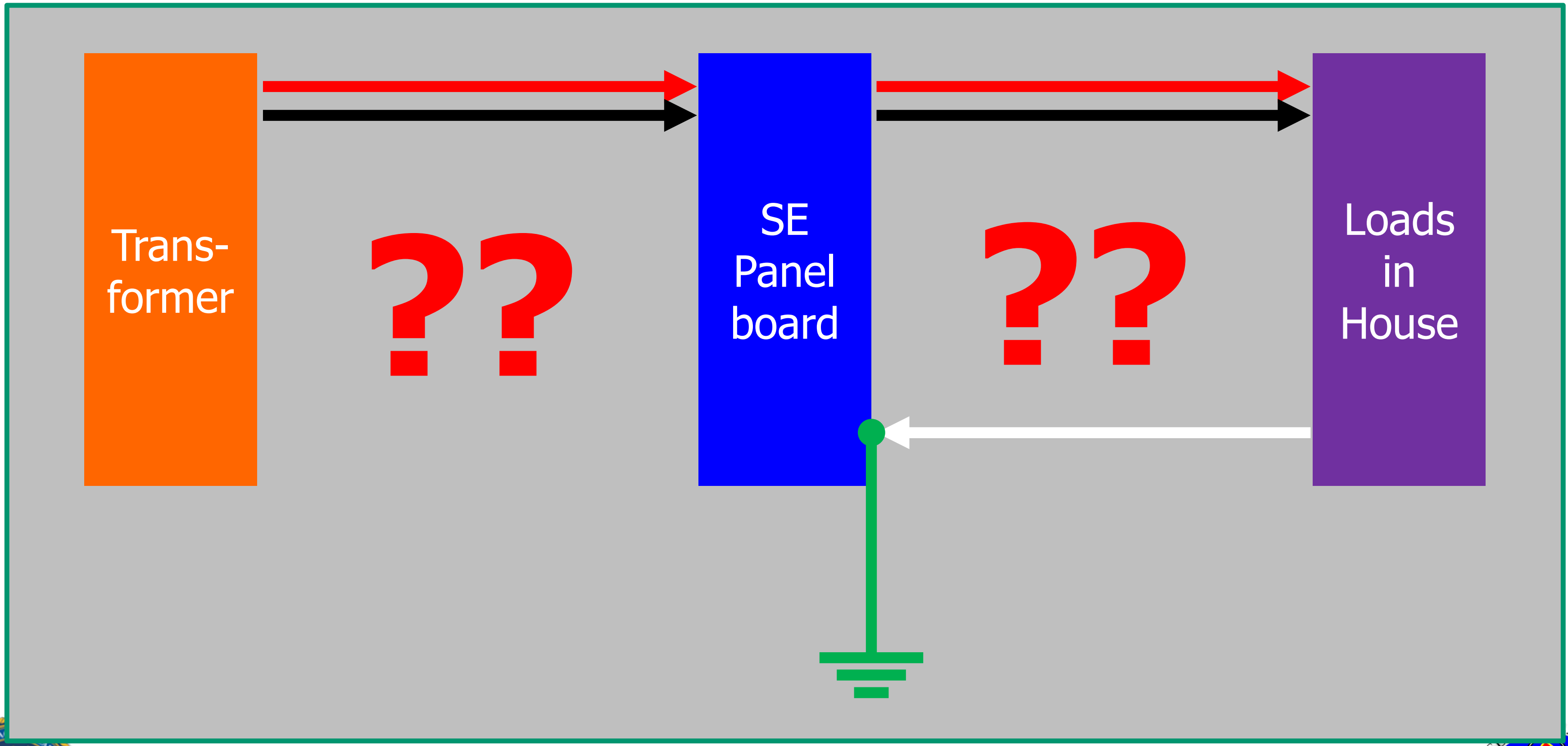
Residential Structure



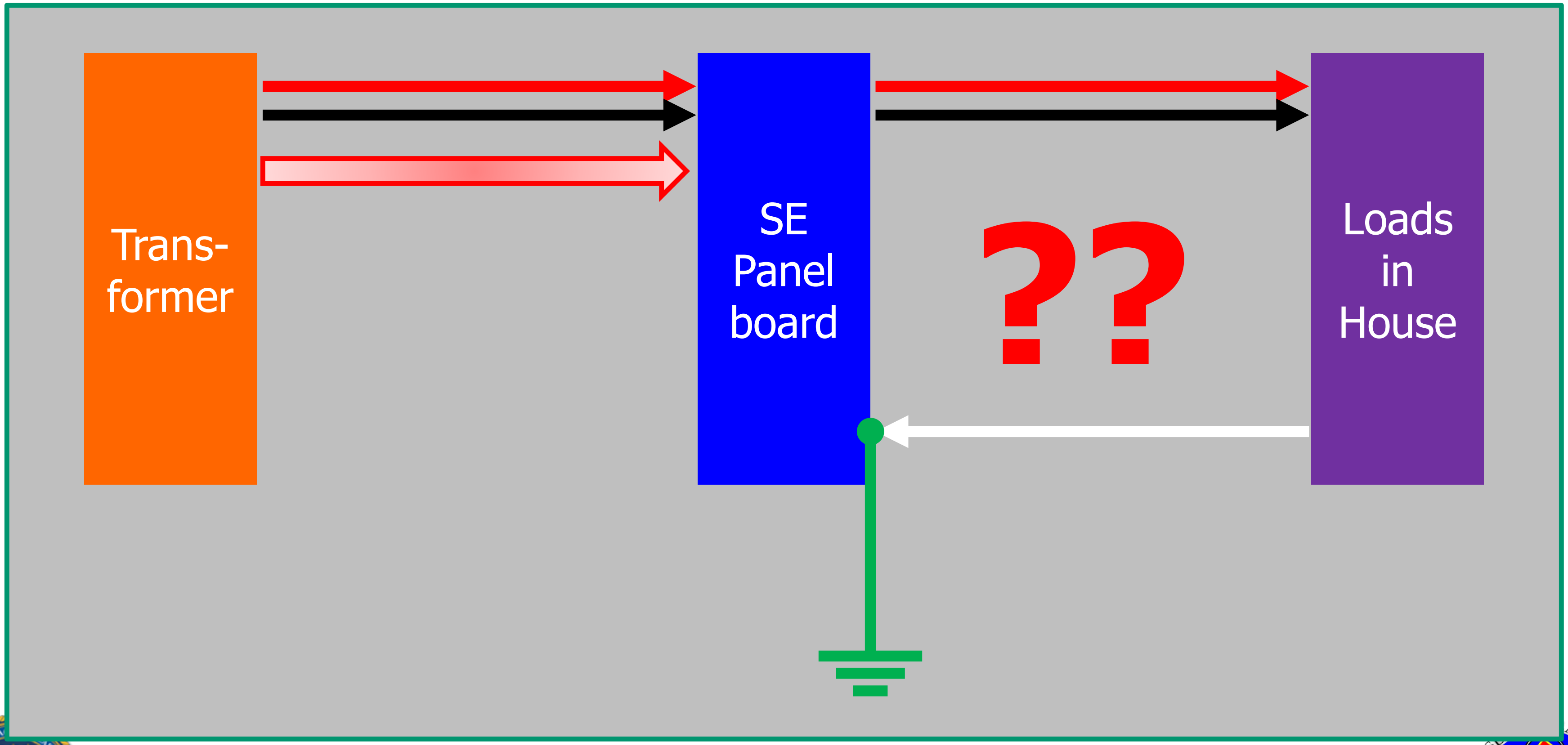
Now What?



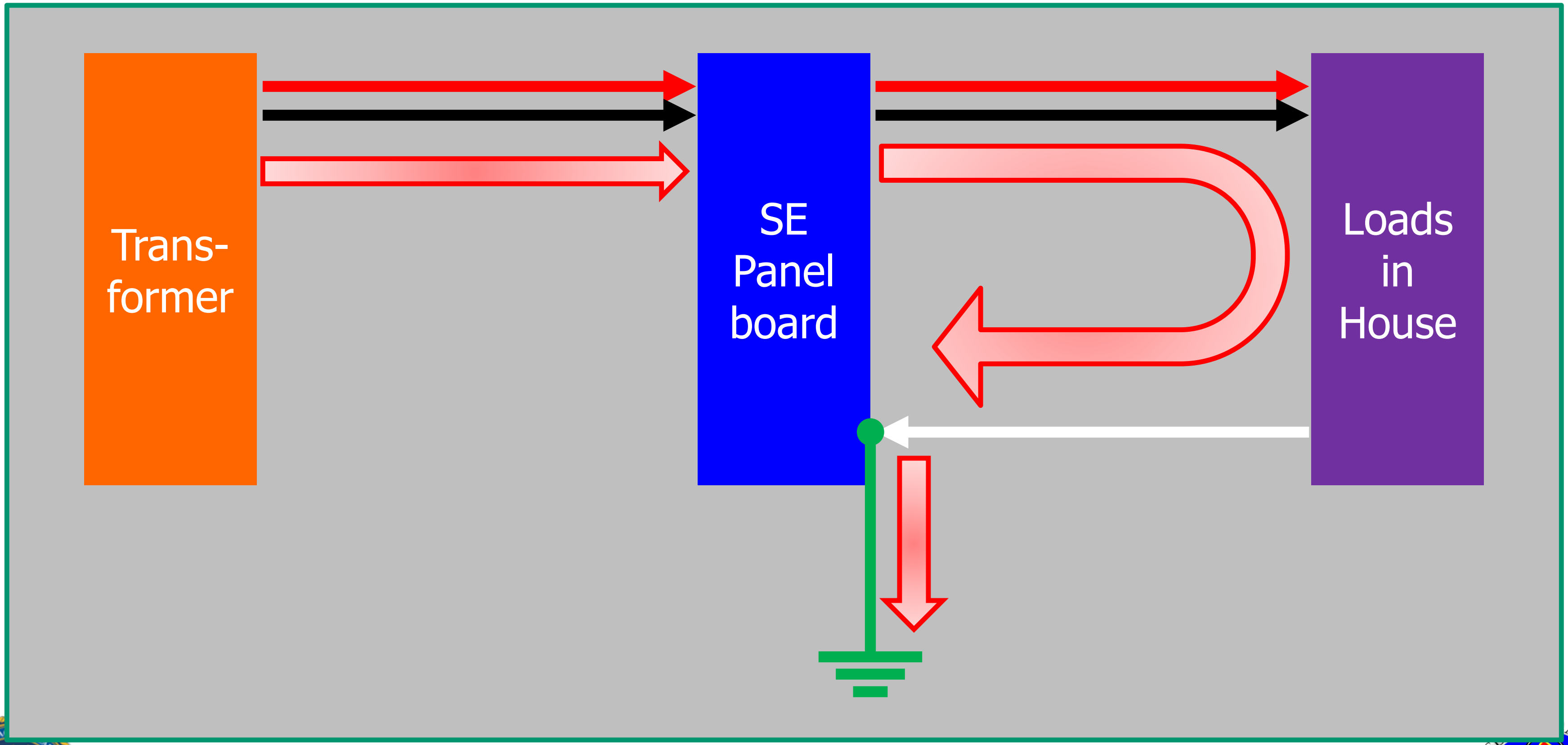
Now What?



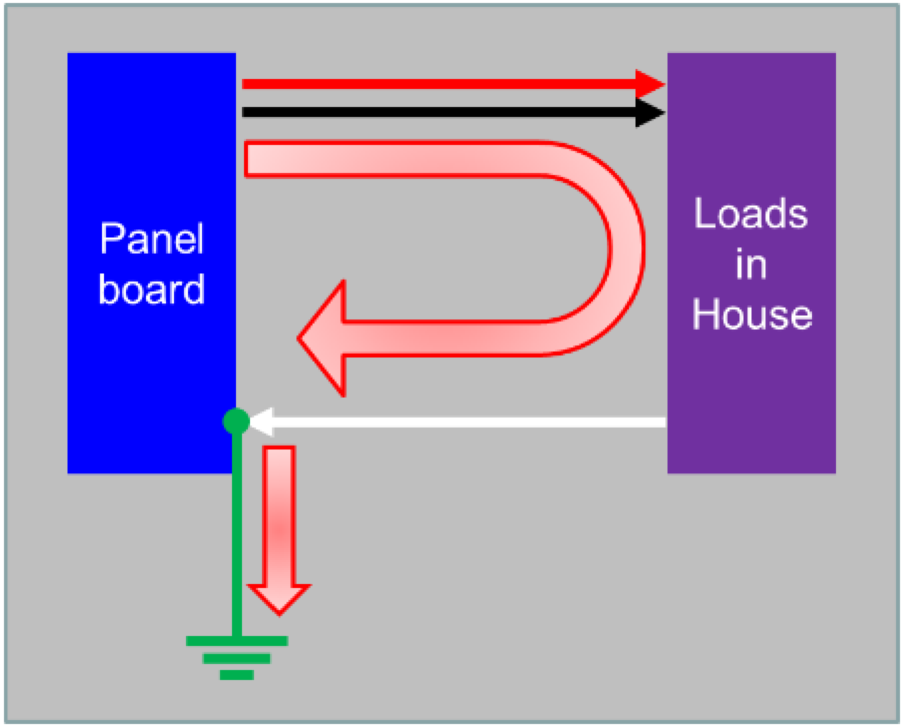
Now What?



Now What



Analysis



- How much current flows to the grounding rod?
  - Is this a problem?
  - Why?
- How long will this occur?
- What will prevent this?

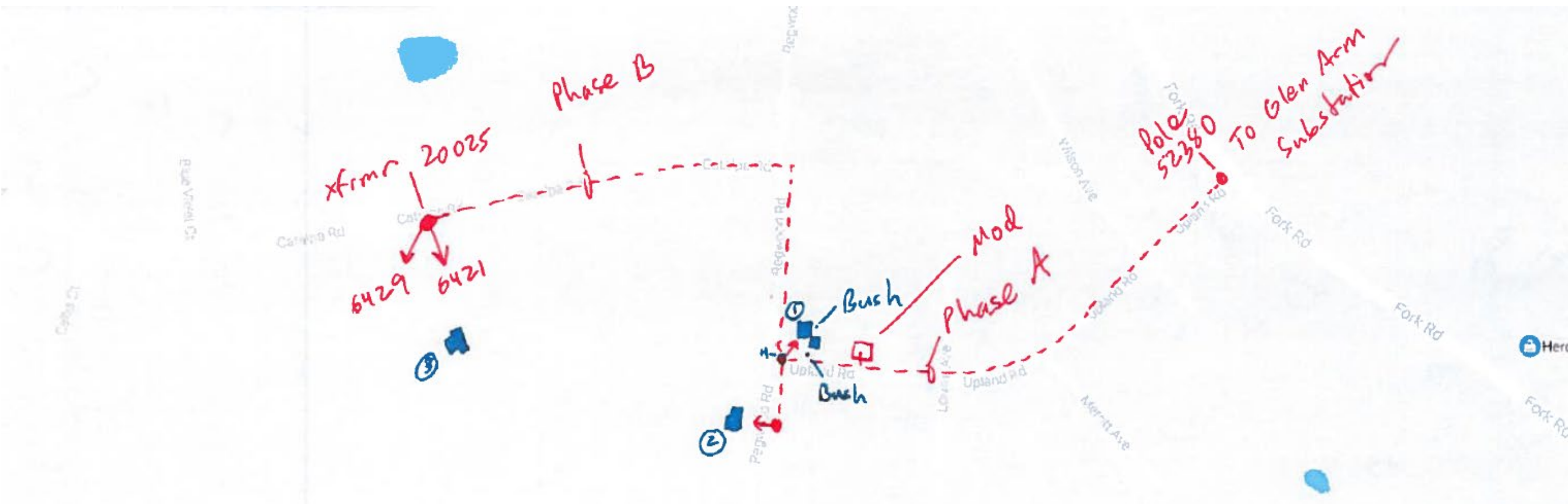
Open Neutral Fires

- Fires resulting from an open neutral can be caused by:
  - Resistance heating
    - Wires sized too small
    - Connections
    - Conductors that normally do not carry any current
  - Damage from voltage fluctuations
    - Motors
    - Ballasts
    - Electronics

Cross Line Failure

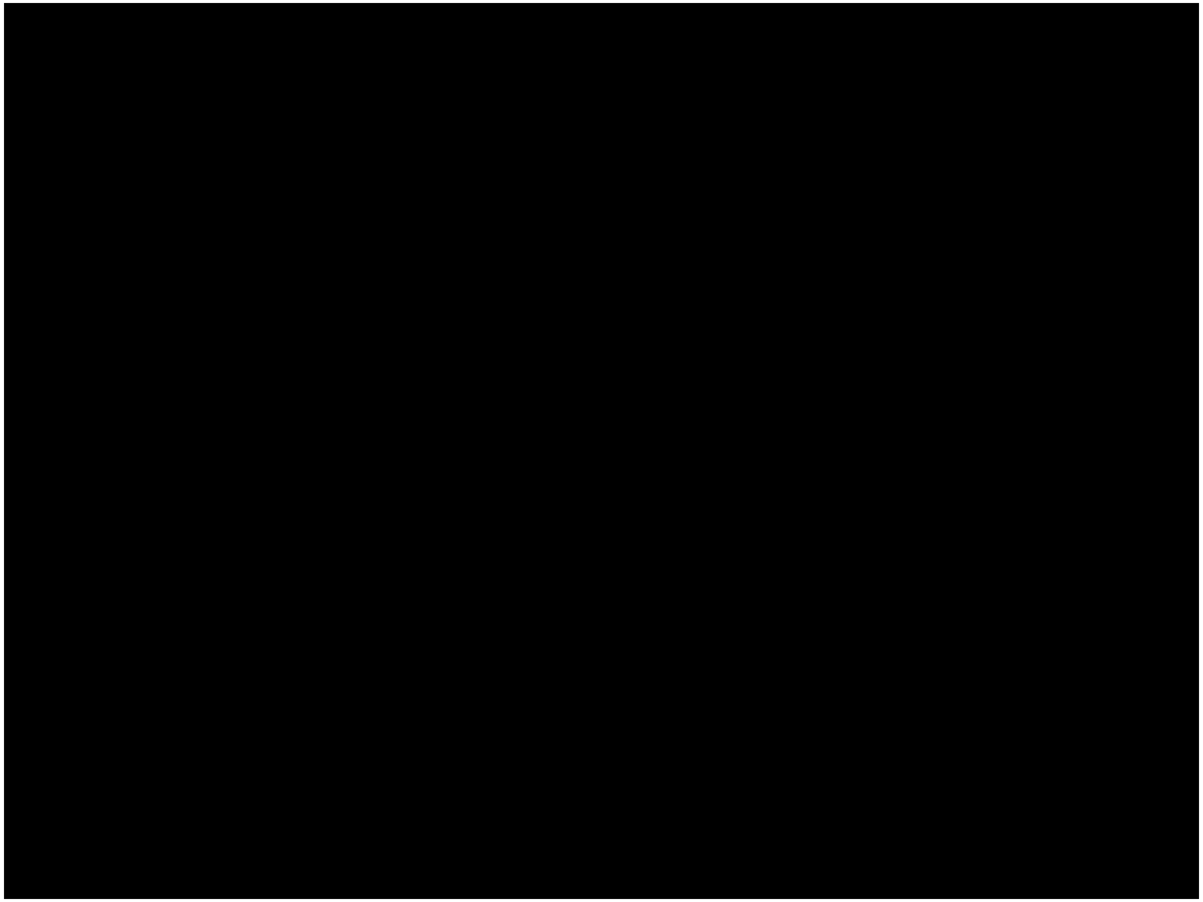
Glowing Fence

The Burning Bush



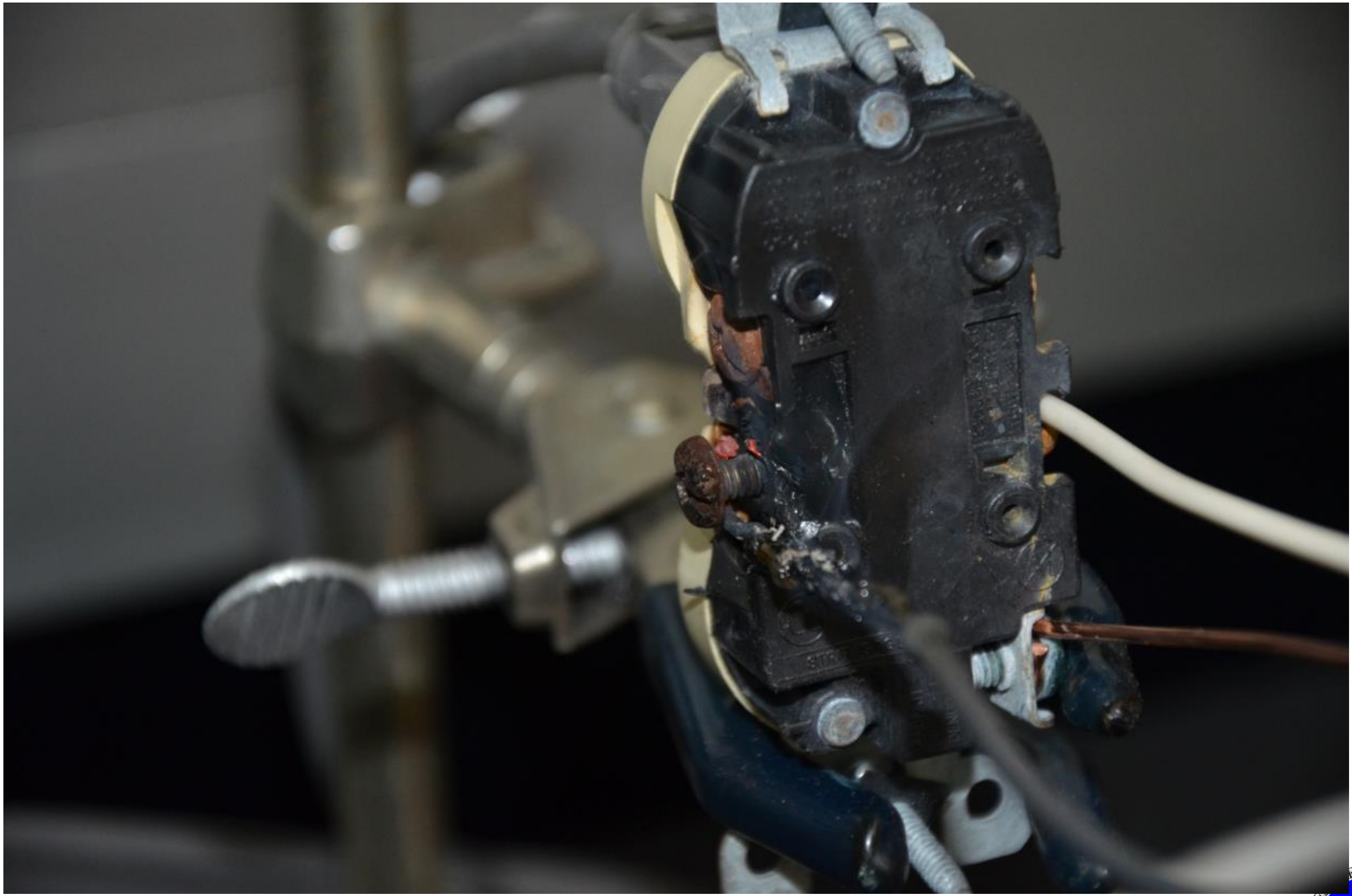
FIRE RESEARCH LABORATORY
ATF

FIRE RESEARCH LABORATORY
ATF



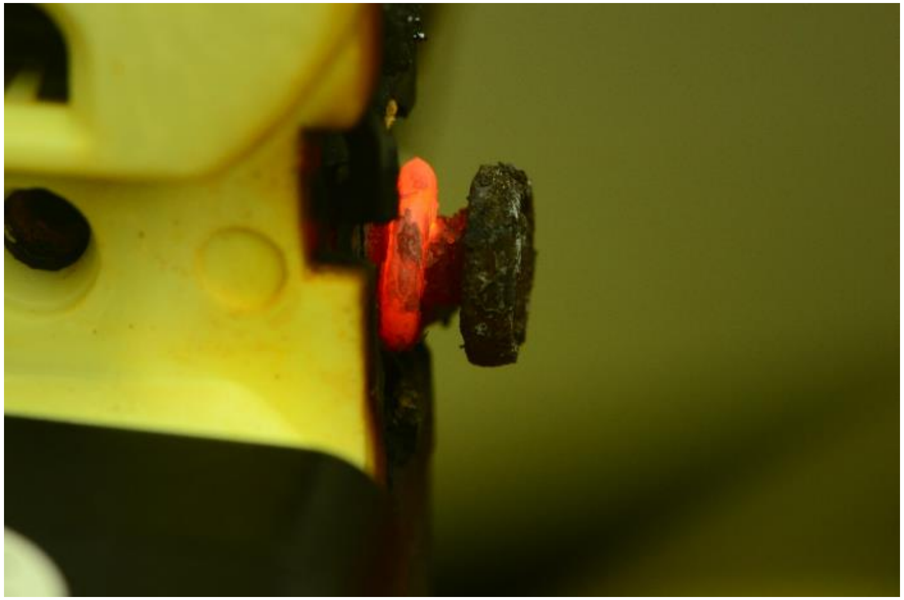
Receptacles

Receptacle Failure



Receptacle Failure

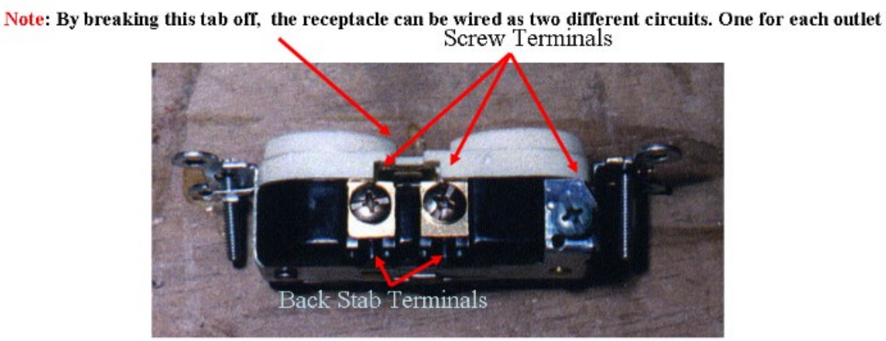
Receptacle Failure



Receptacle Failure

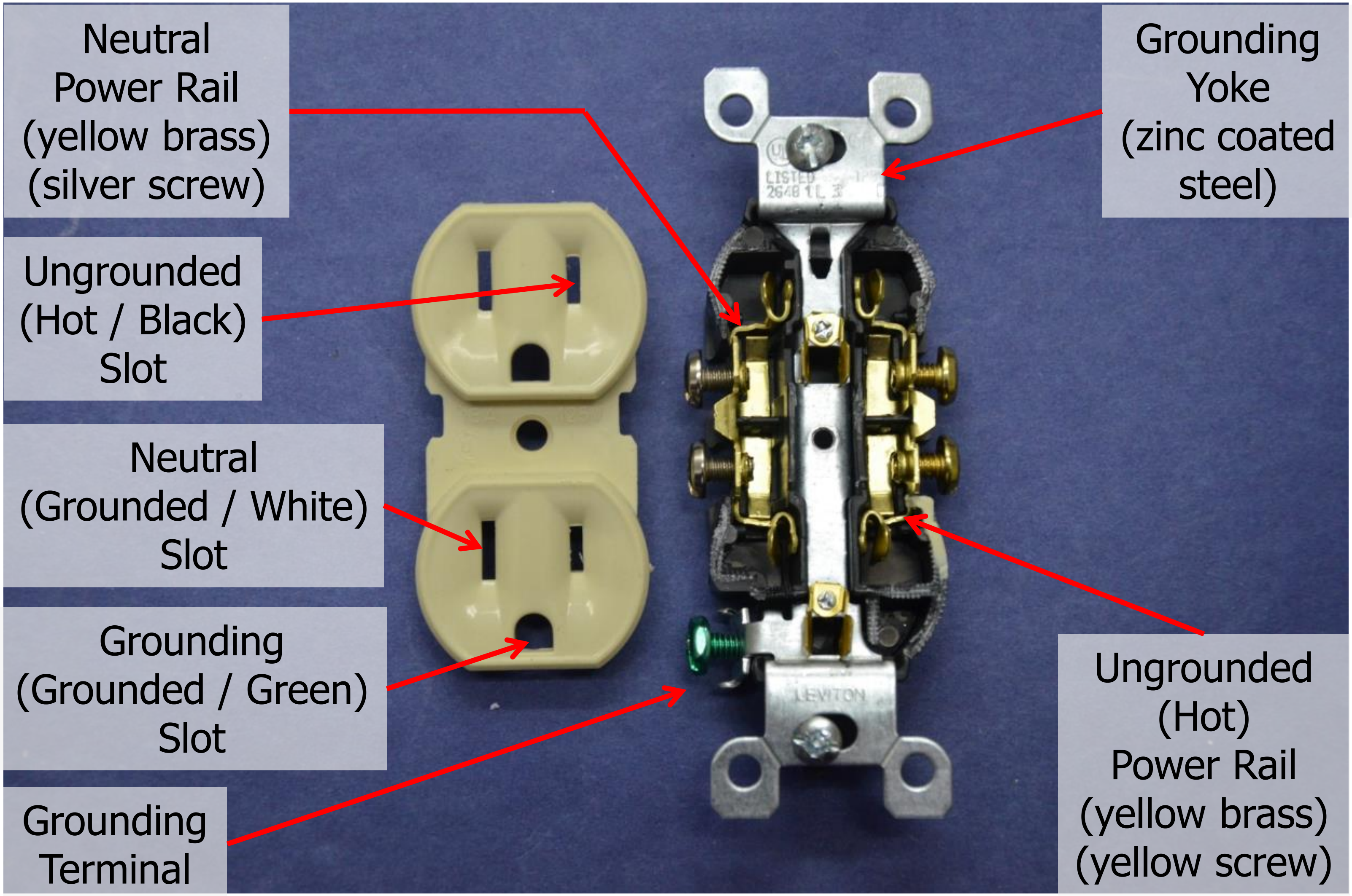
Damaged Receptacle

Loose Connections

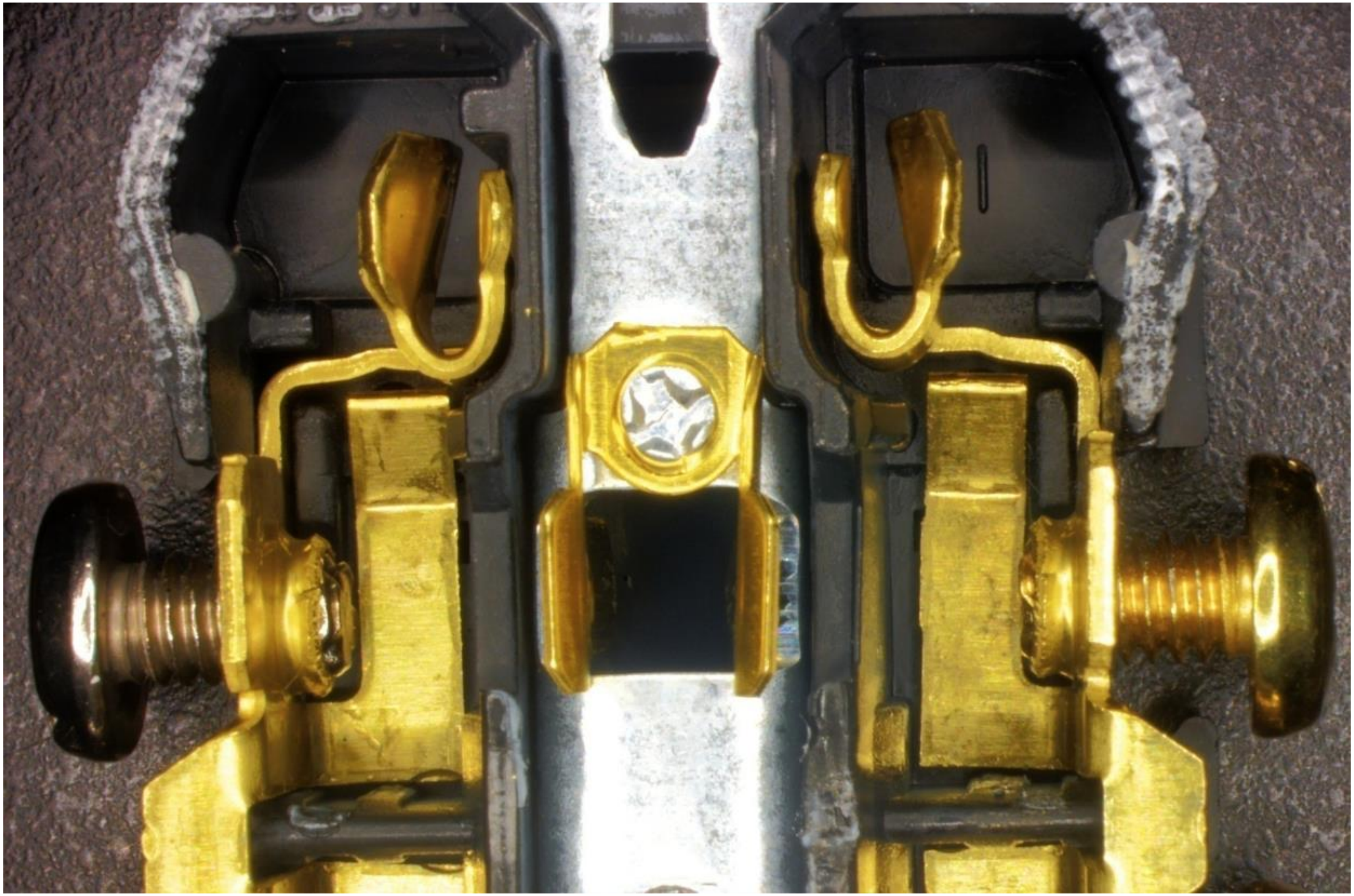


- A standard receptacle can be screw terminal or push terminal (back stabbed) connected
- Back Stabbing of connections caused fires in the past - NOT because this is a bad way to connect wires but because the terminals allowed the use of 12 AWG wire
- When the receptacles were pushed back into the outlet box the heavy gauge wire placed pressure on the plastic body which then 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

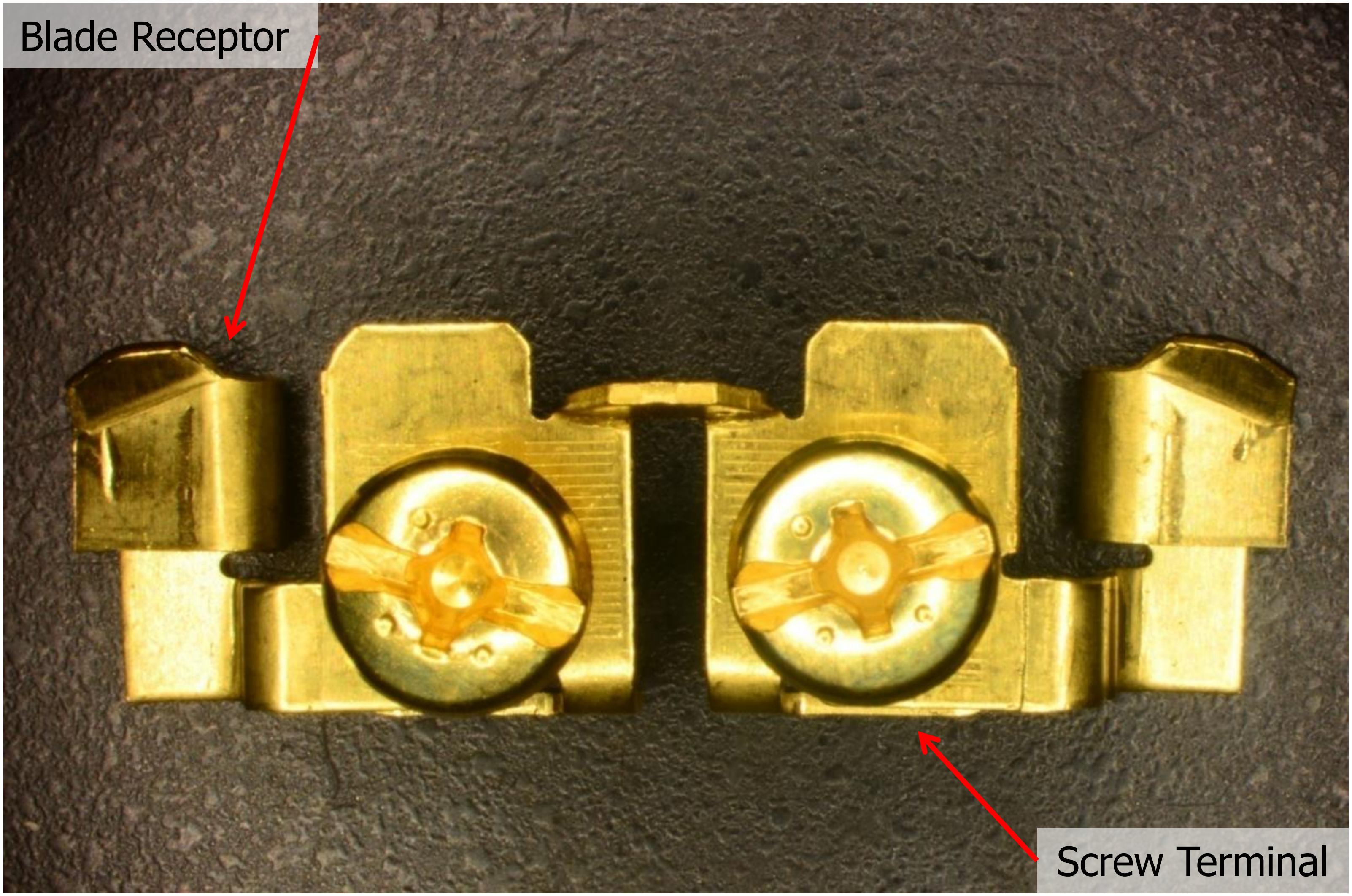
15 Amp Receptacle



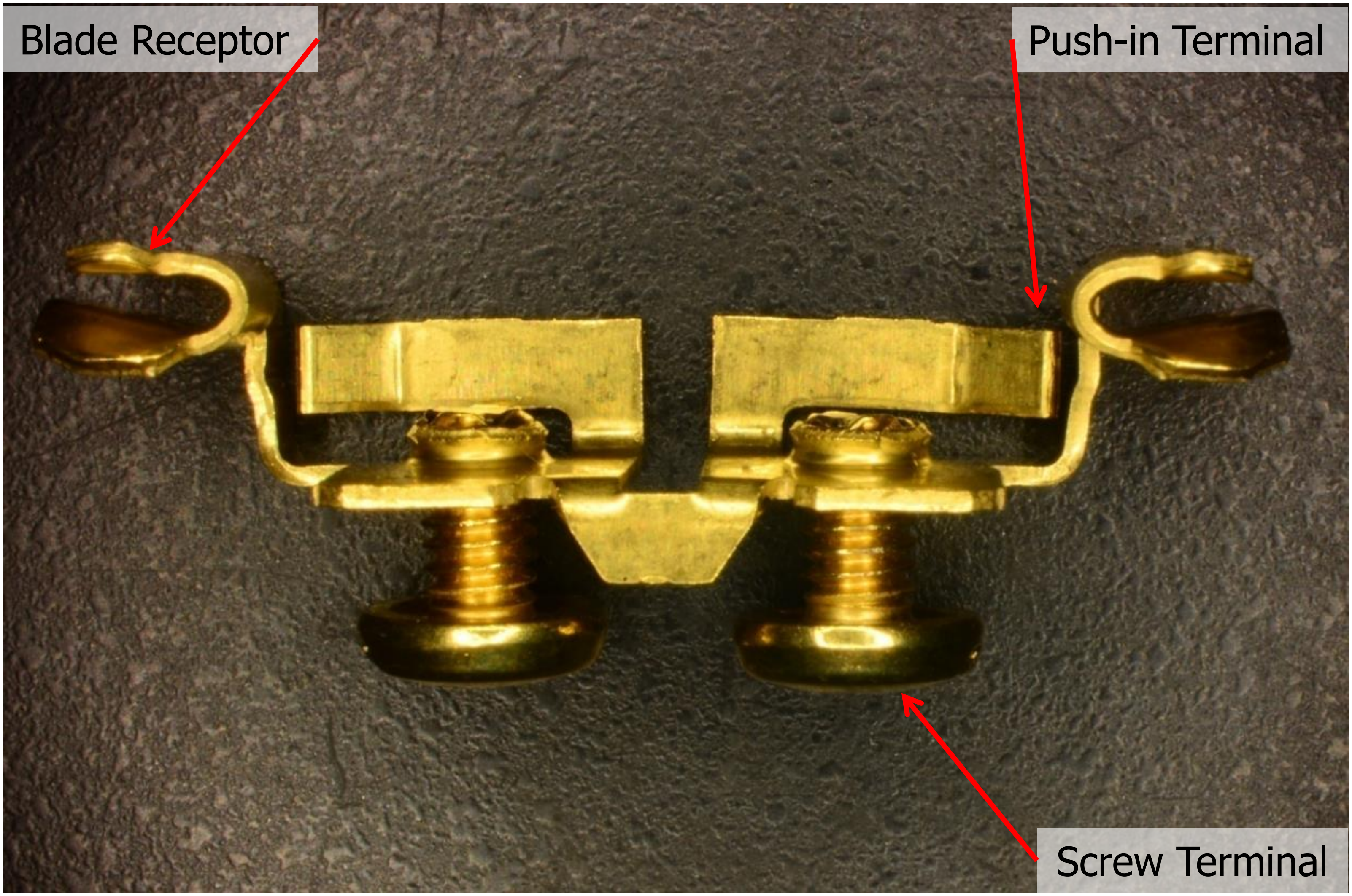
15 Amp Receptacle



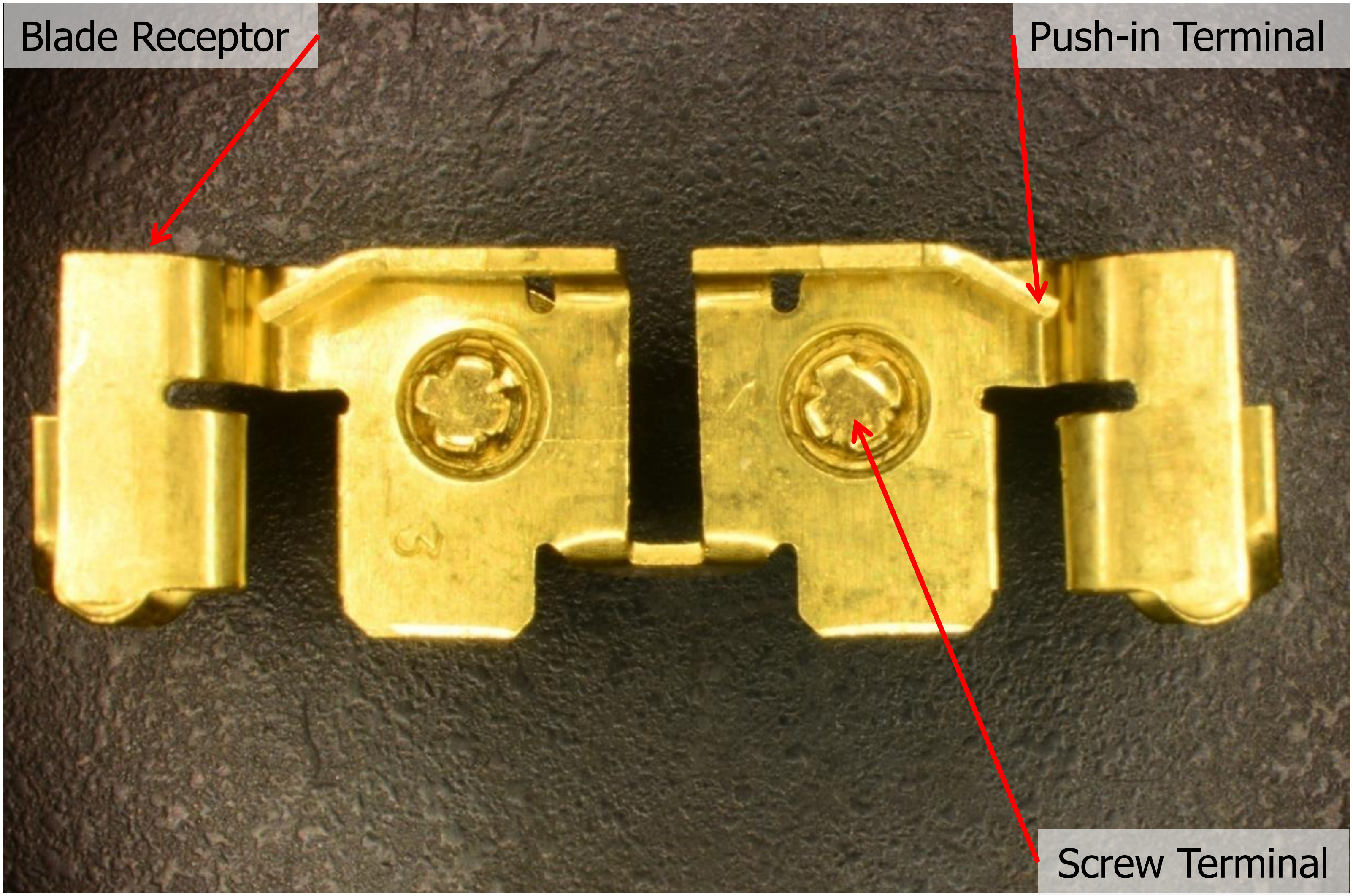
15 Amp Power Rail



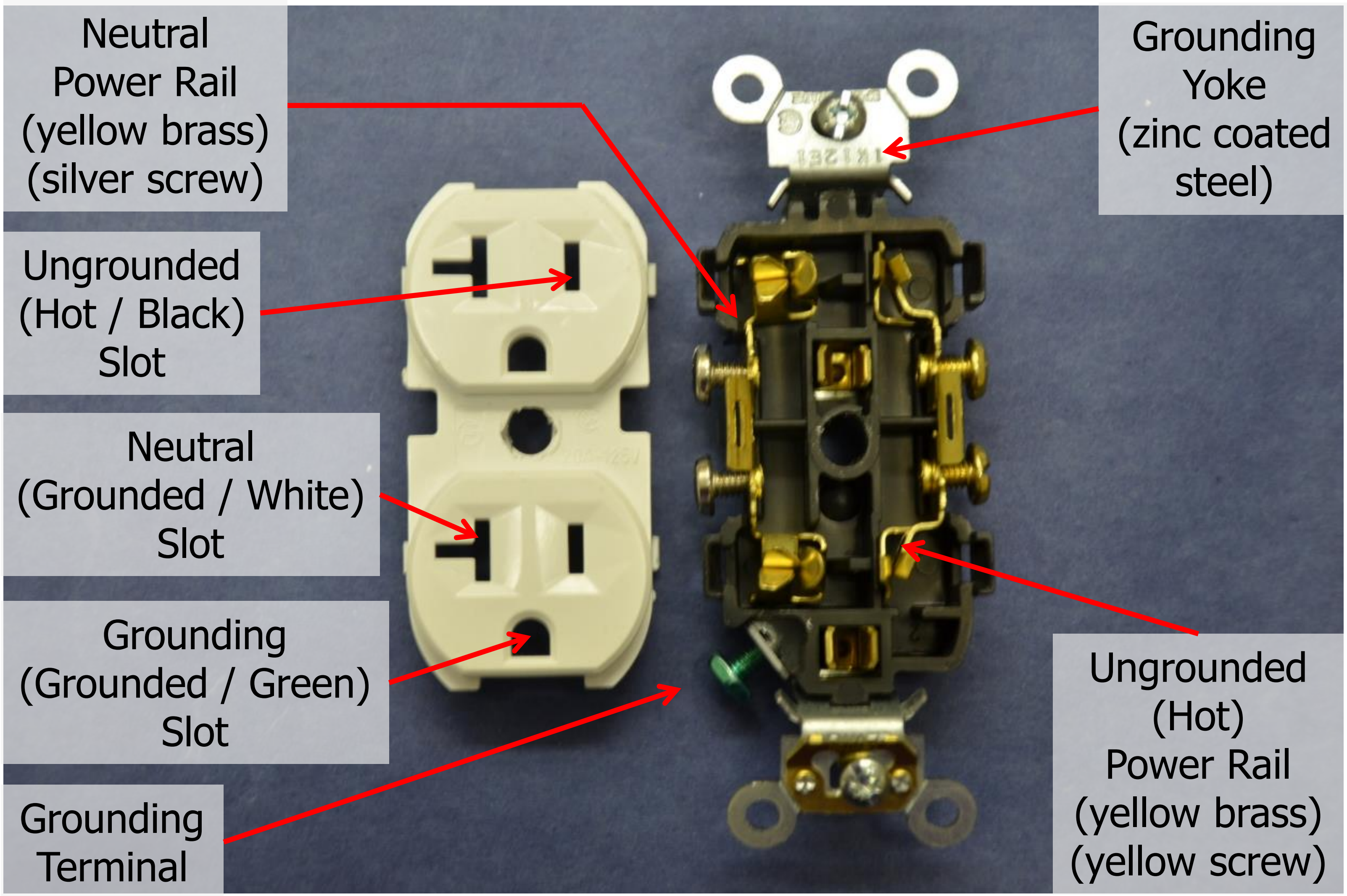
15 Amp Power Rail



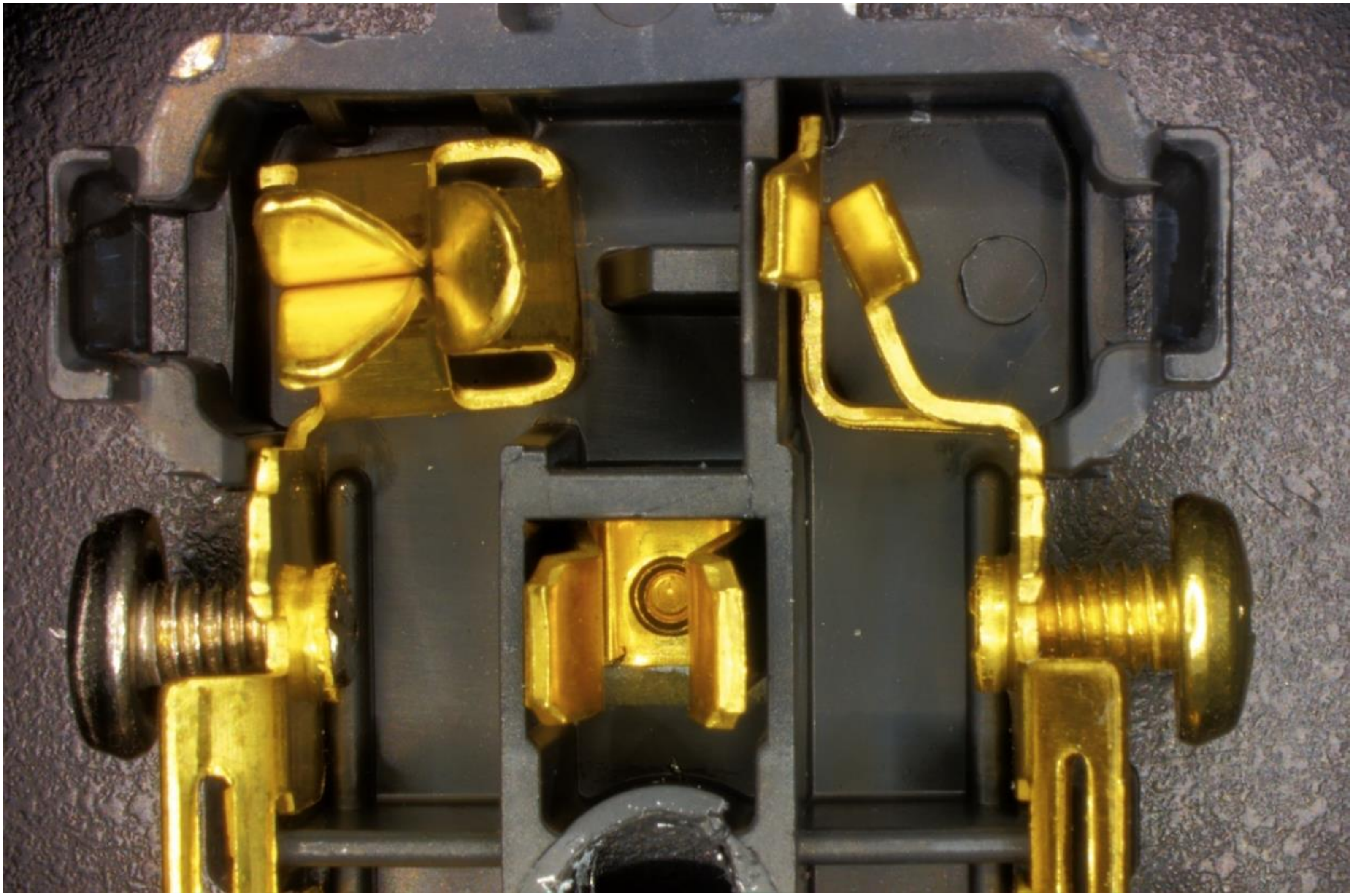
15 Amp Power Rail



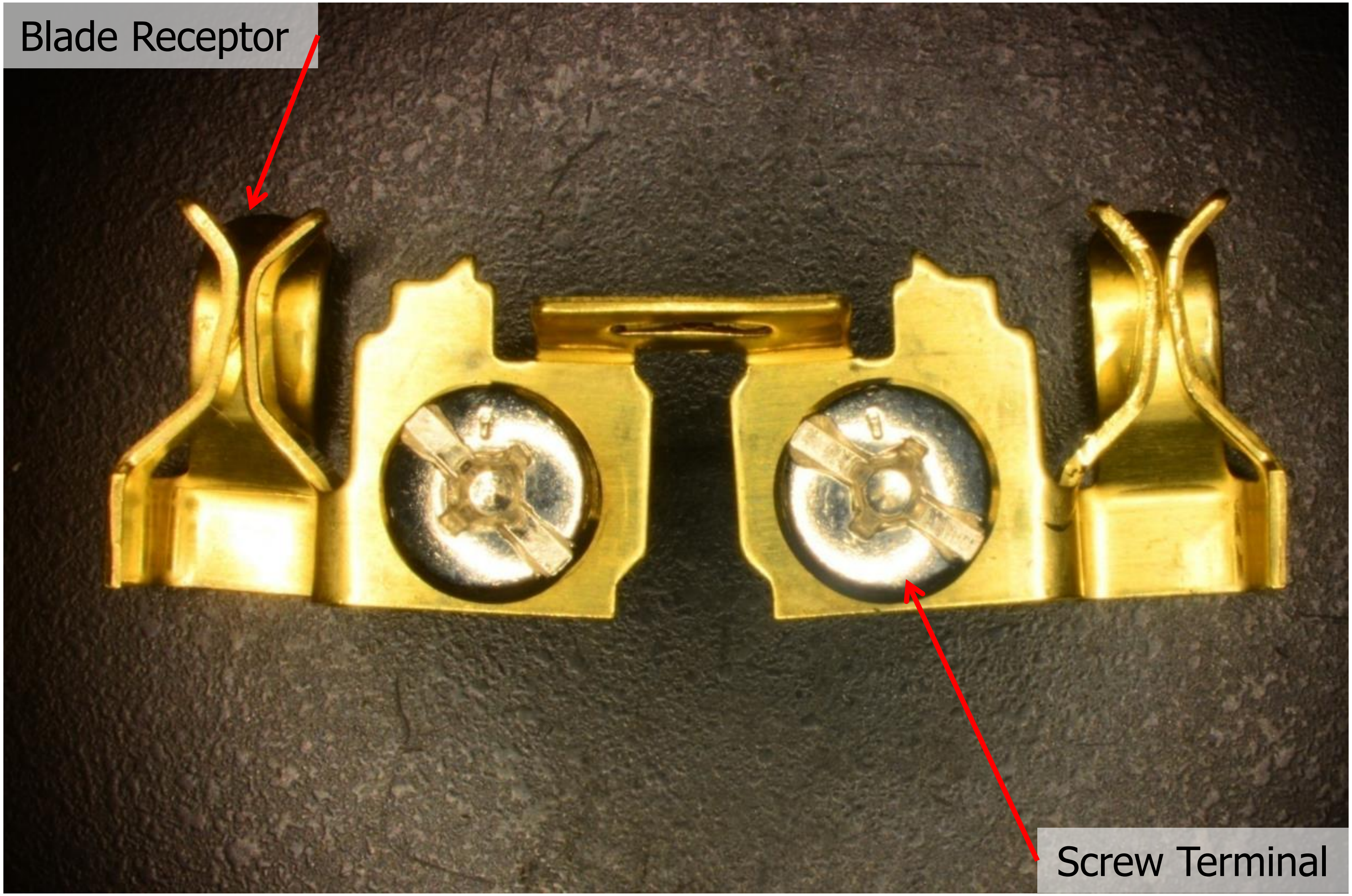
20 Amp Receptacle



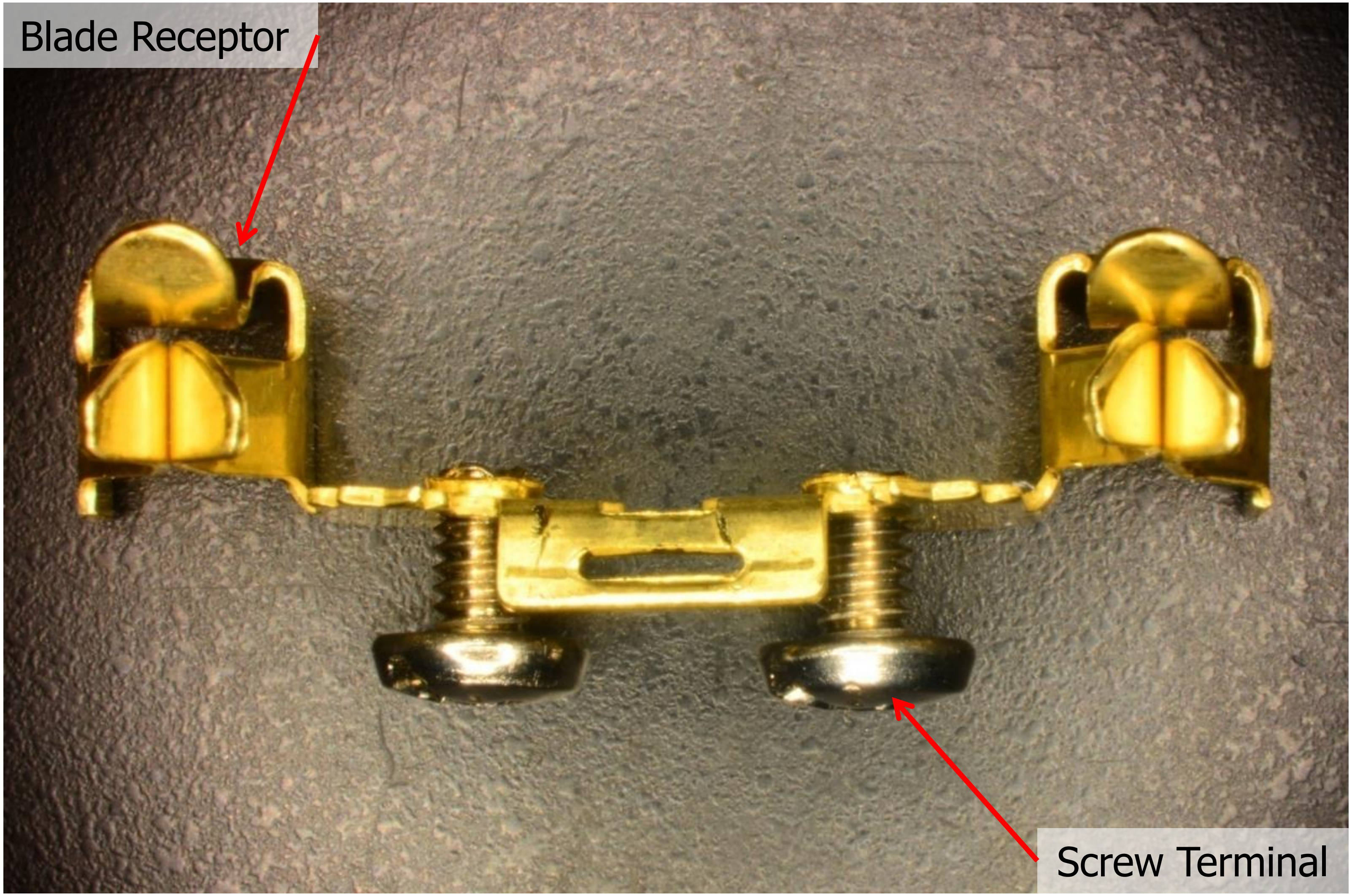
20 Amp Receptacle



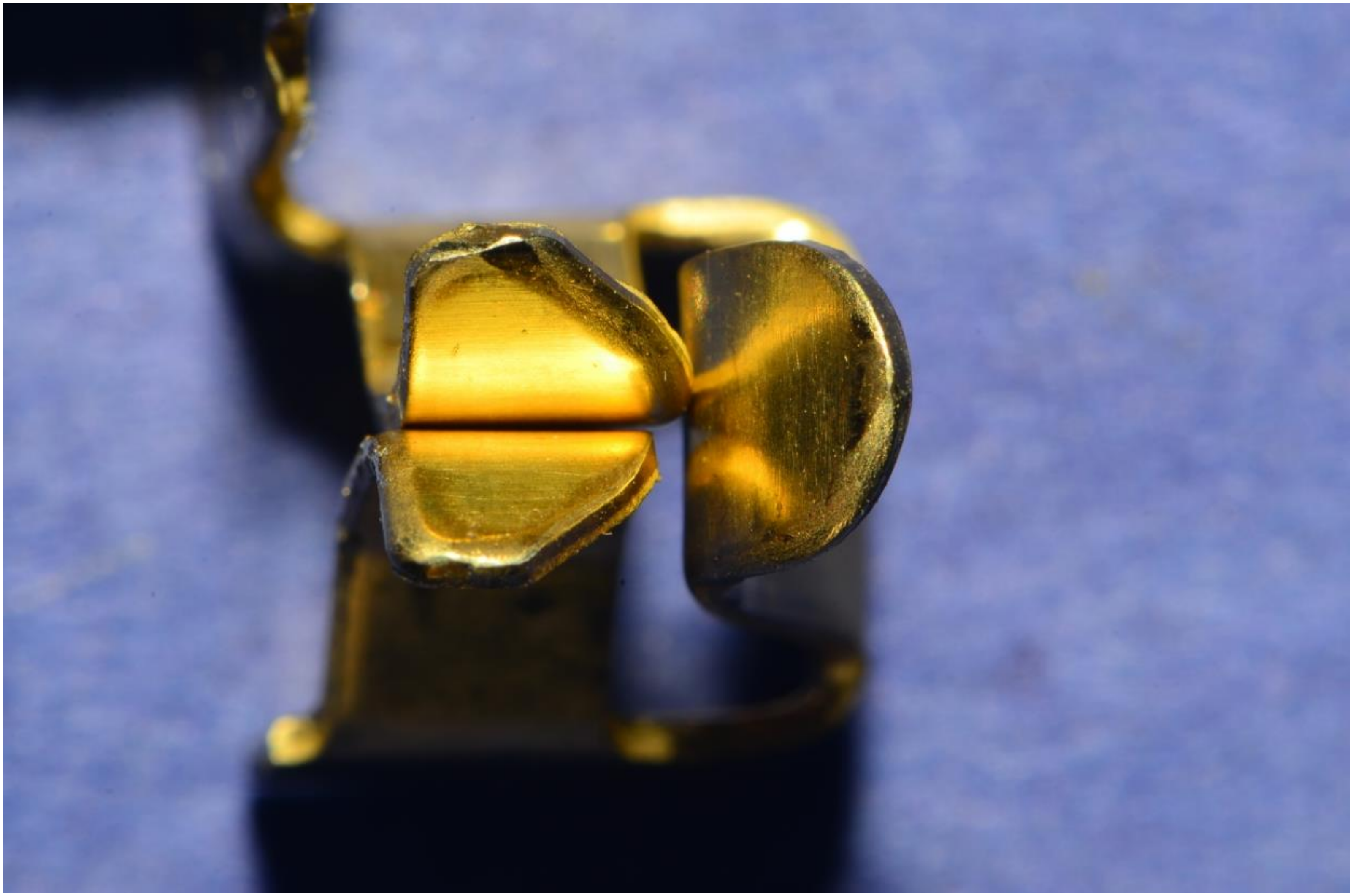
20 Amp Neutral Power Rail



20 Amp Neutral Power Rail

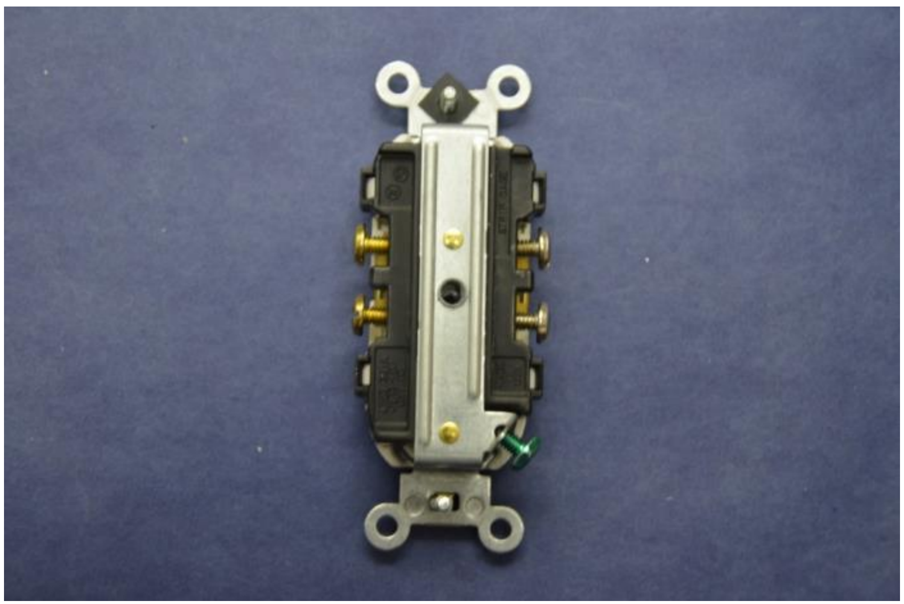


20A Neutral Blade Receptor

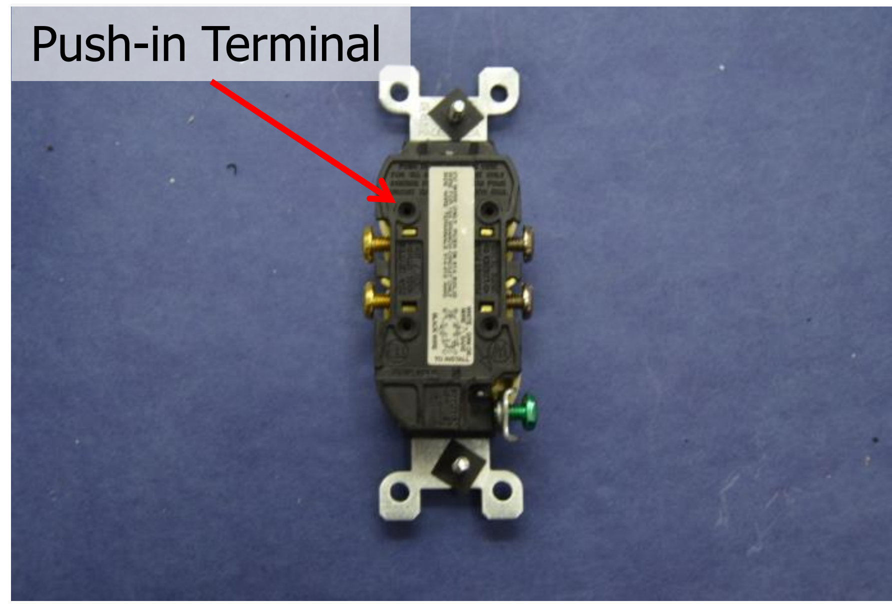


Comparison

20 Amp

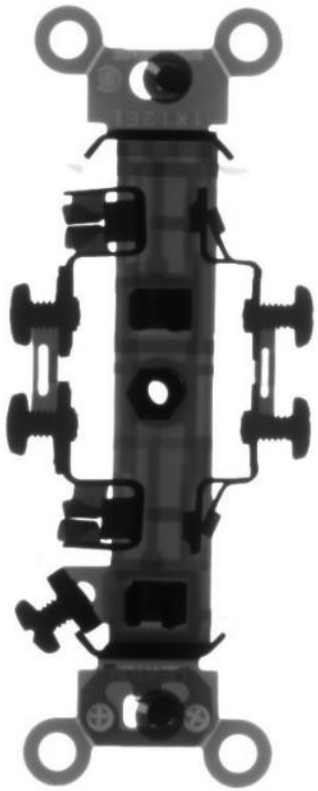


15Amp



Comparison

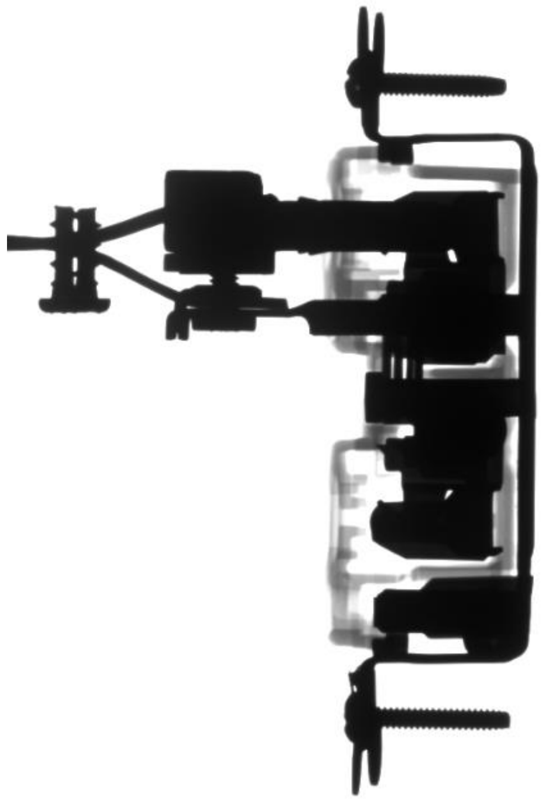
20 Amp



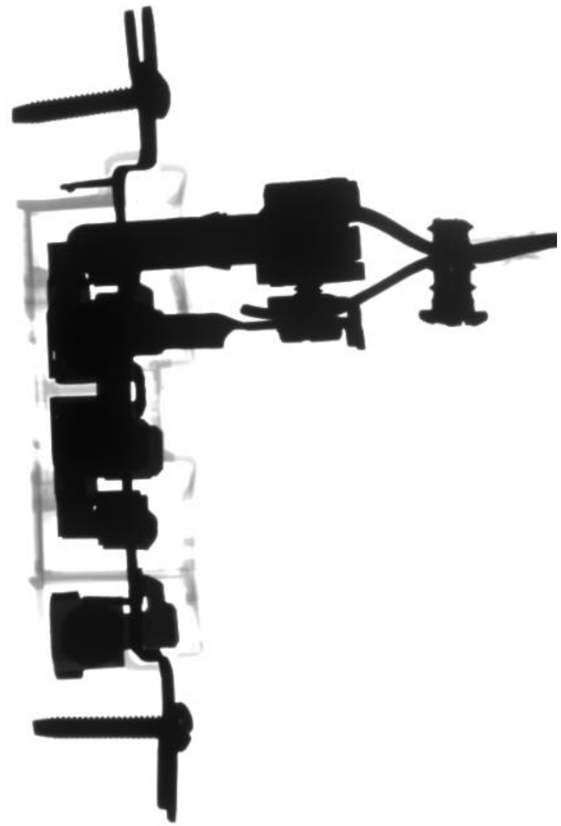
15Amp

Comparison

20 Amp



15Amp



Push-in Terminal

Push-in Terminal

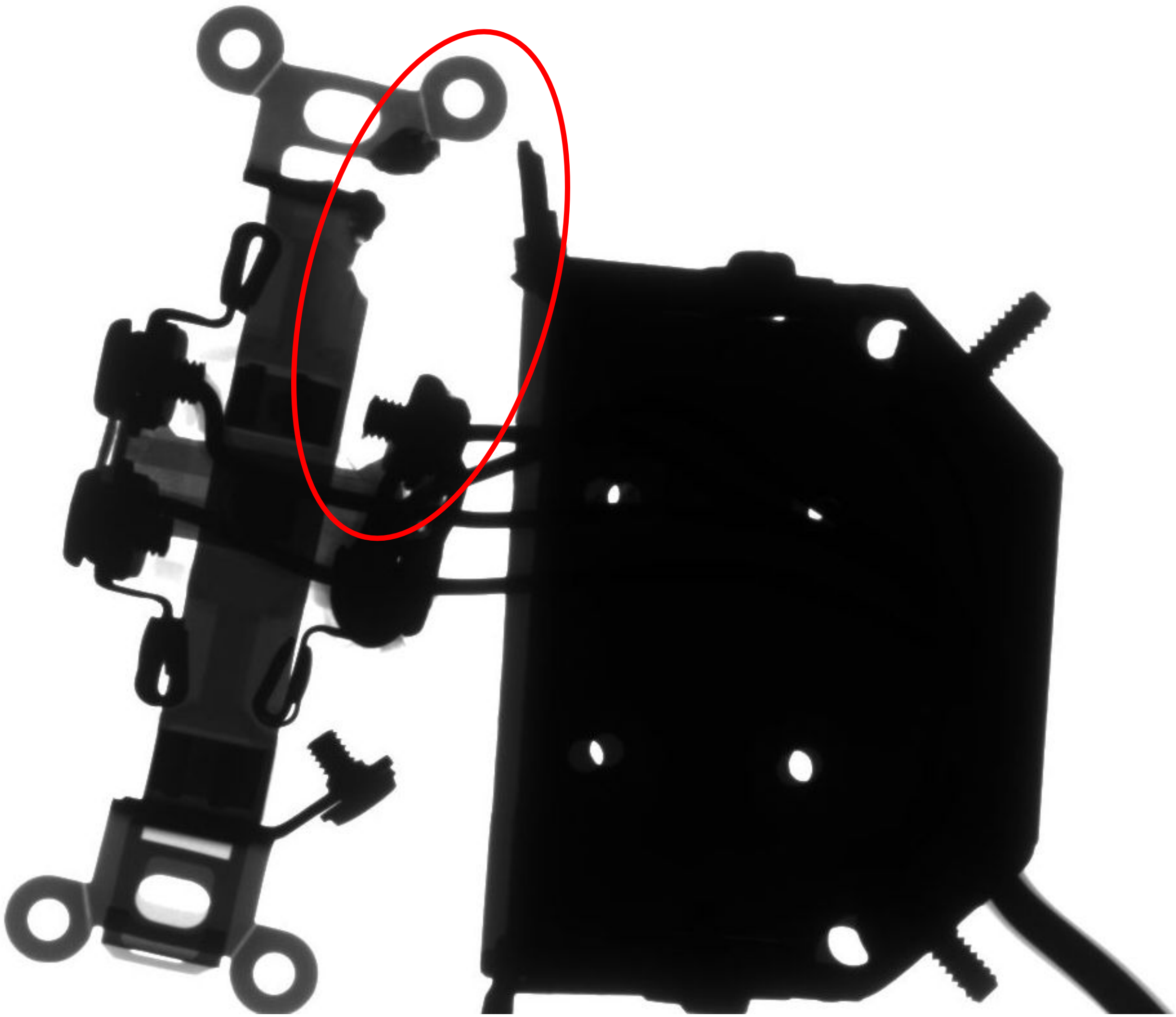
Push-in Terminal

Failure?

Screw Connections

Receptacle Failure

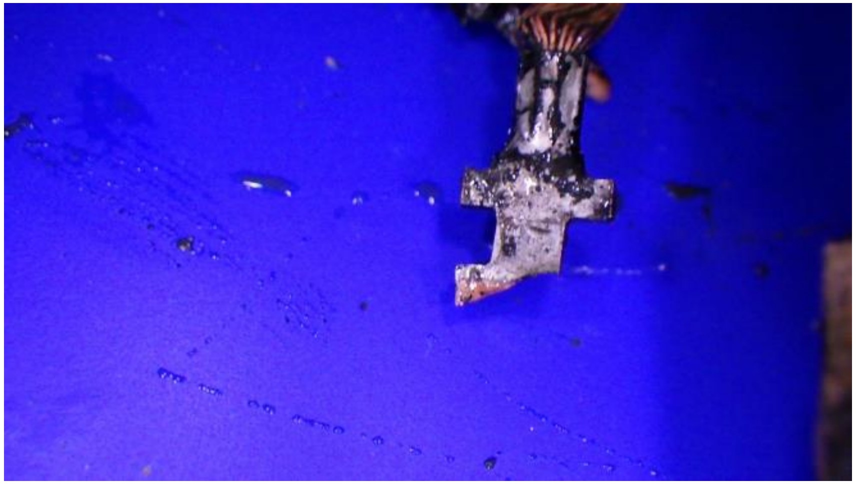
Receptacle Failure



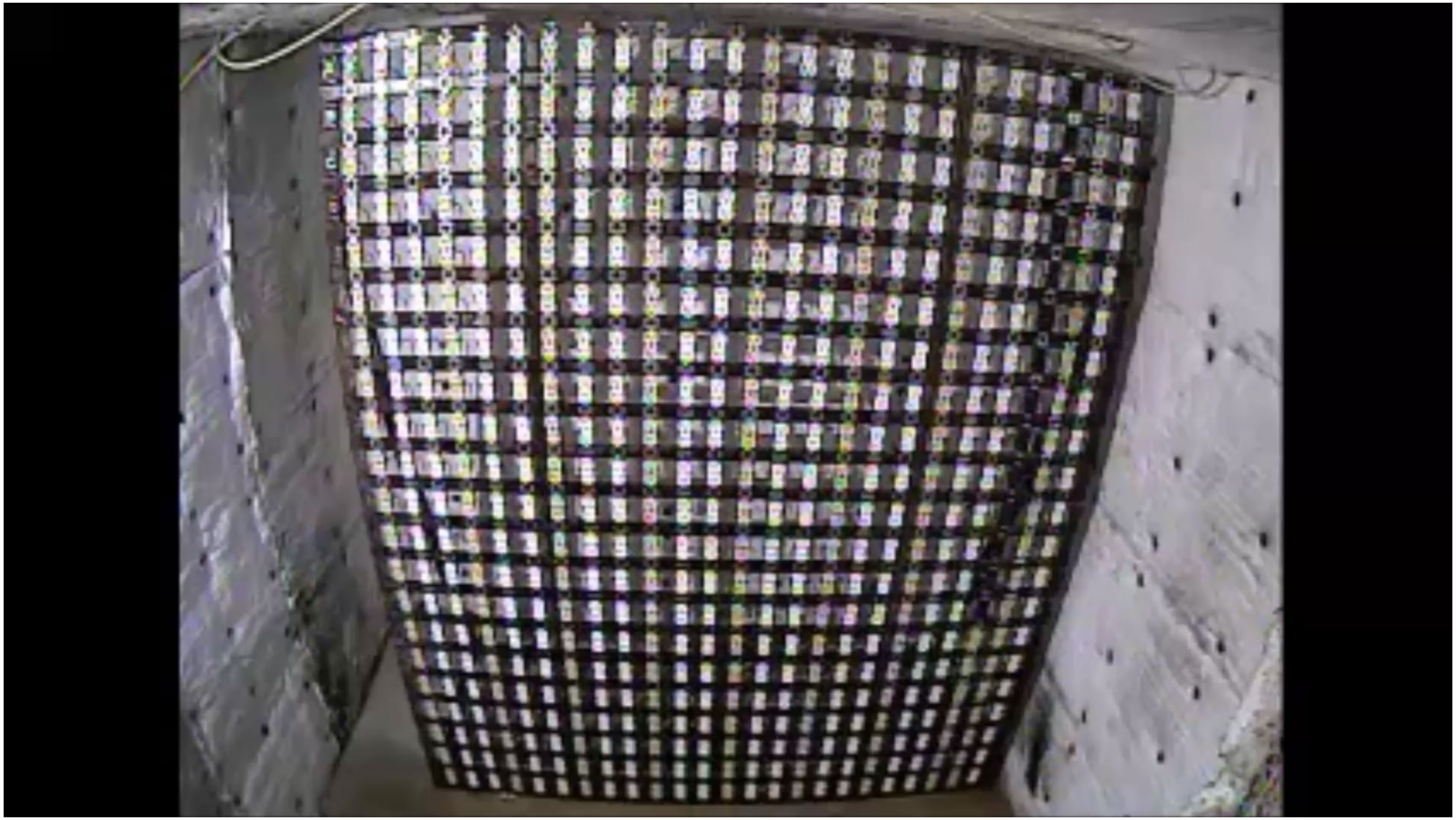
Receptacle Failure

Plug Blade Receptacle Failure

Plug Blade Receptacle Failure



CJN/GG Receptacle CFIC Project

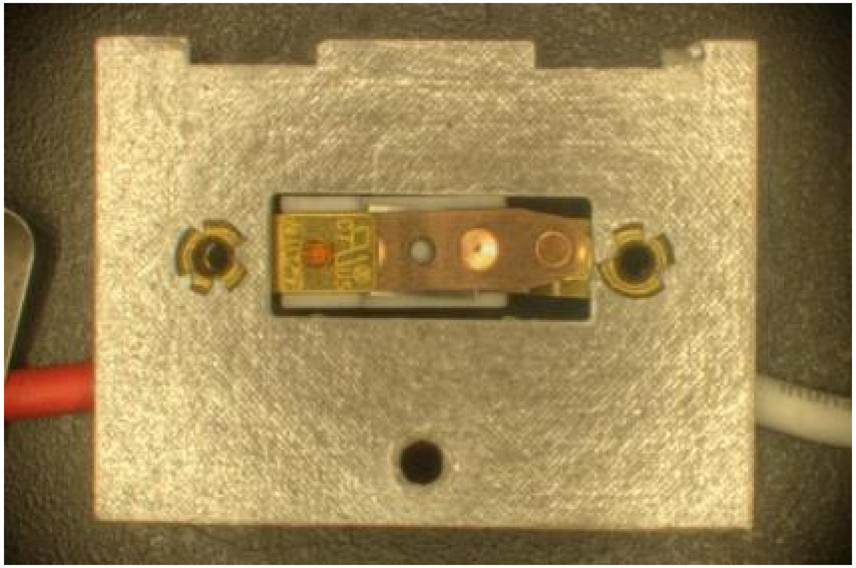



FLIR

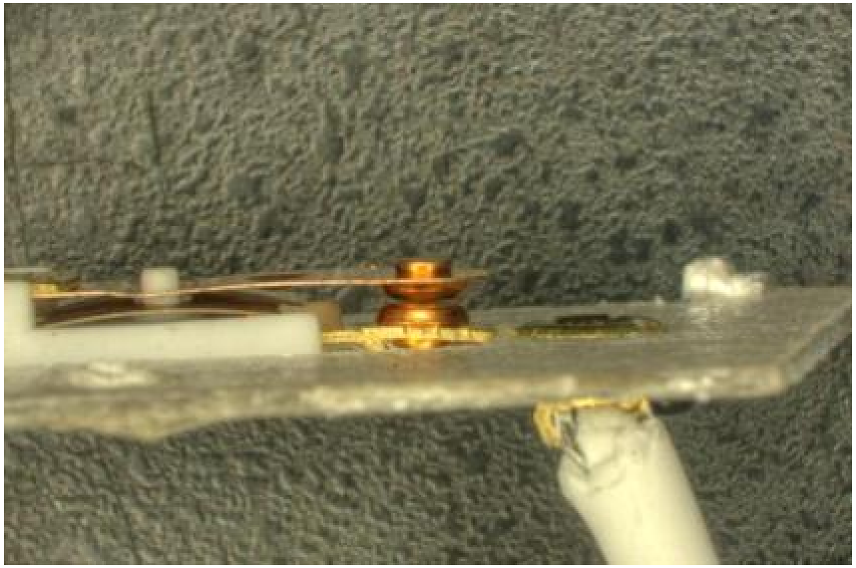
Thermal Protection

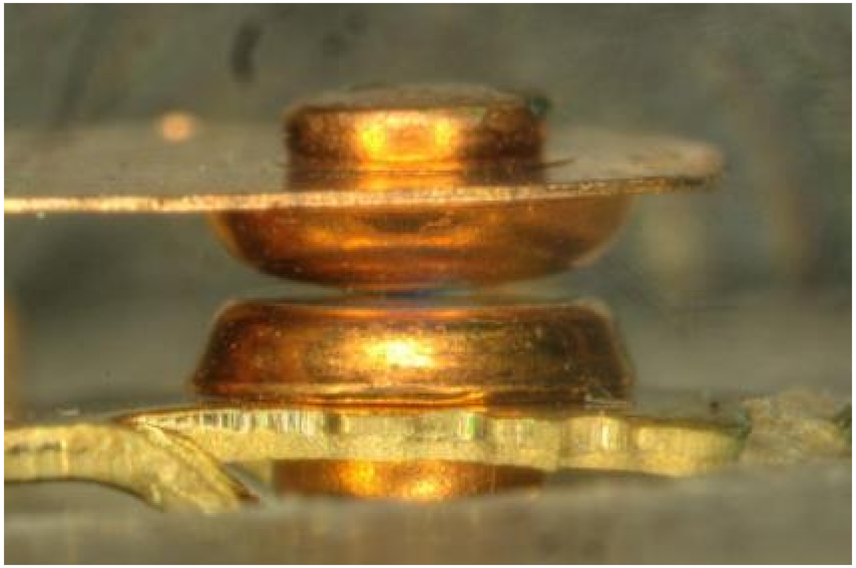
Bi-metal Thermostat / Resettable Thermal Cutoff

Bi-metal Thermostat / Resettable Thermal Cutoff

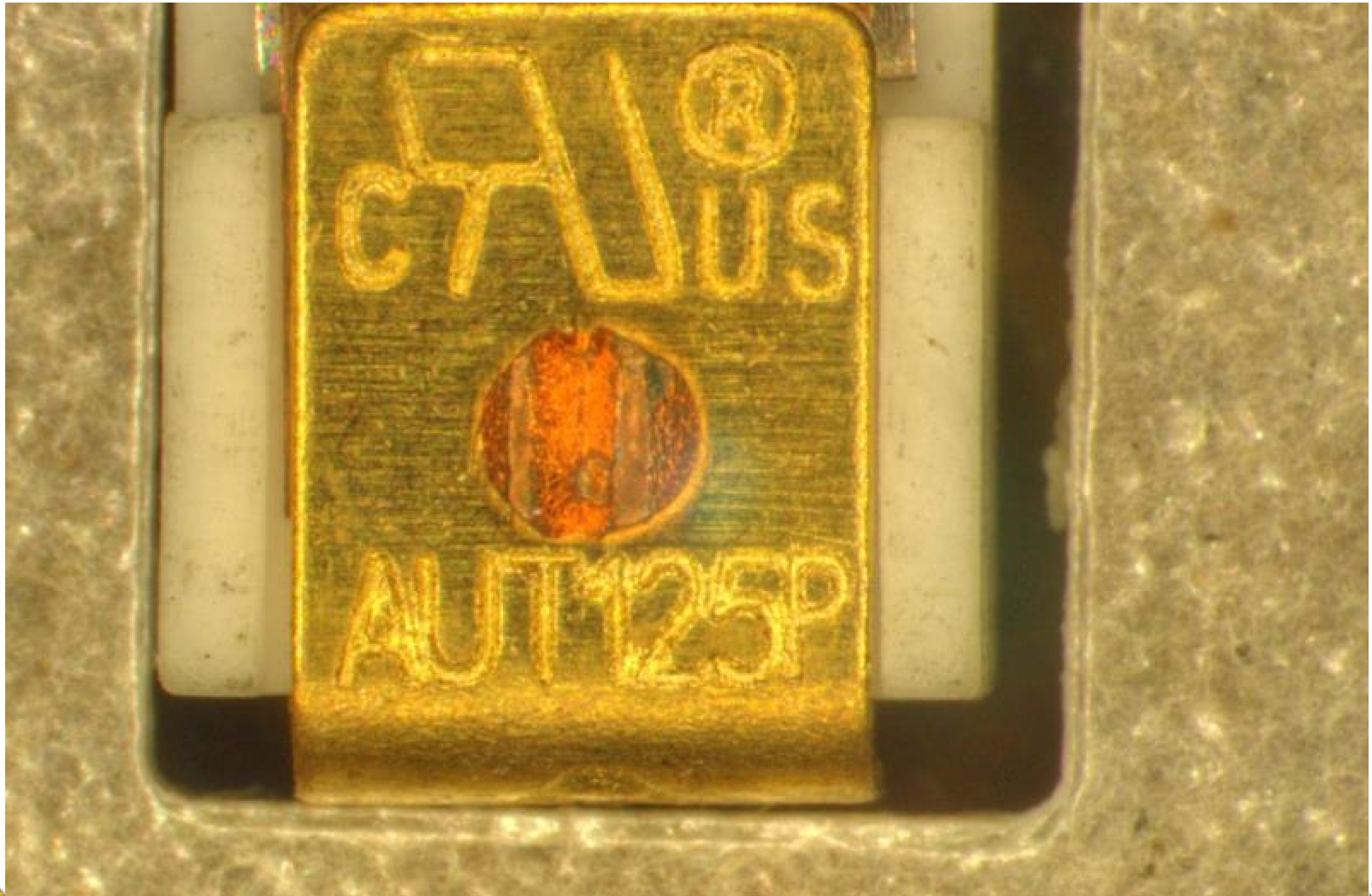


Bi-metal Thermostat / Resettable Thermal Cutoff



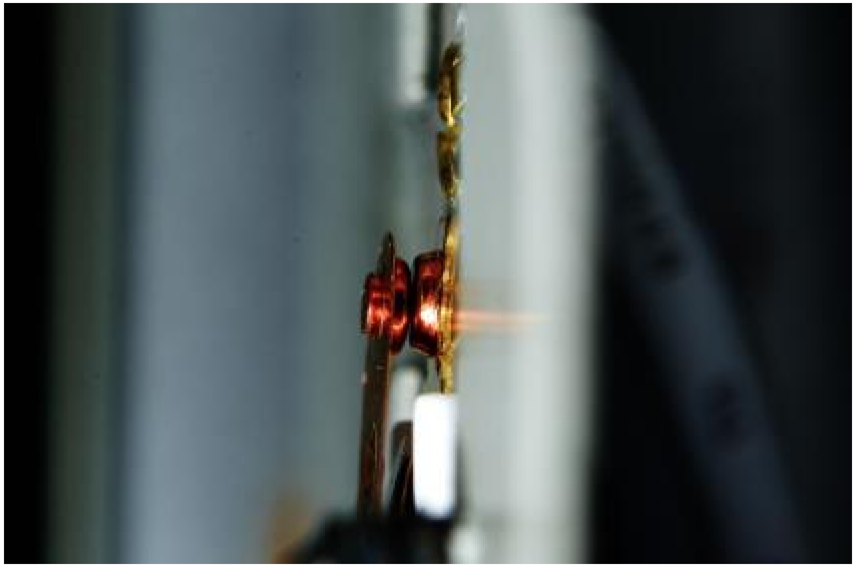


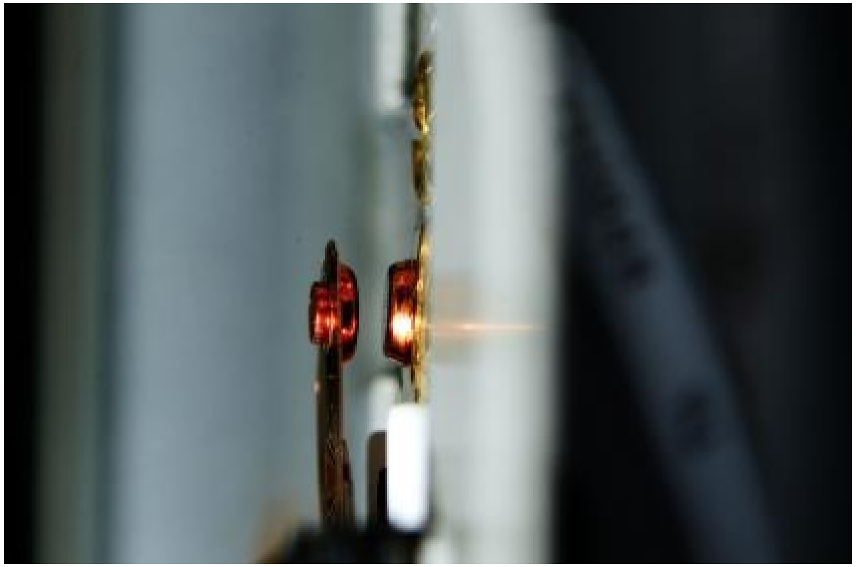
Bi-metal Thermostat / Resettable Thermal Cutoff



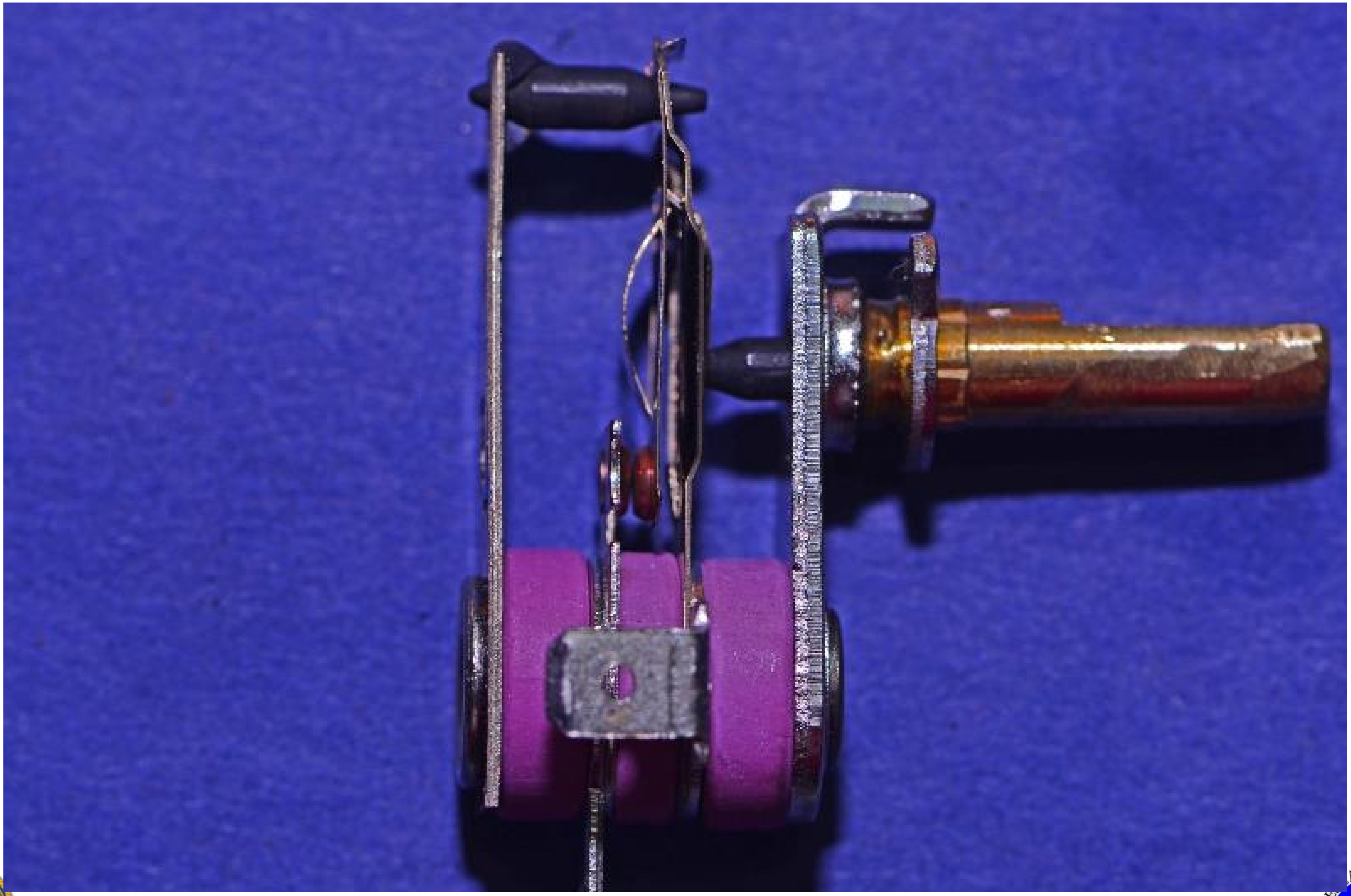
Bi-metal Thermostat / Resettable Thermal Cutoff

Bi-metal Thermostat / Resettable Thermal Cutoff

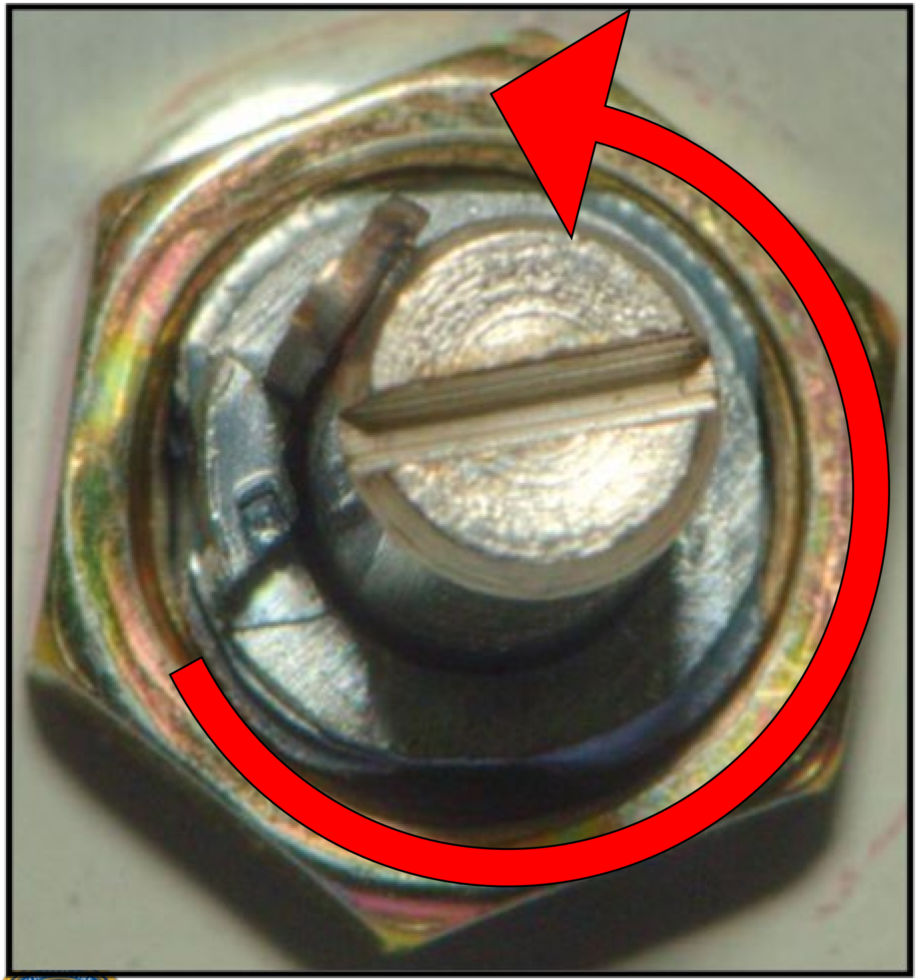




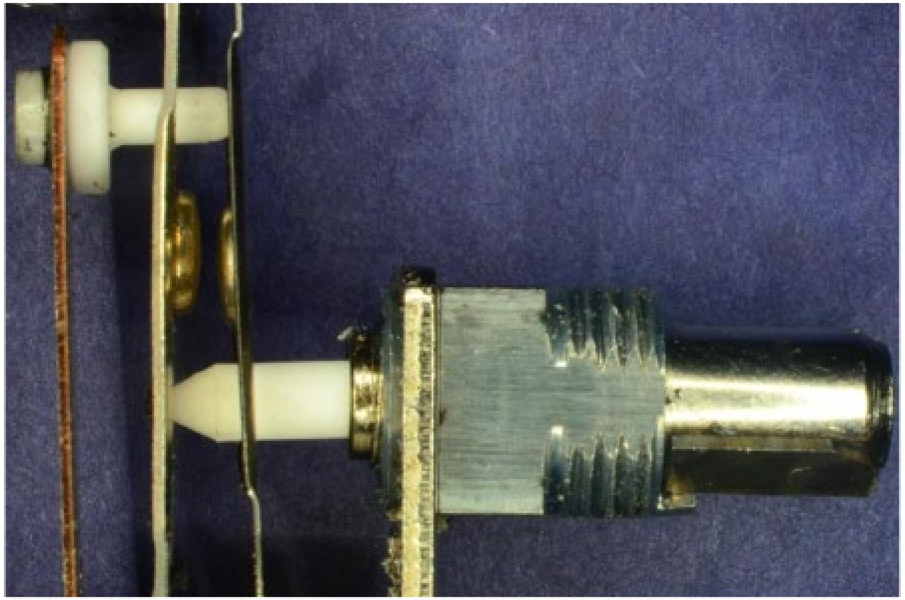
Variable Bimetal Thermostat / Resettable Thermal Cutoff



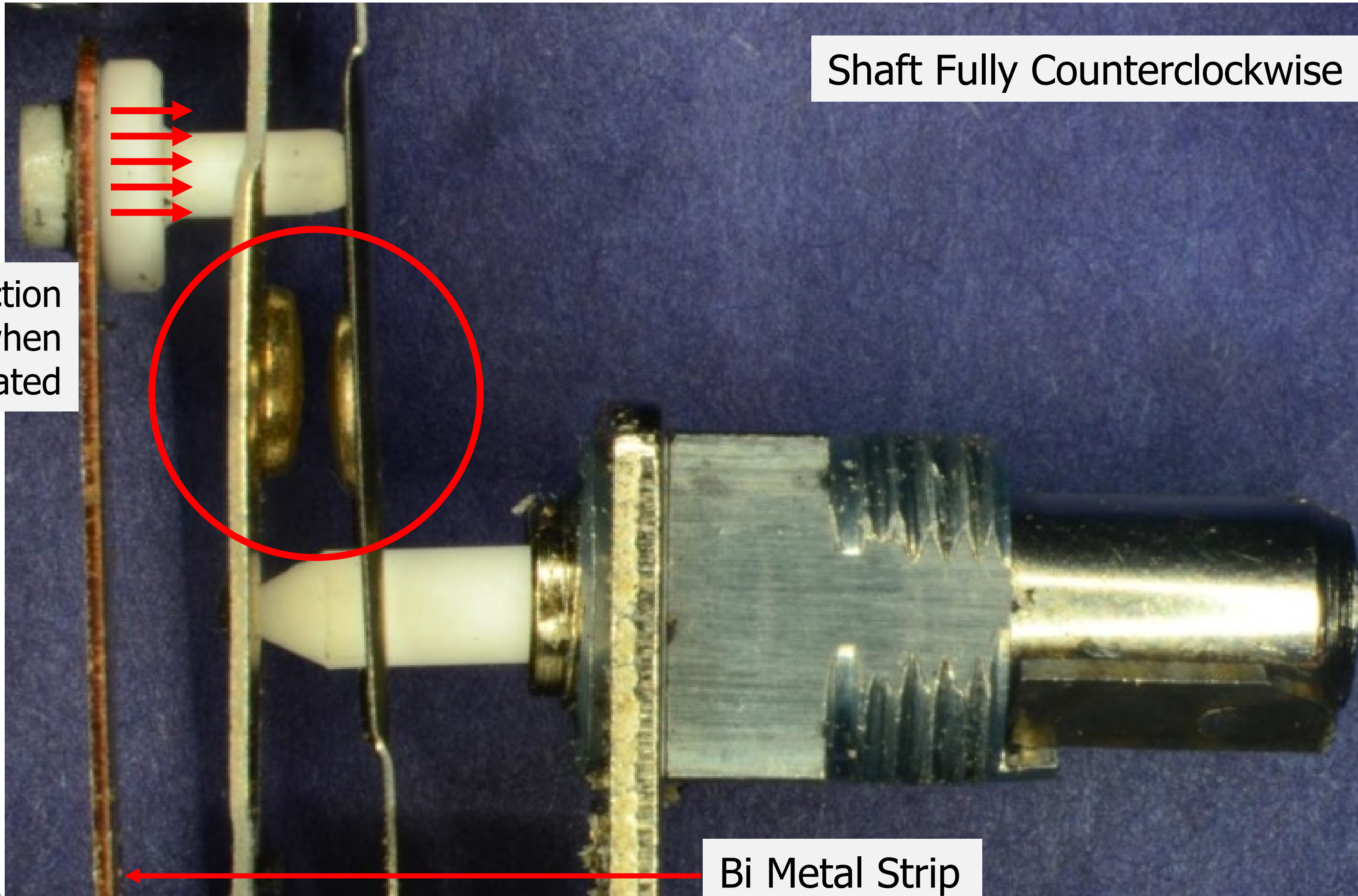
Variable Bimetal Thermostat / Resettable Thermal Cutoff



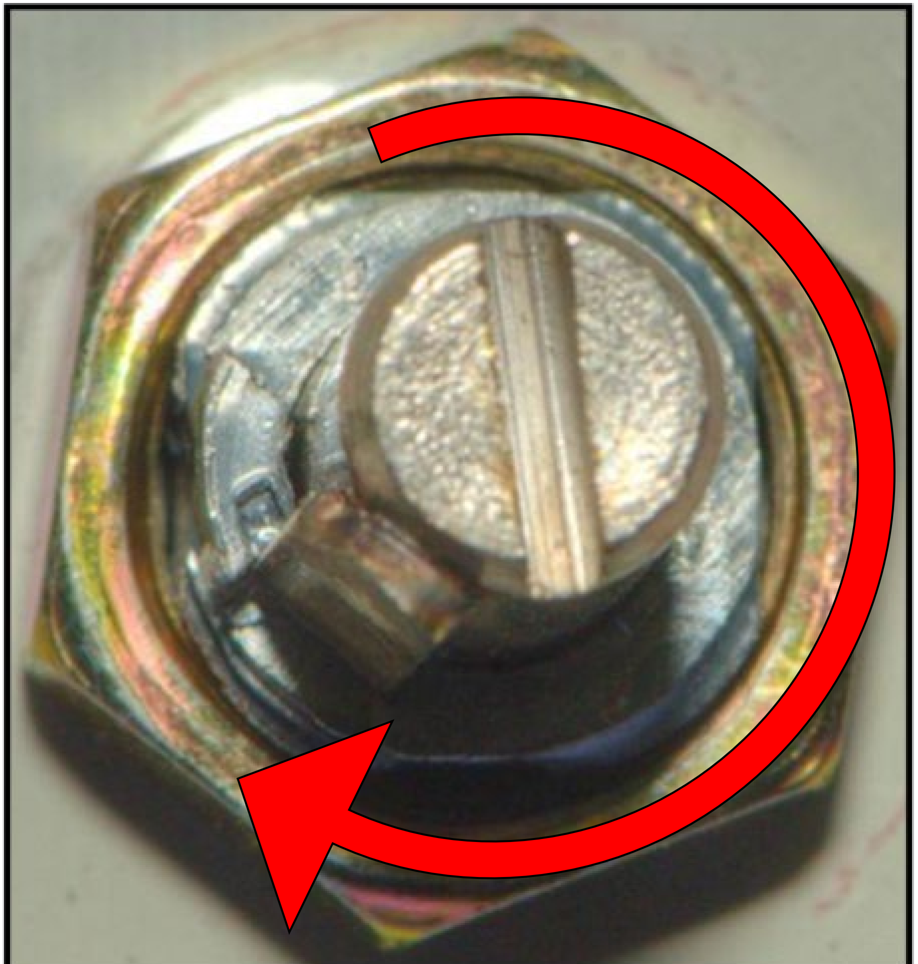
Shaft Fully Counterclockwise



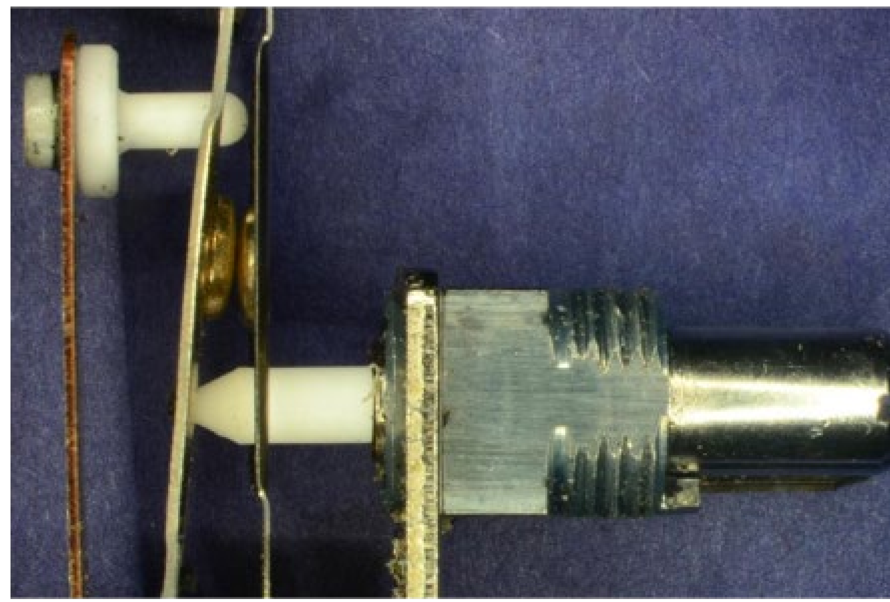
Variable Bimetal Thermostat / Resettable Thermal Cutoff



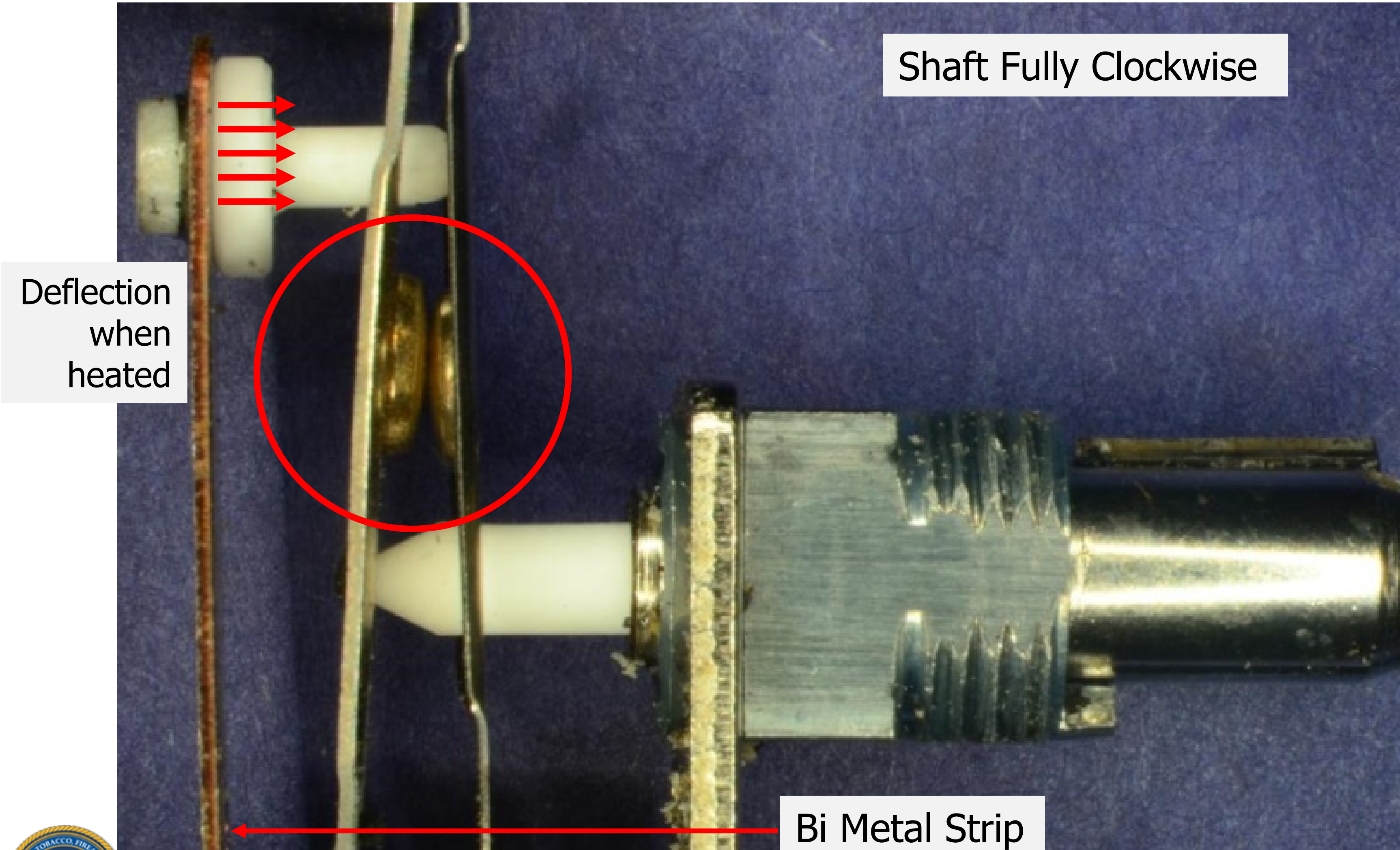
Variable Bimetal Thermostat / Resettable Thermal Cutoff



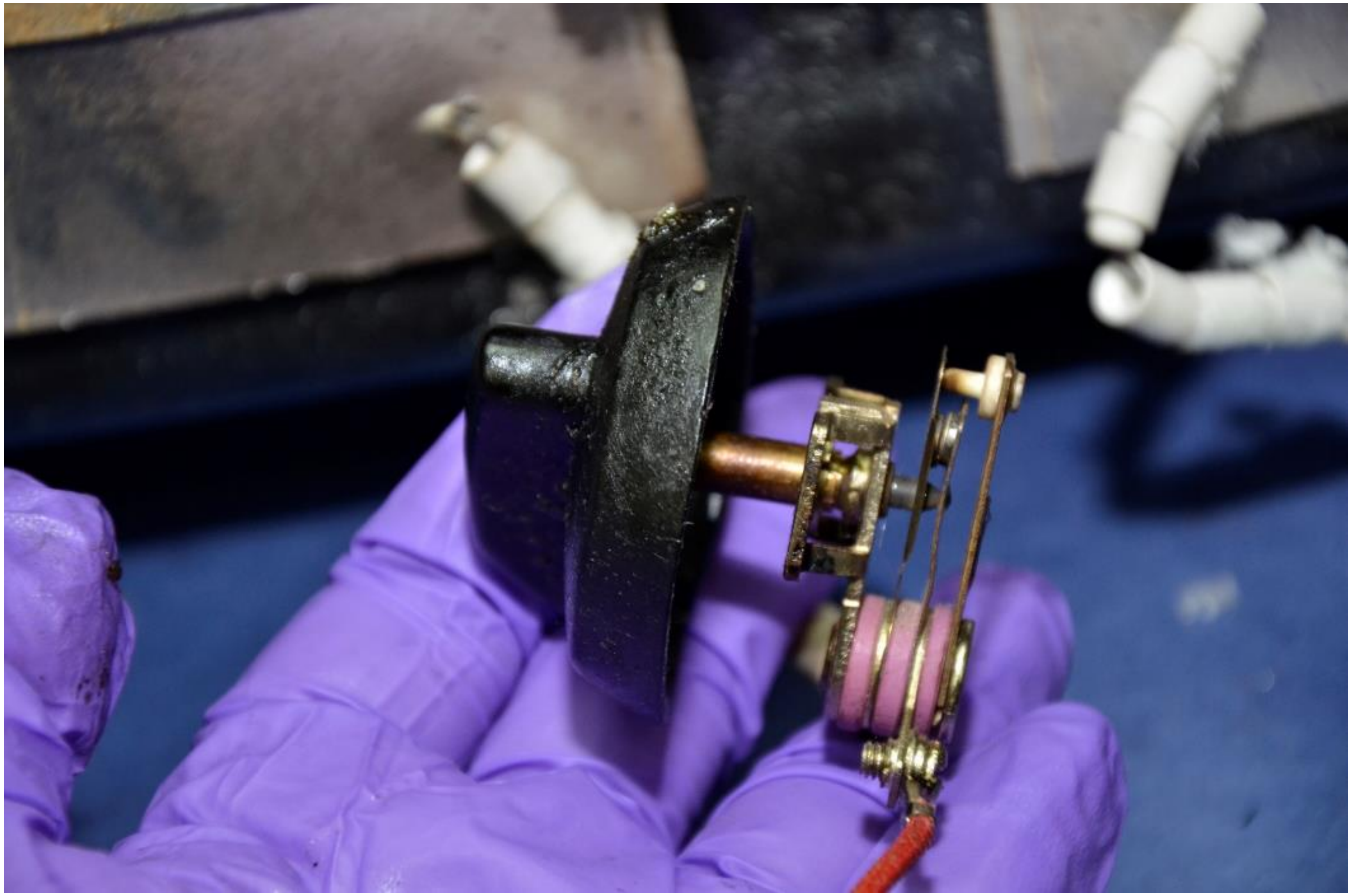
Shaft Fully Clockwise



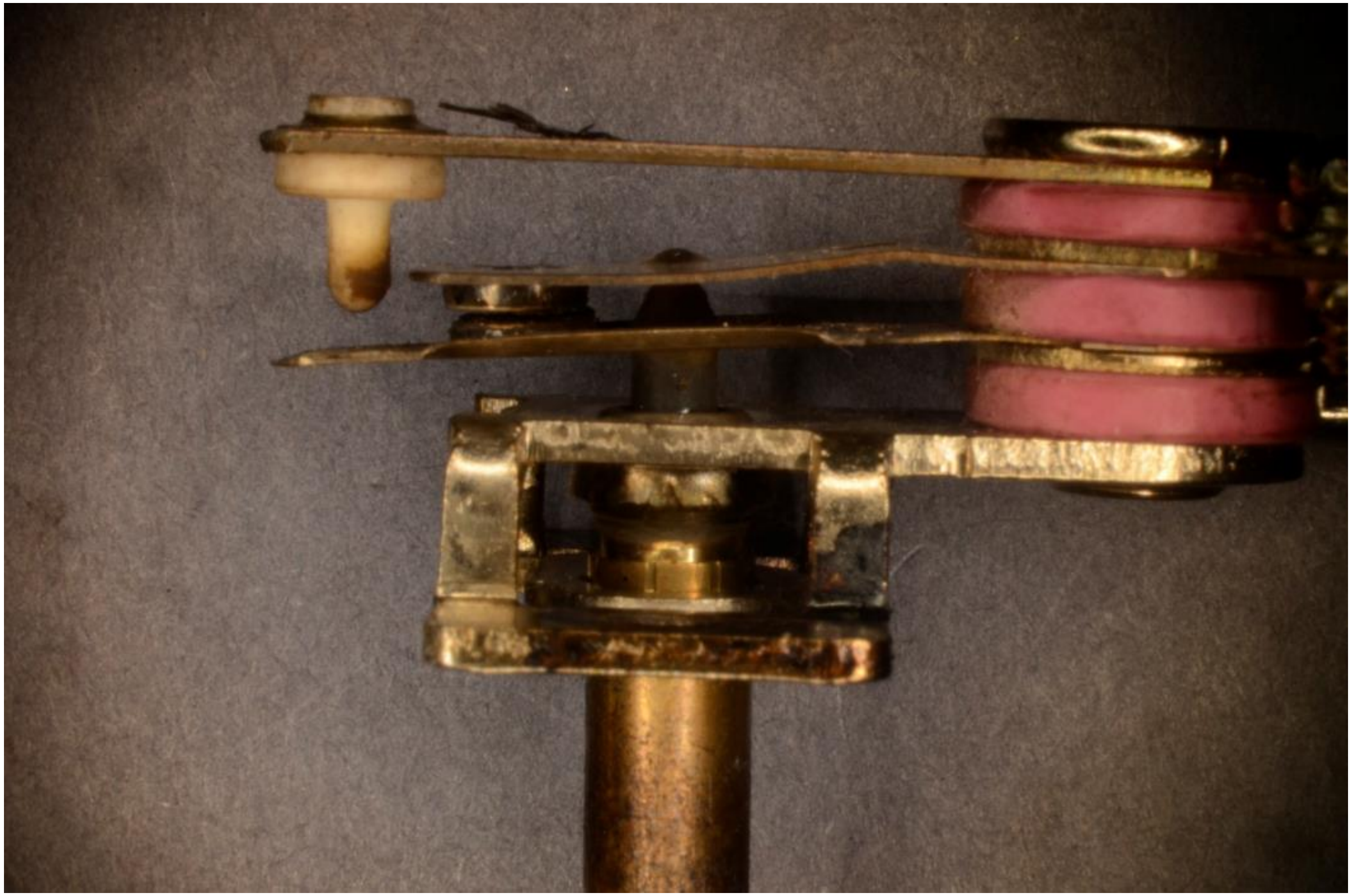
Variable Bimetal Thermostat / Resettable Thermal Cutoff



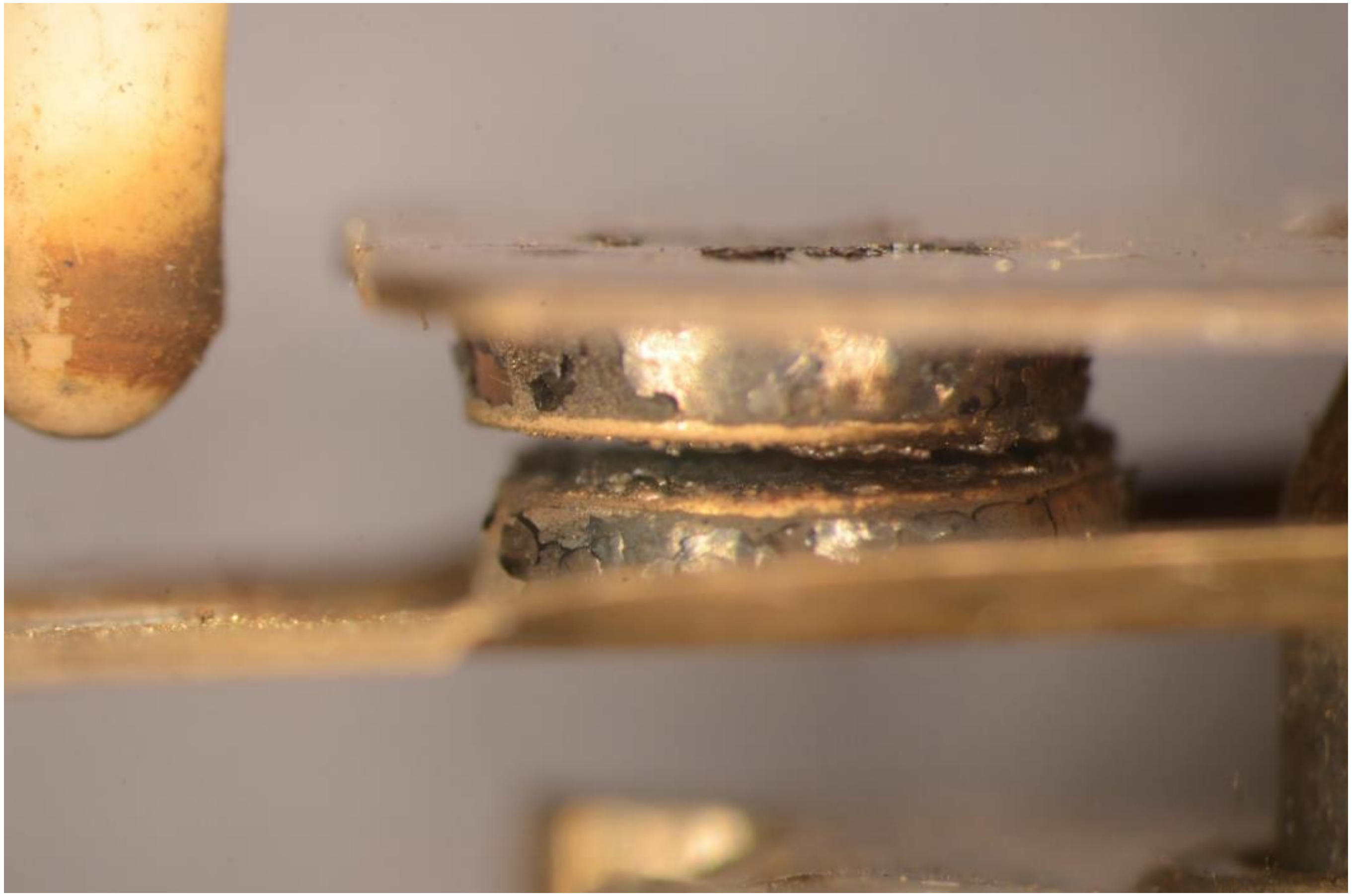
Thermostat – Damaged Contacts



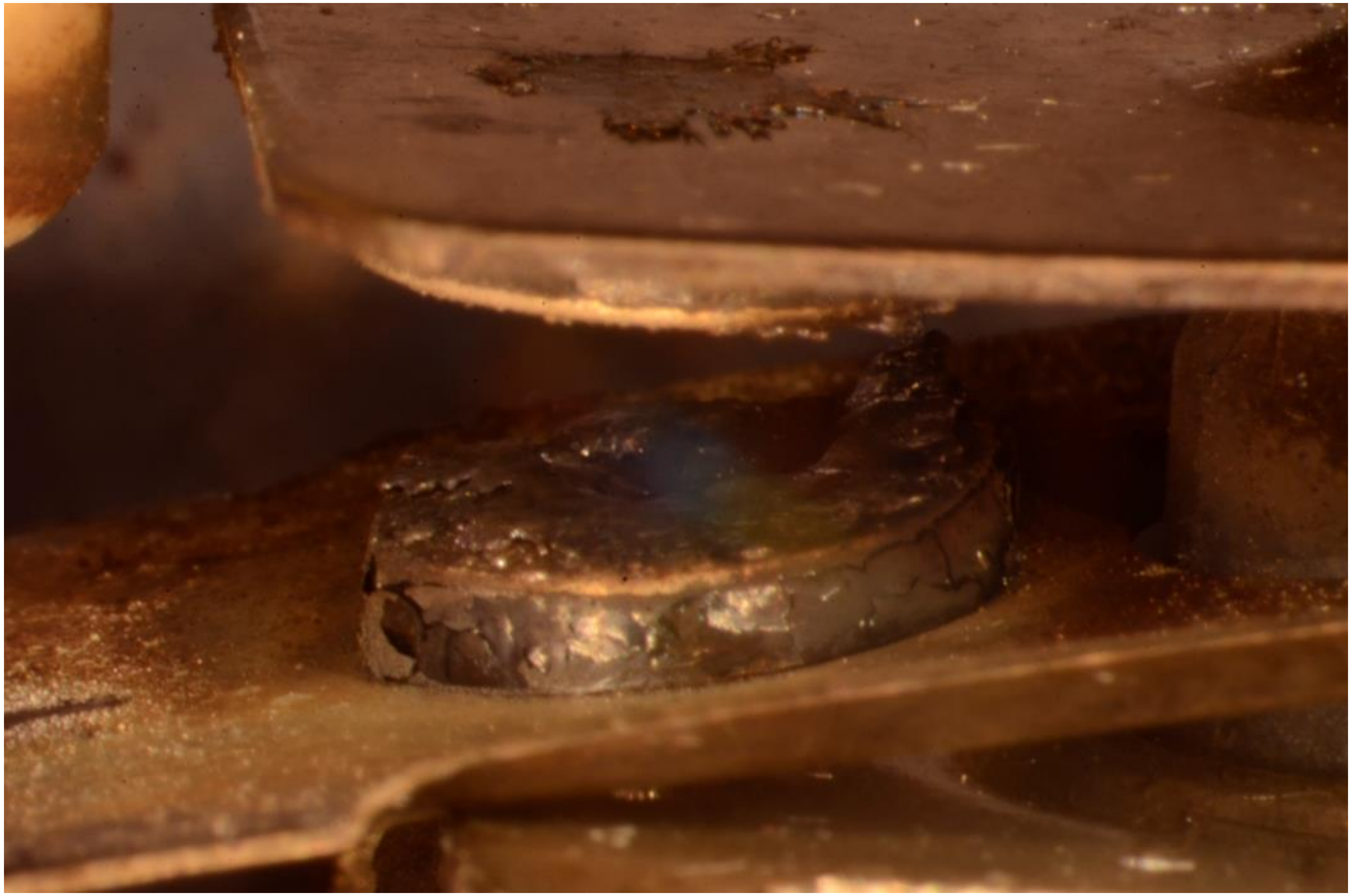
Thermostat – Damaged Contacts



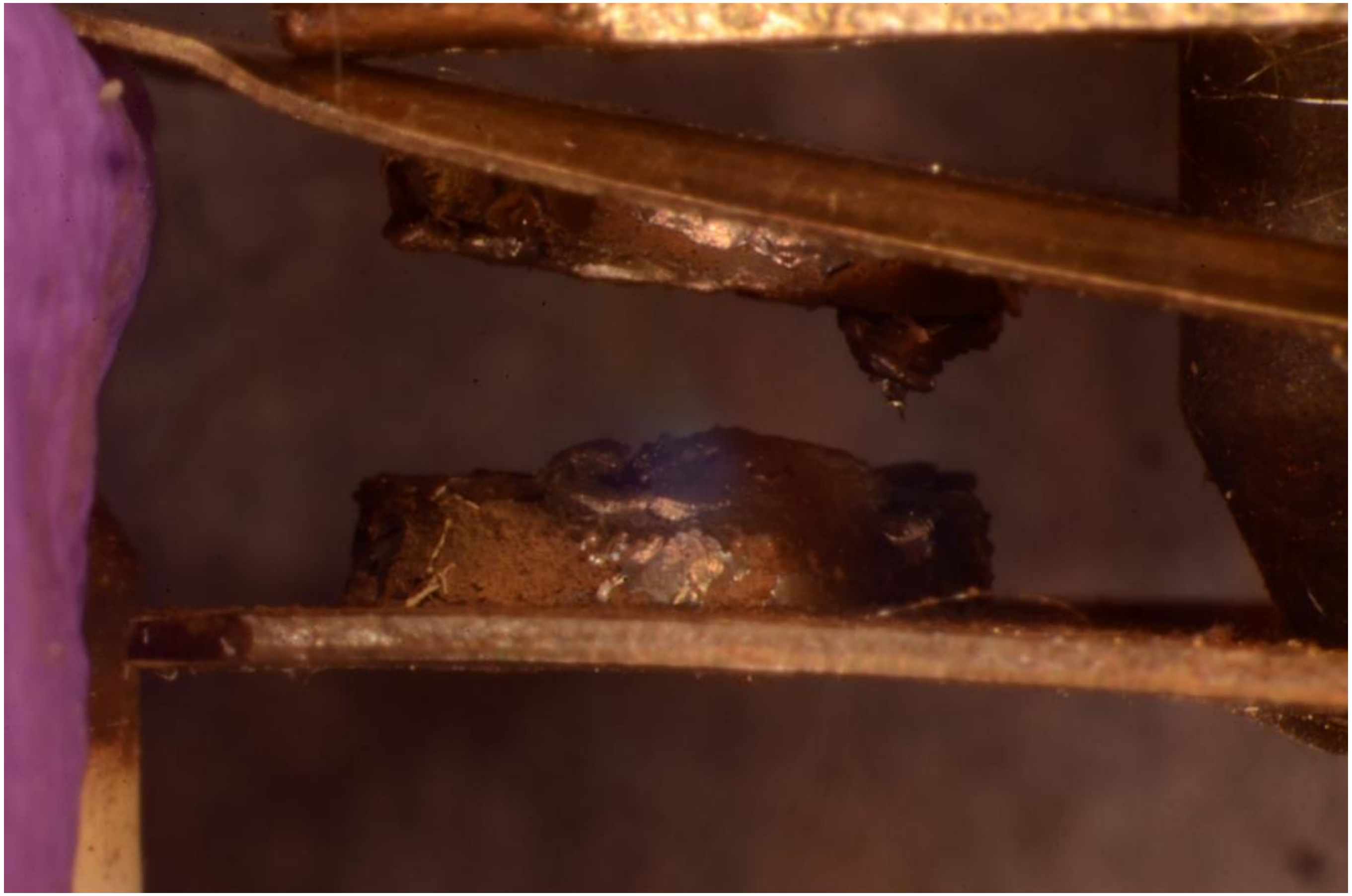
Thermostat – Damaged Contacts



Thermostat – Damaged Contacts

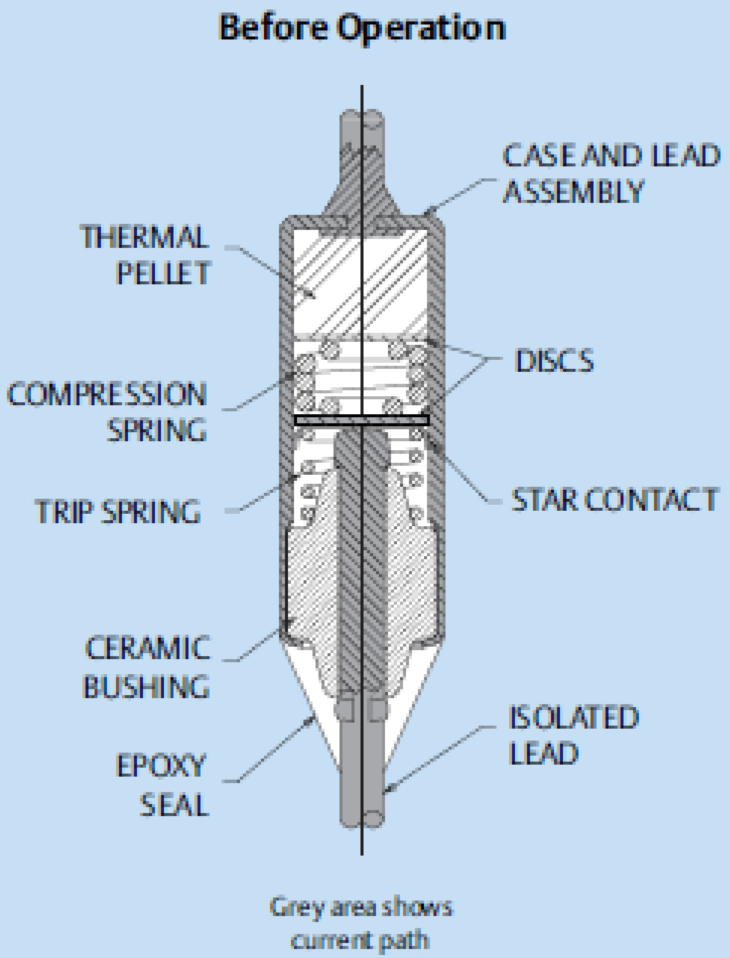


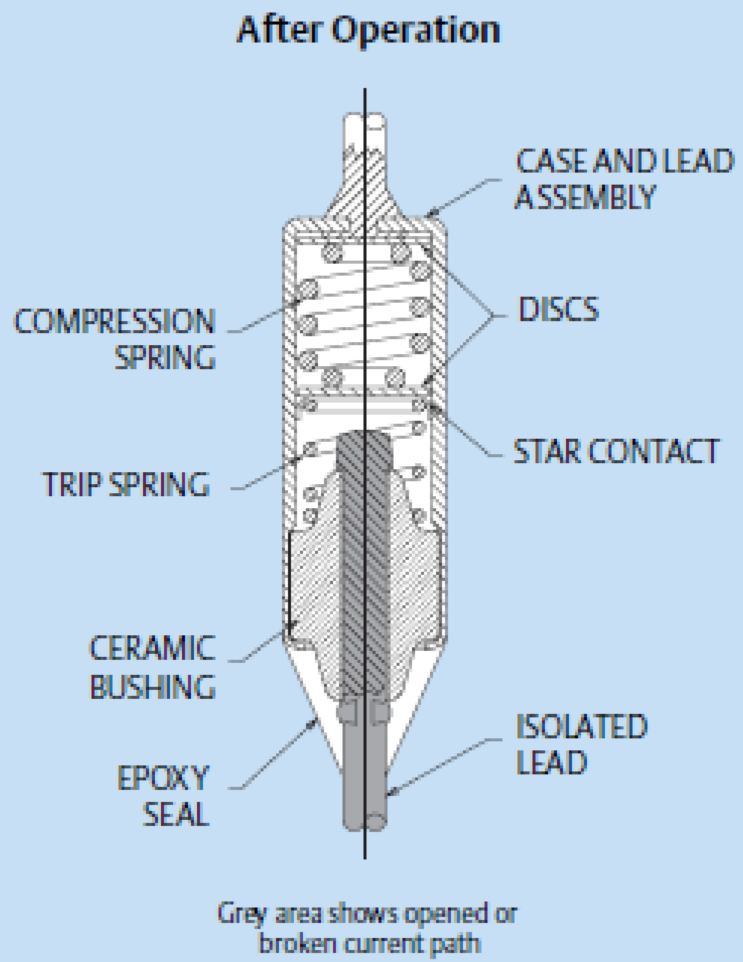
Thermostat – Damaged Contacts



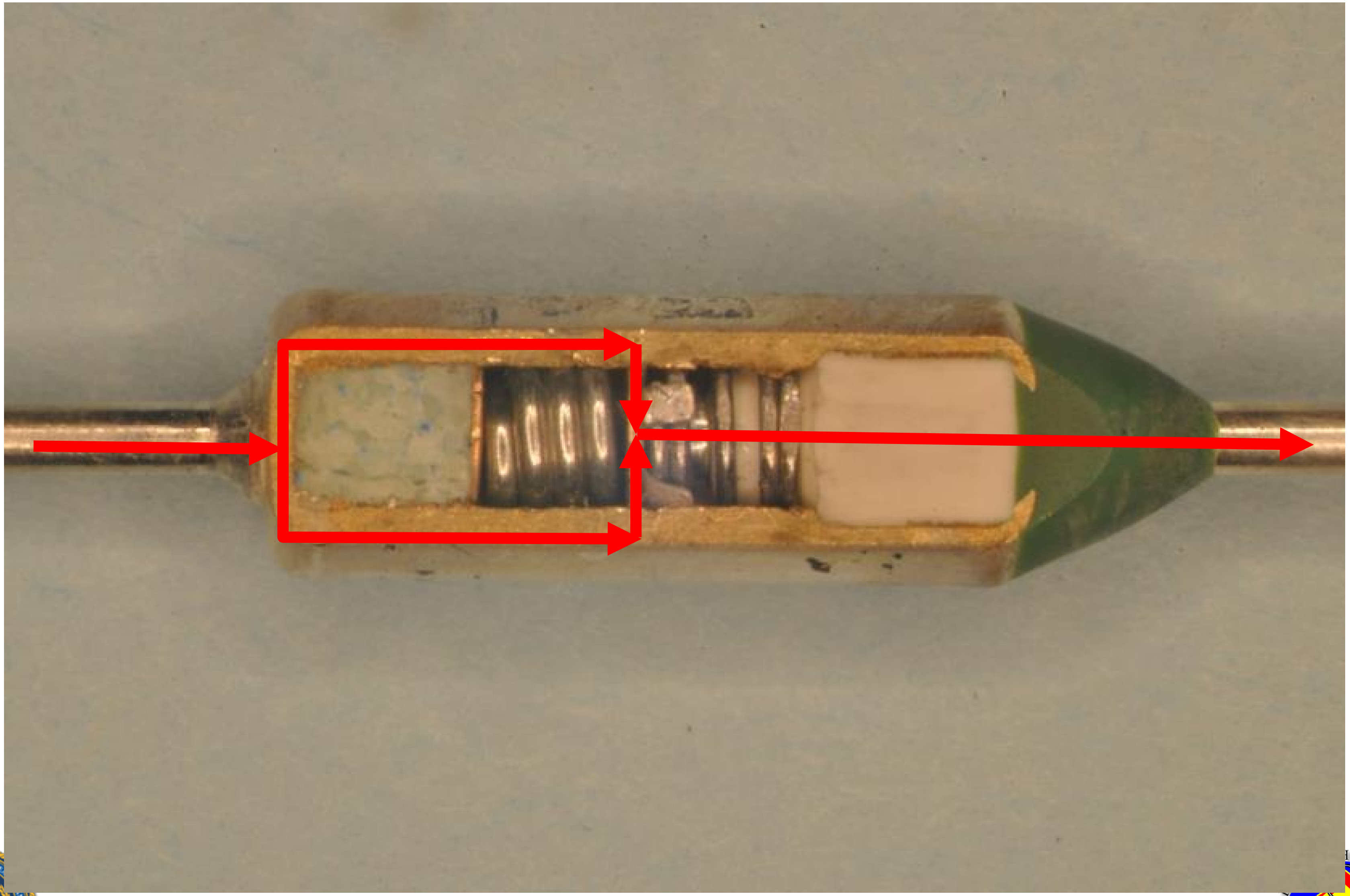
Non-Resettable Thermal Cutouts

Non-Resettable Thermal Cutouts

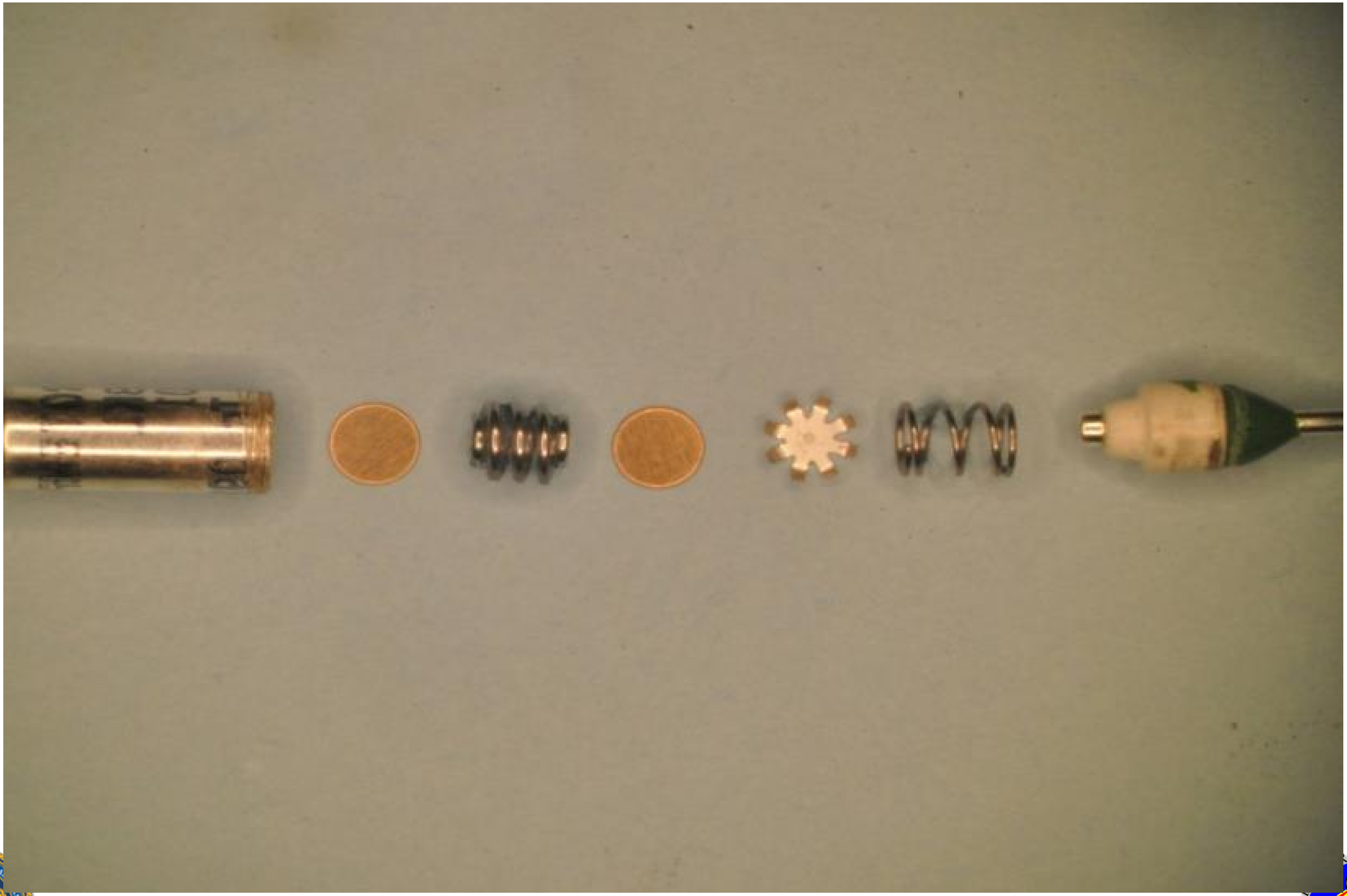




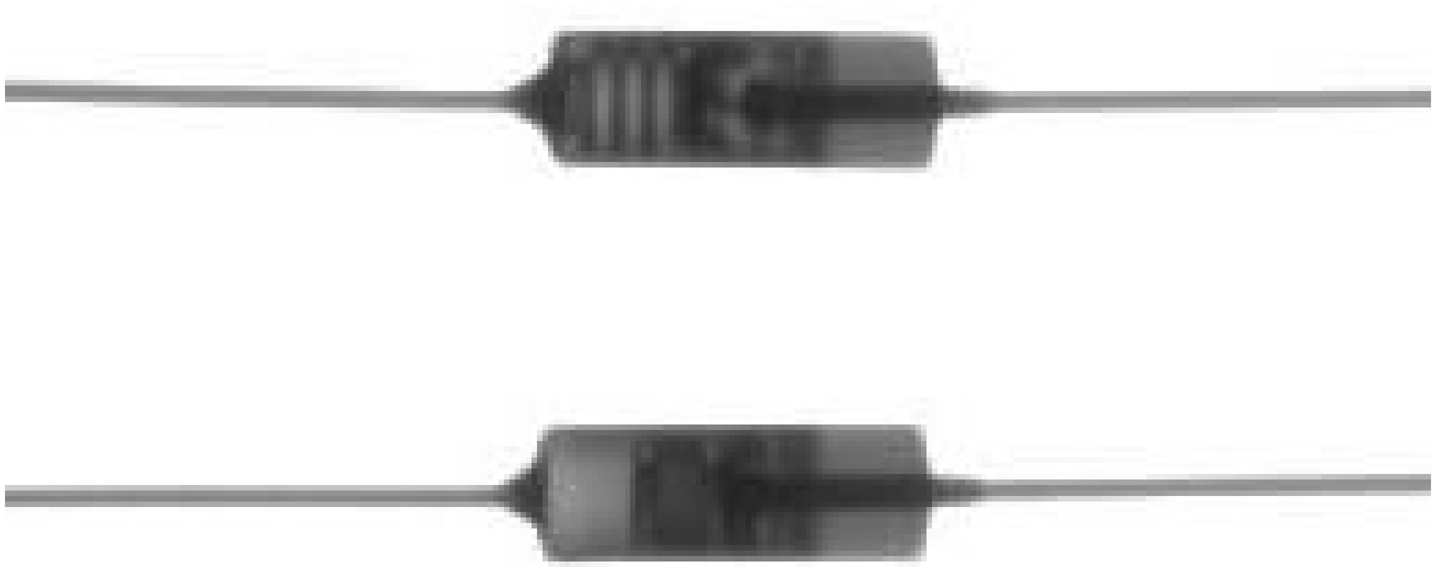
Non-Resettable Thermal Cutouts



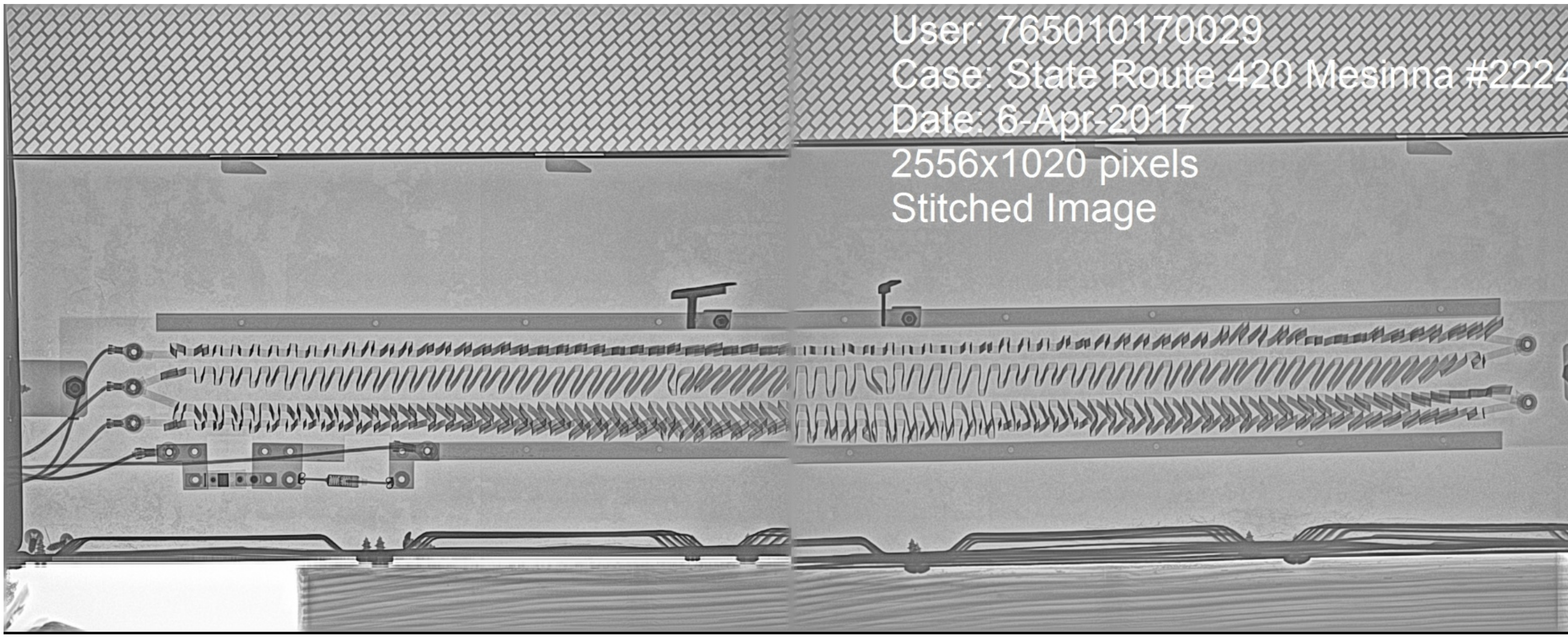
Non-Resettable Thermal Cutouts



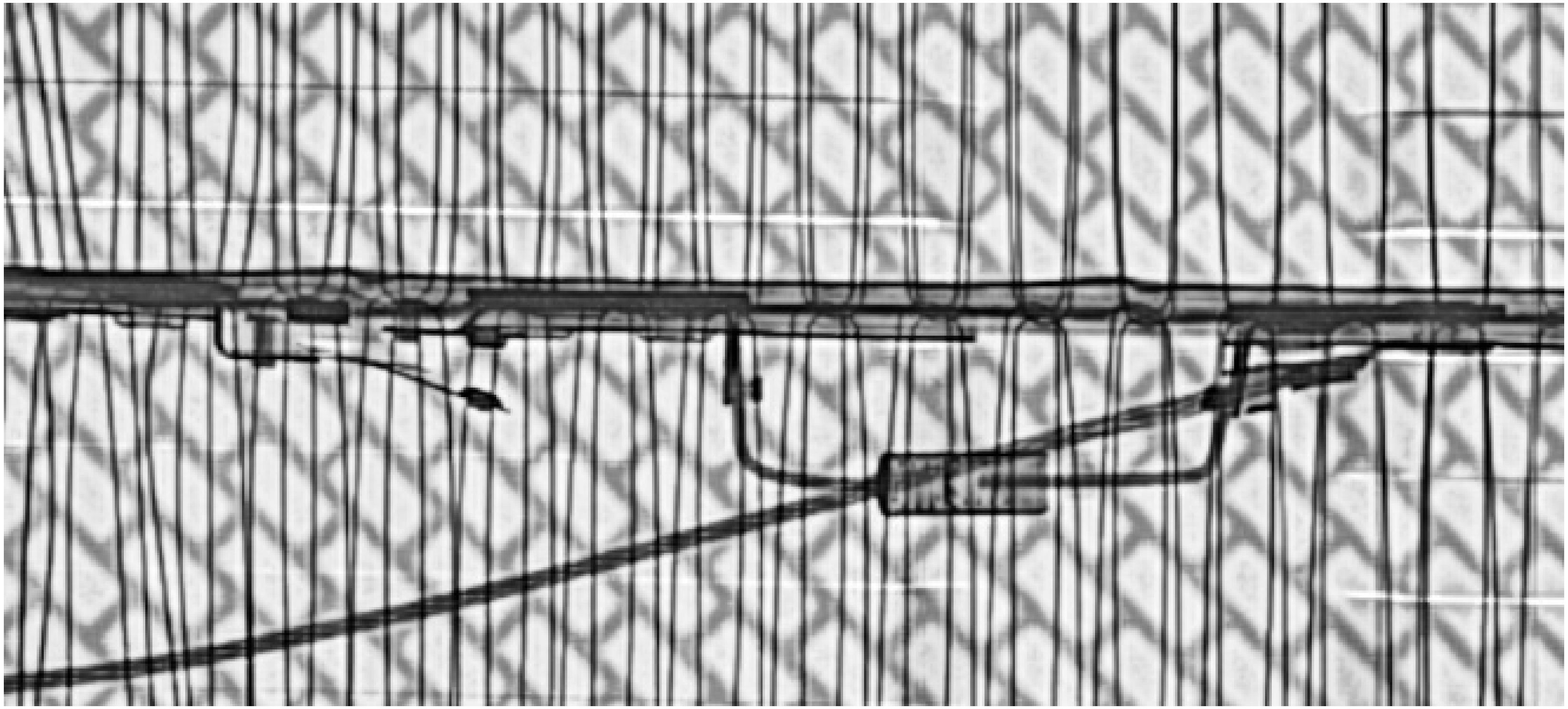
Non-Resettable Thermal Cutouts

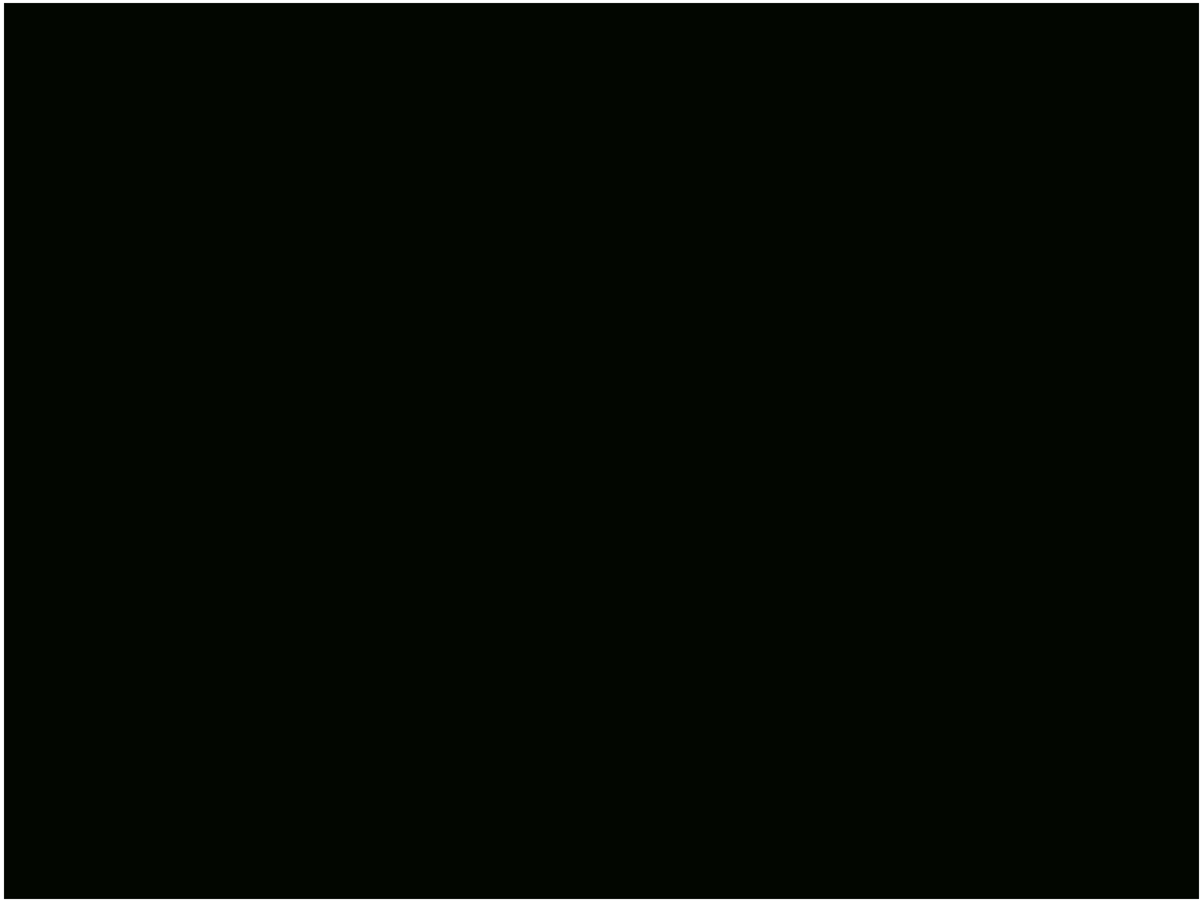


Upstate NY Fatal Fire Heater X-Ray



Heater Thermal Protective Devices

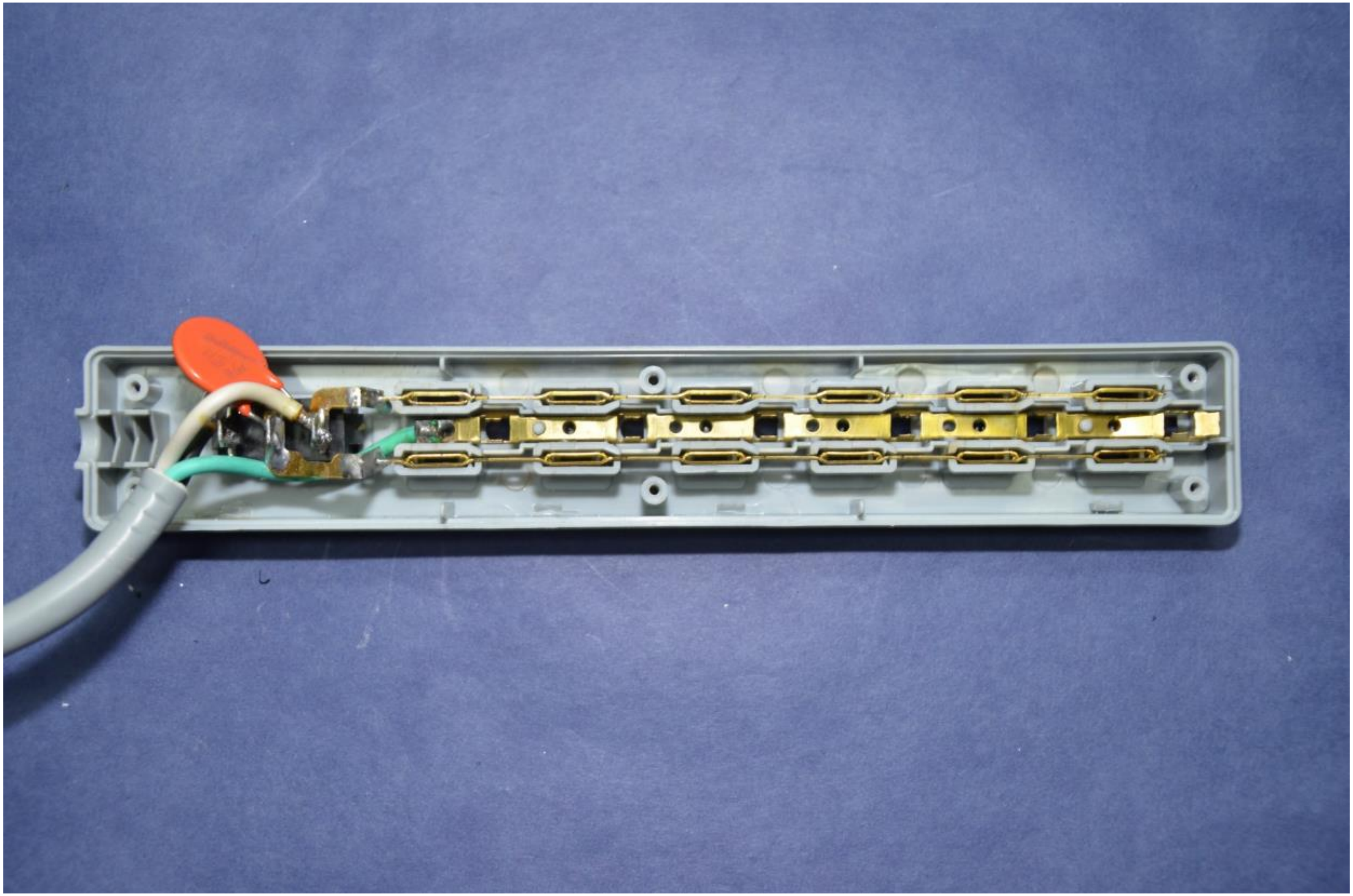




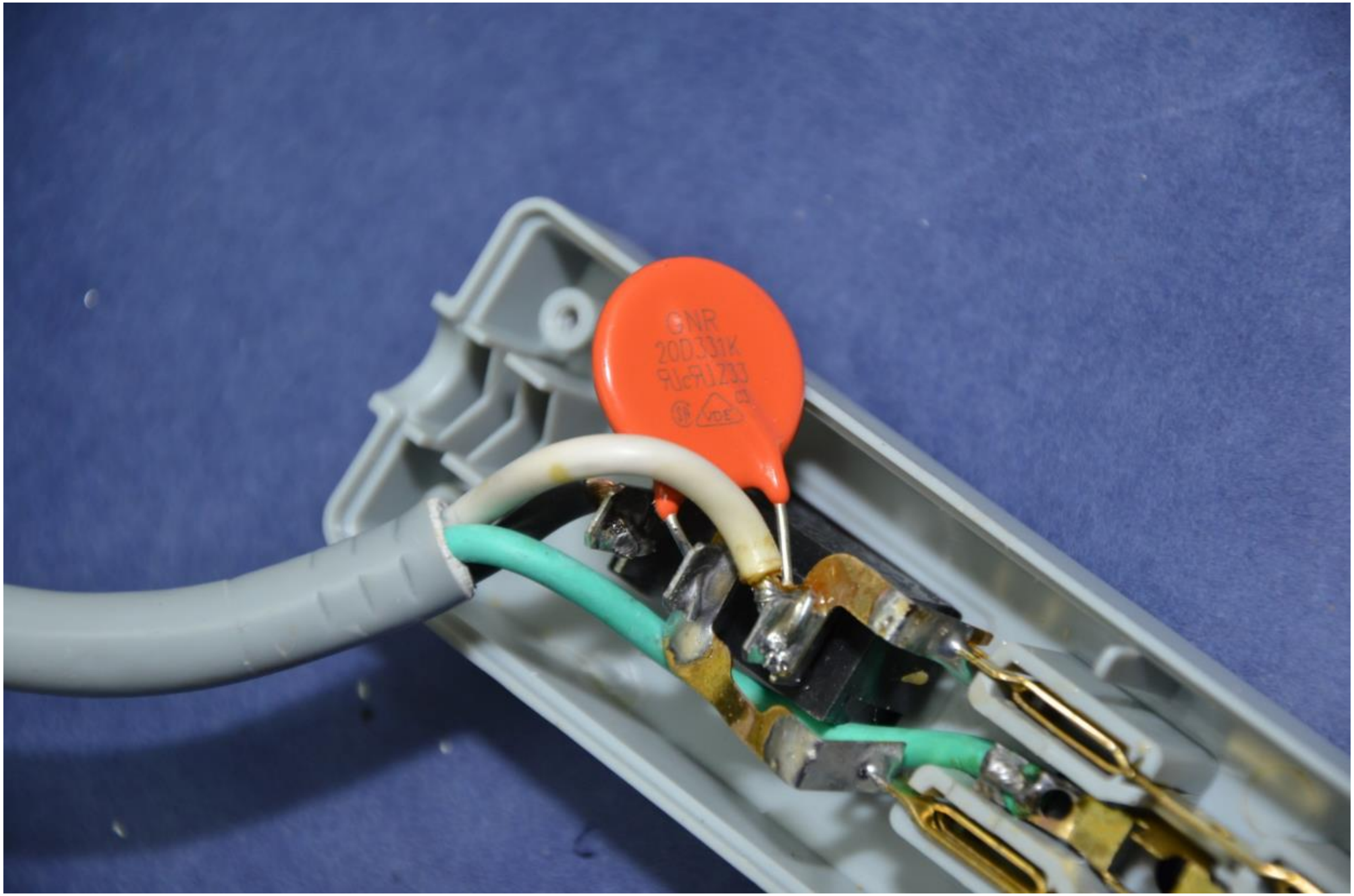
Relocatable Power Tap

Power Tap

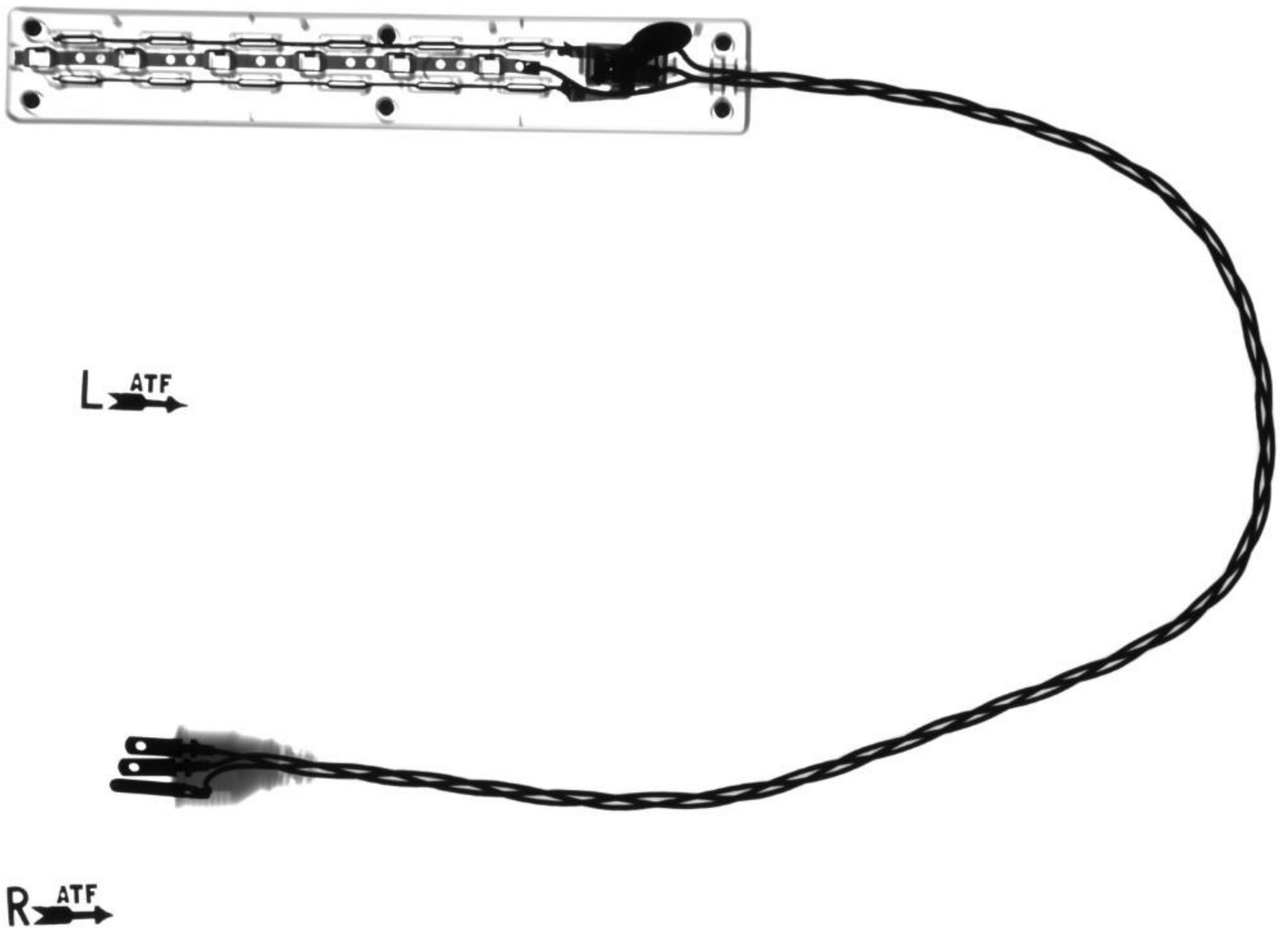
Interior View



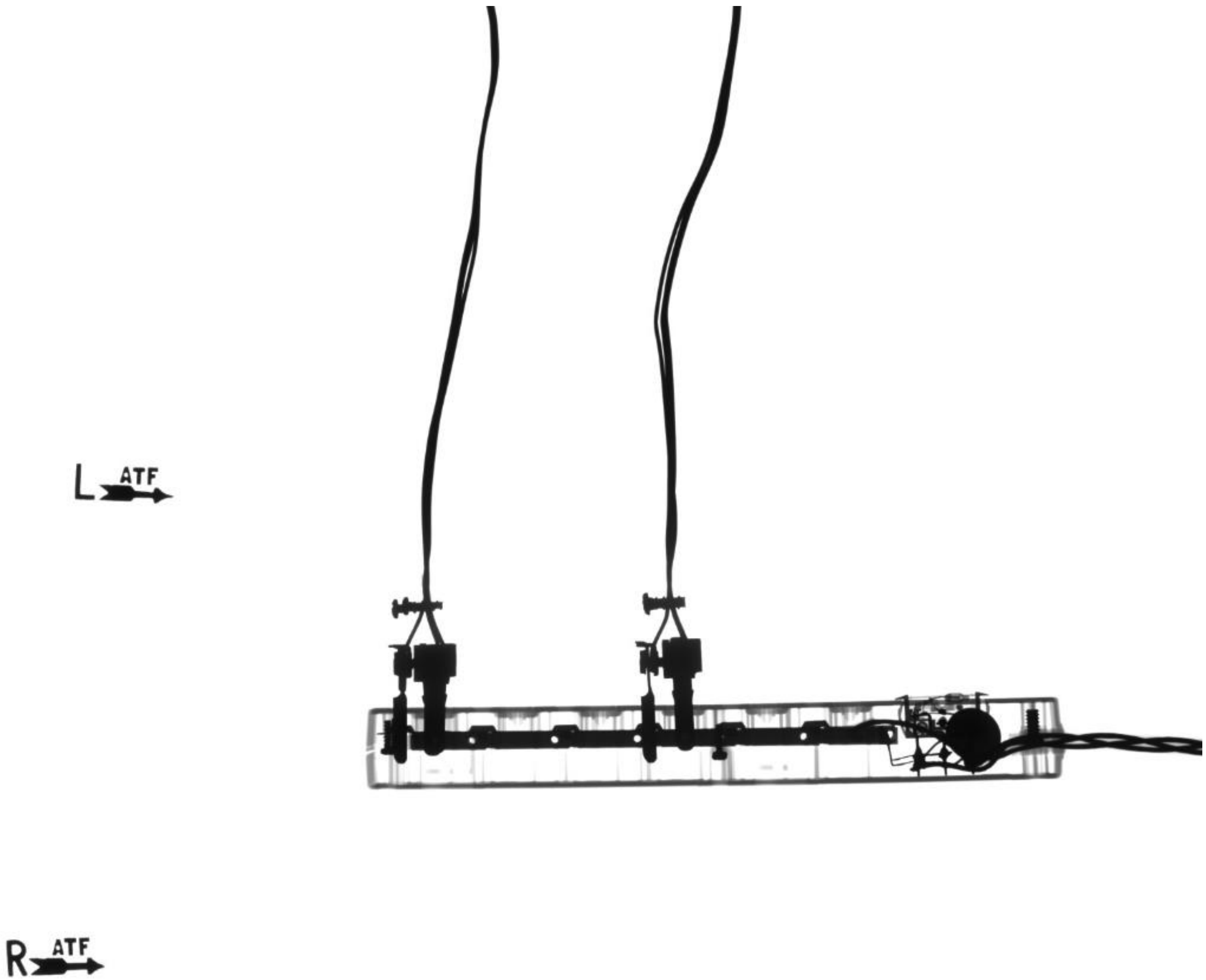
Metal Oxide Varistor



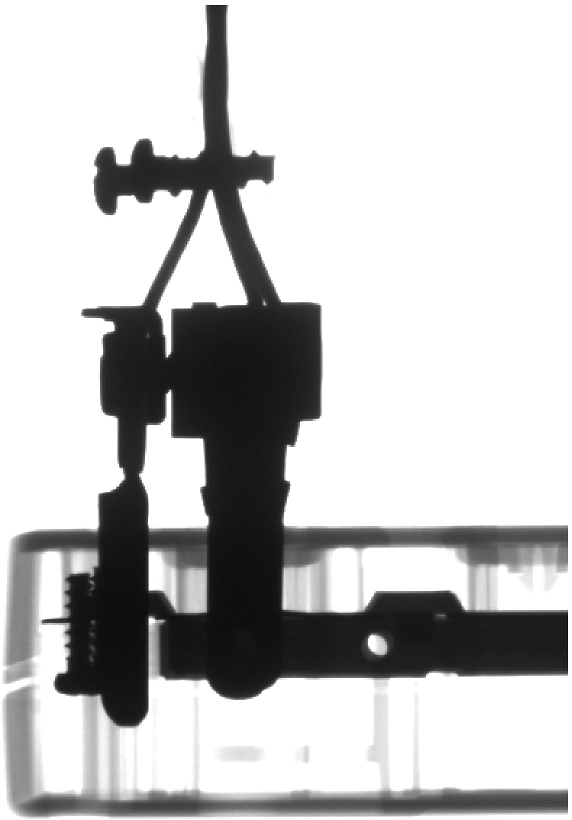
X-Ray

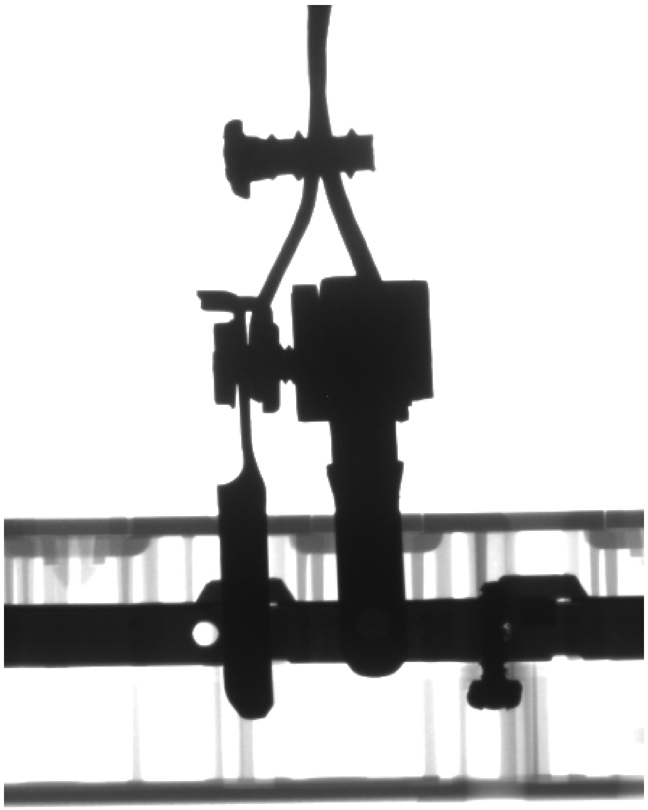


X-Ray

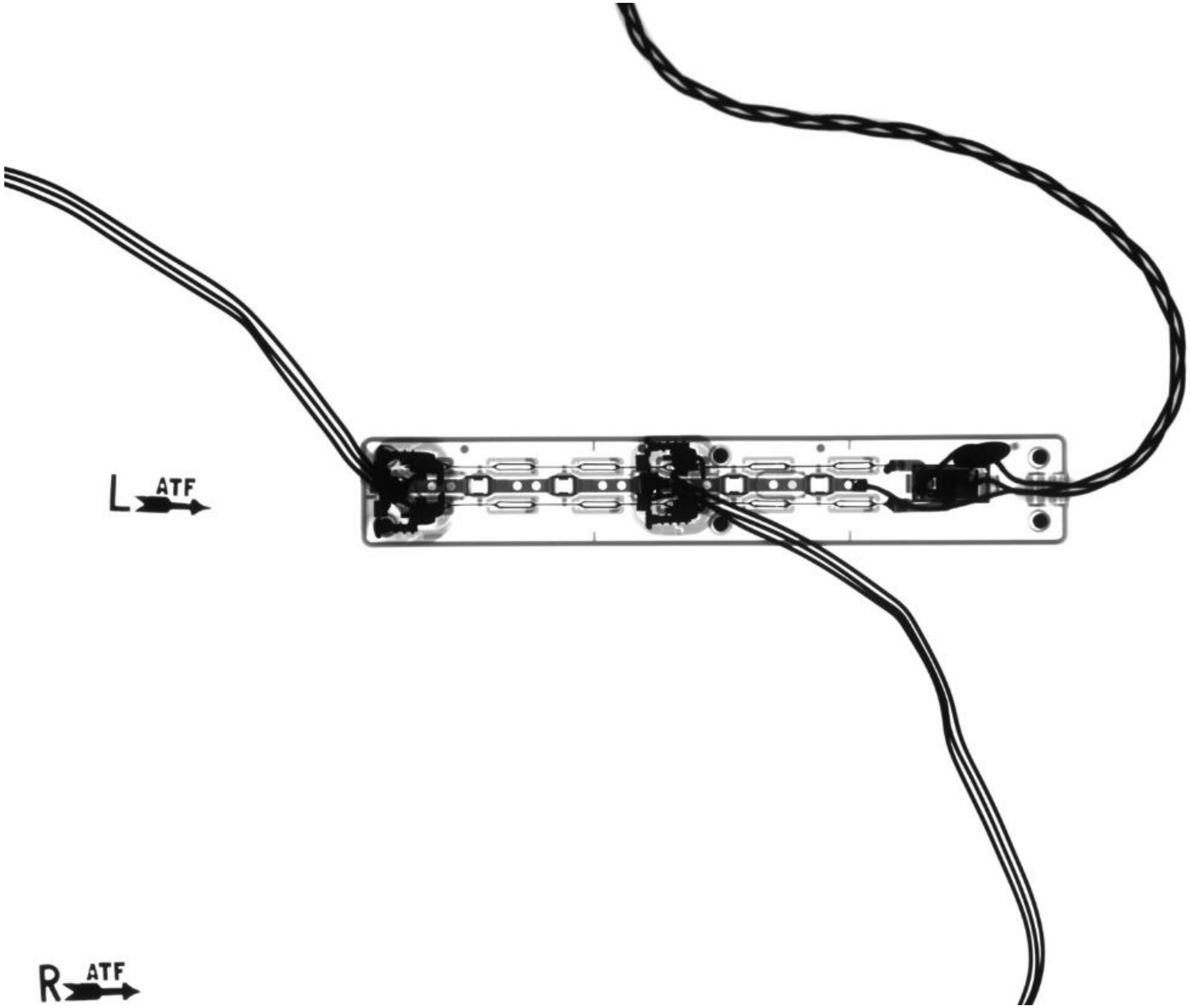


Side View

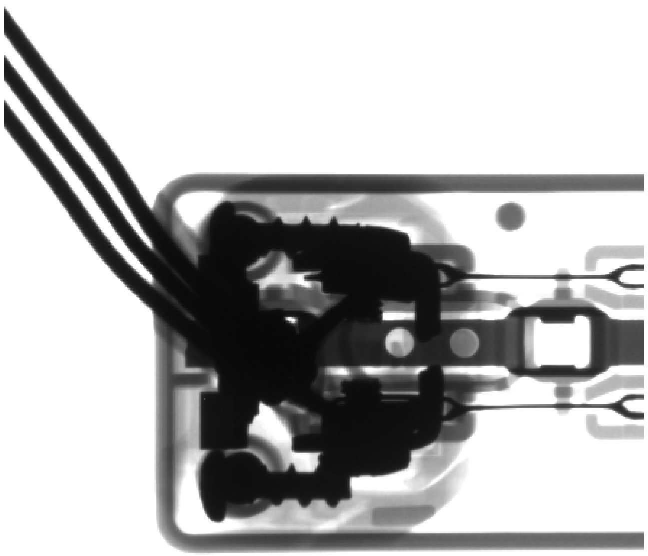


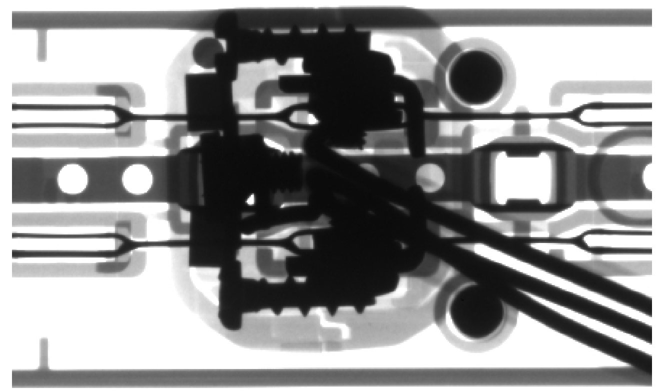


Top View

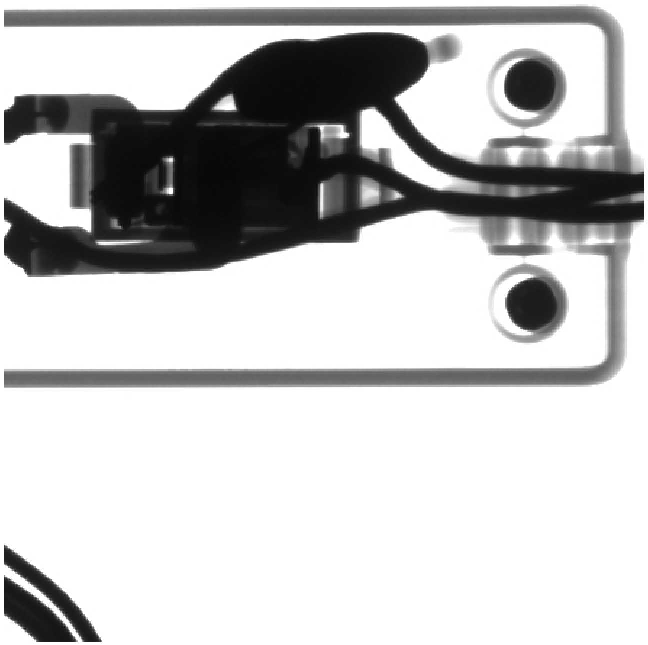


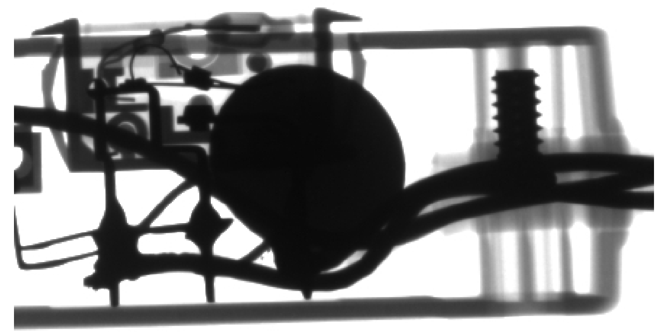
Top View





Metal Oxide Varister





COFFEE MAKER

Coffee Maker Recall History

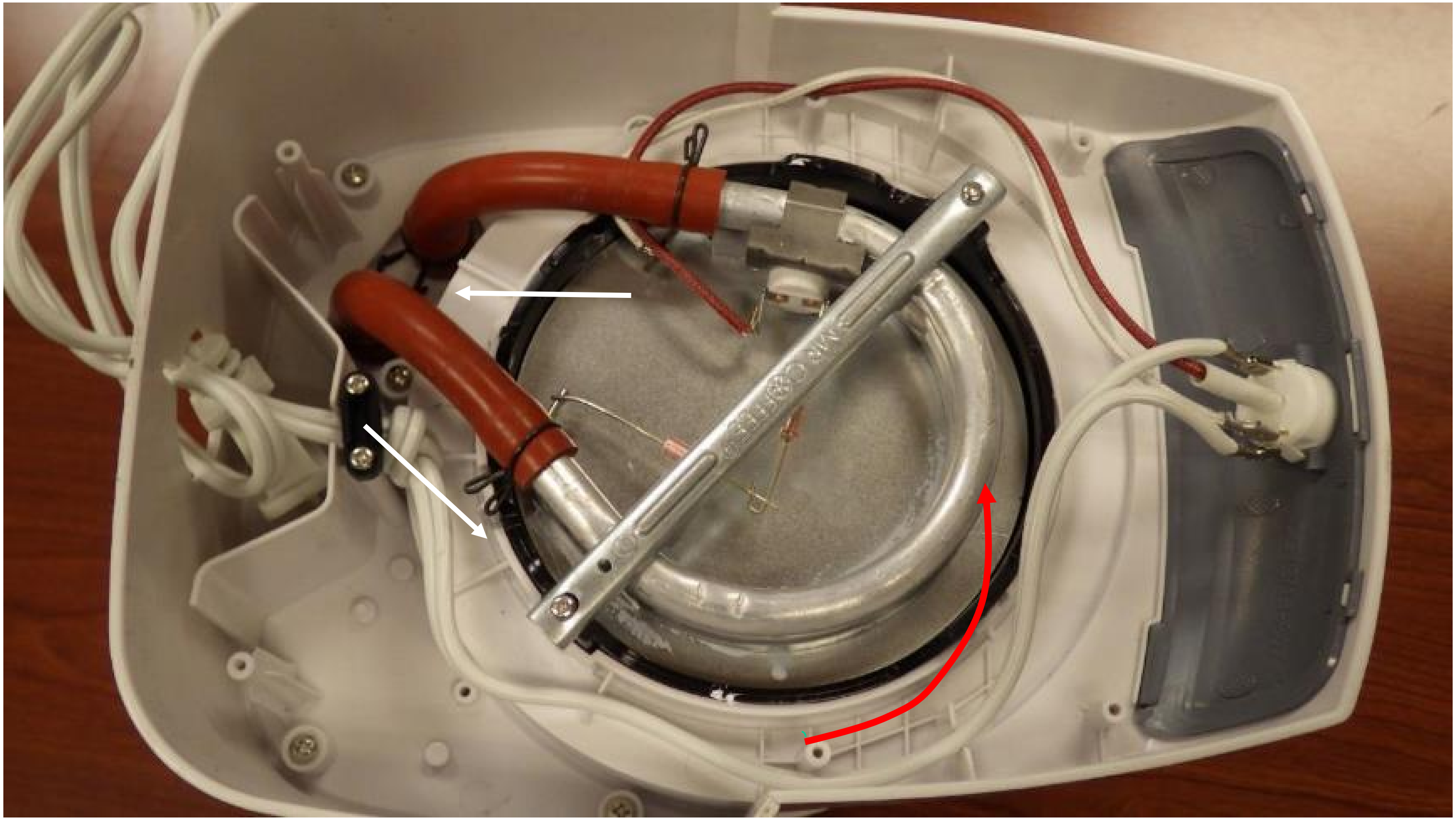
- In 1990, Proctor-Silex in cooperation with the U.S. Consumer Product Safety Commission recalled certain automatic drip coffeemakers made in 1985/86 that may pose a fire hazard.
  - The thermostats and thermal fuses may both malfunction causing overheating and a potential fire hazard. Approximately 181 reports of fires have been received.
  - When the recall was issued, it was estimated that 800,000 of these coffeemakers were still in use.

Coffee Maker Recall History

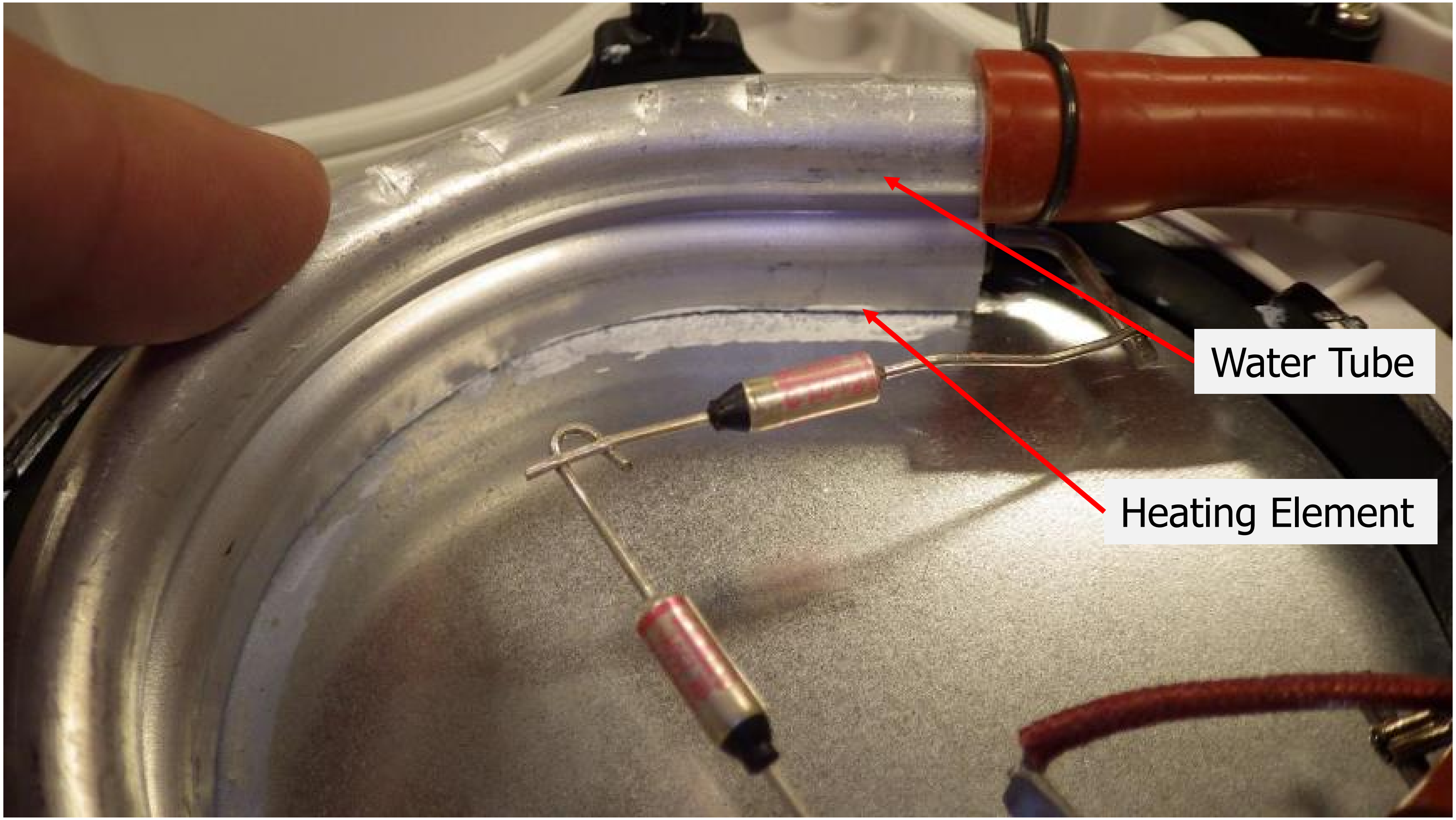
- In 1991, nine million drip coffee makers bearing the GE or Universal name were recalled. The coffee makers were manufactured between 1976 and 1984.
  - The safety thermal cutoffs (TCO) used in the coffee makers were not reliable.
  - The U.S. Consumer Product Safety Commission (CPSC) sued GE for not reporting the problem in a timely manner as required by law. GE received more than 500 reports of the coffee makers overheating.
  - In 1982, GE designed a coffee maker with two TCO's, but the coffee maker never went into production. GE continued to manufacturer the one TCO design.
  - In 1984, when the small appliance division of GE was sold to Black and Decker, the design was changed to two TCO's.

FIRE RESEARCH LABORATORY
ATF

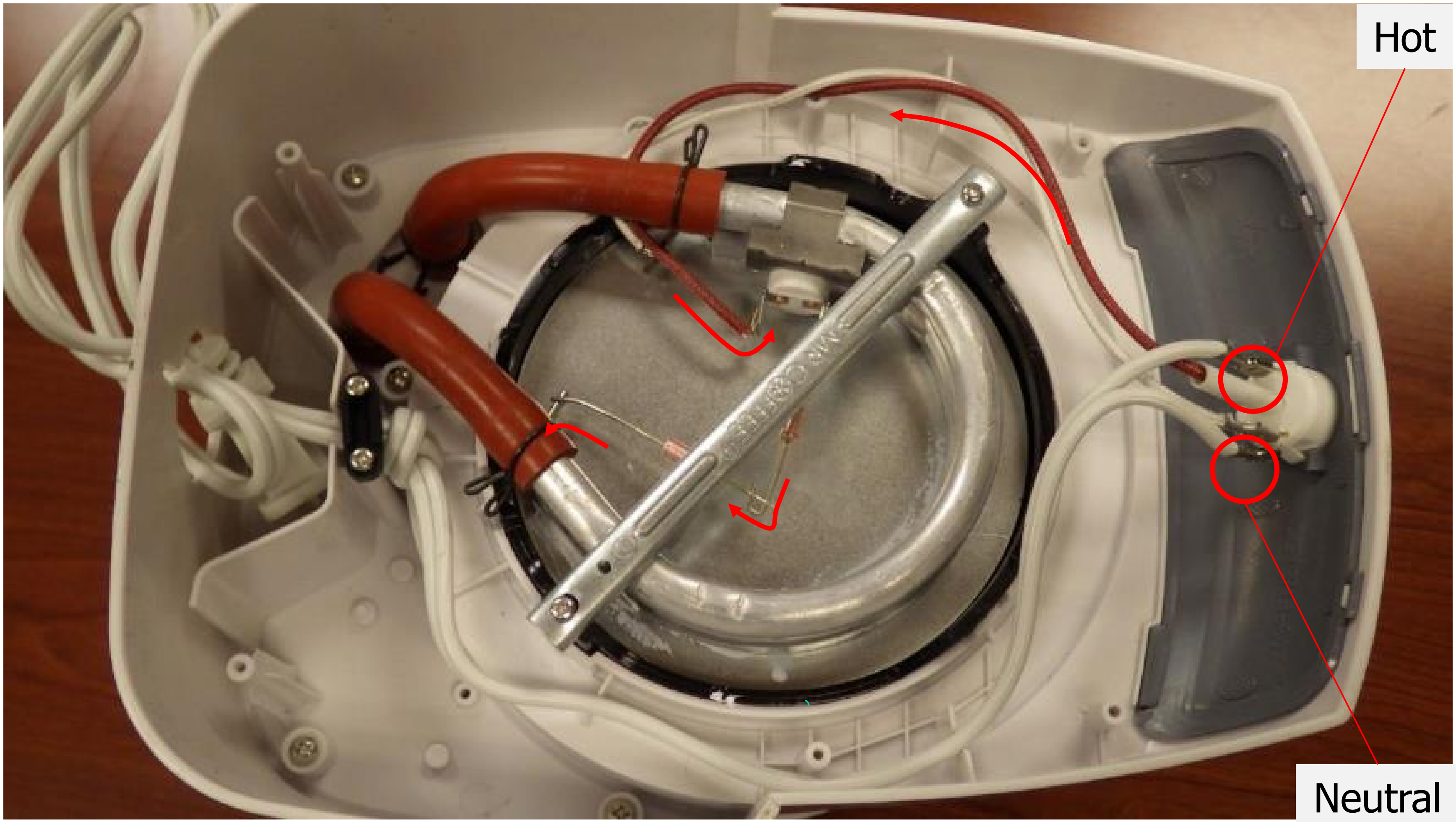
Water Flow



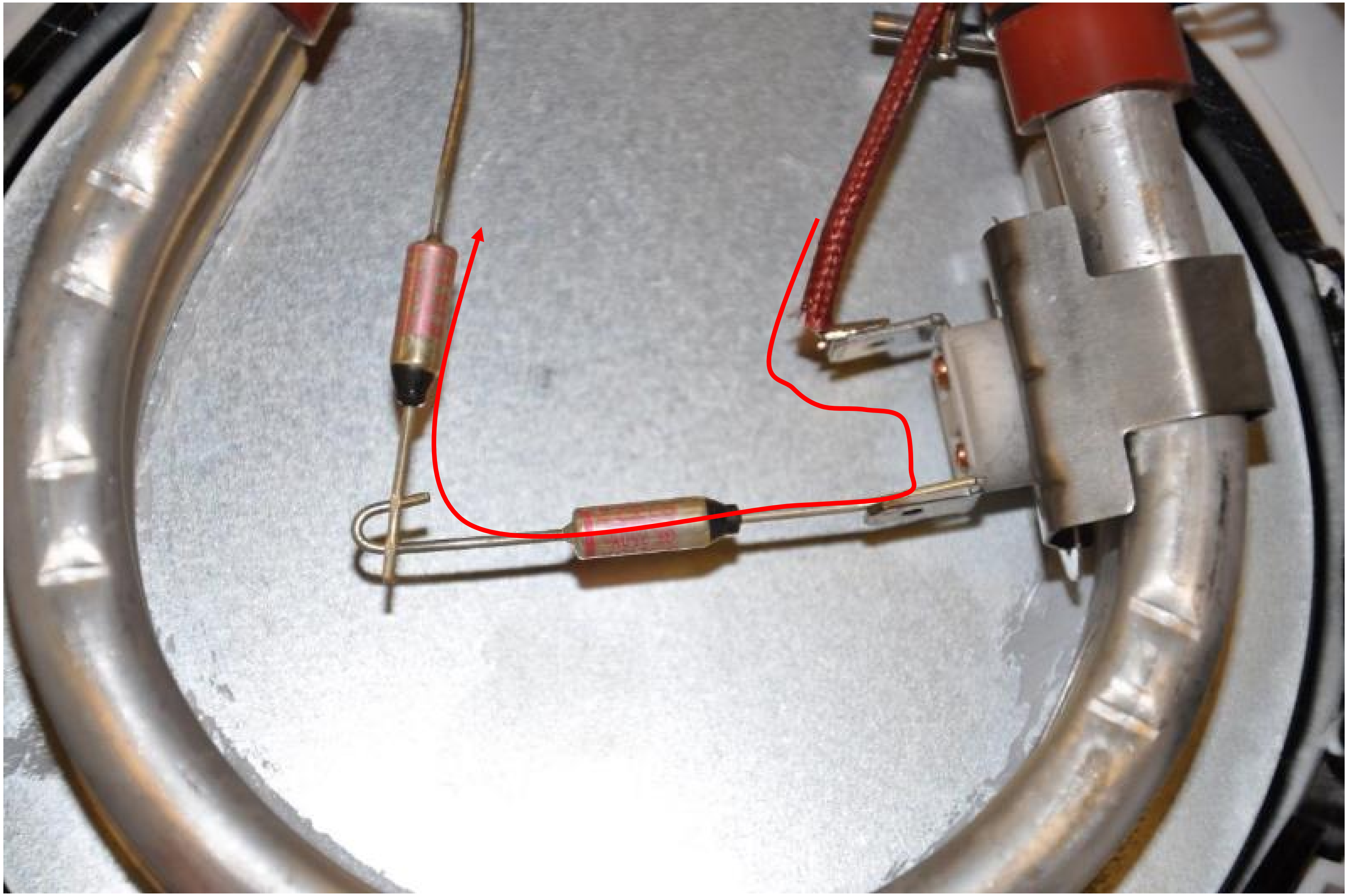
Heating Element



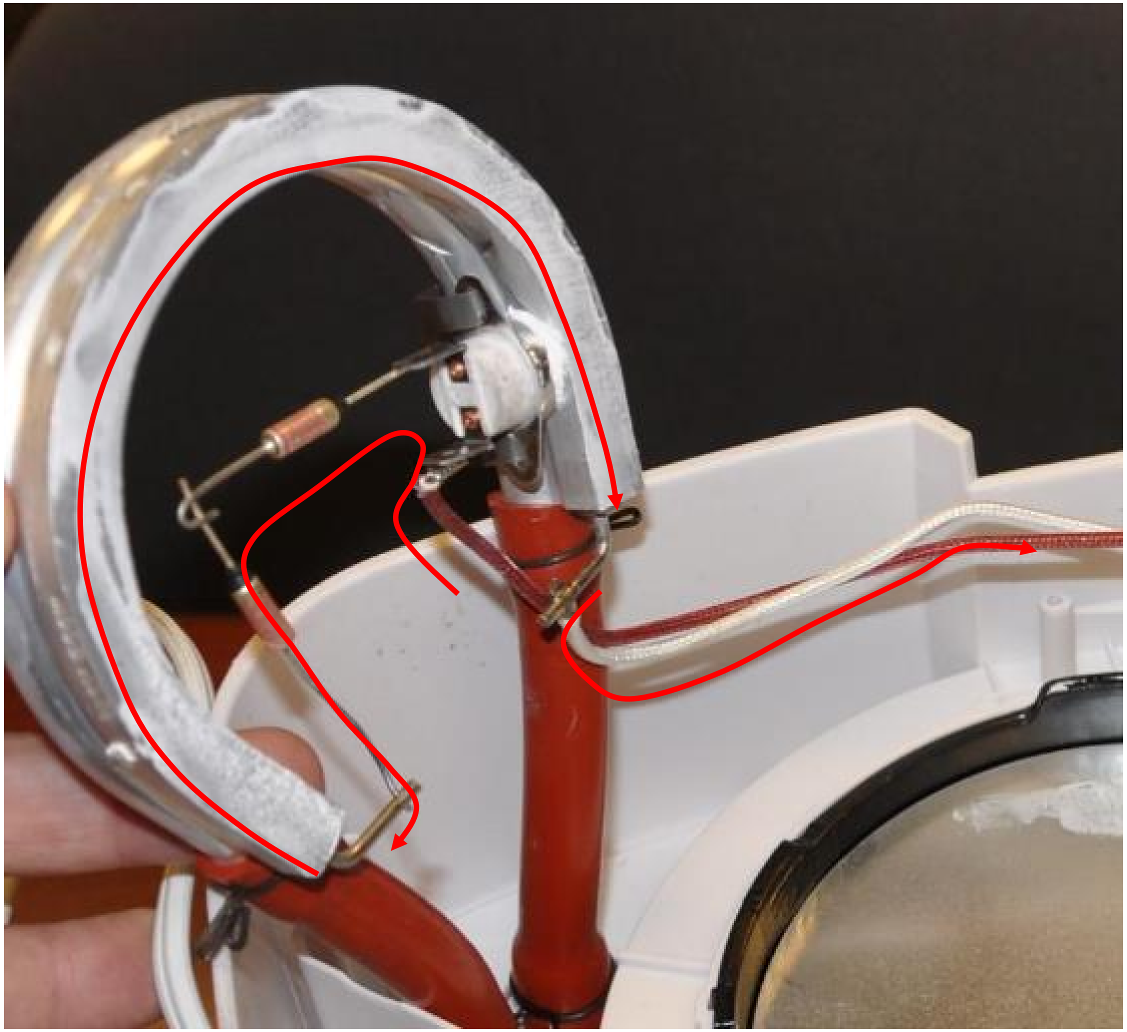
Electricity Flow



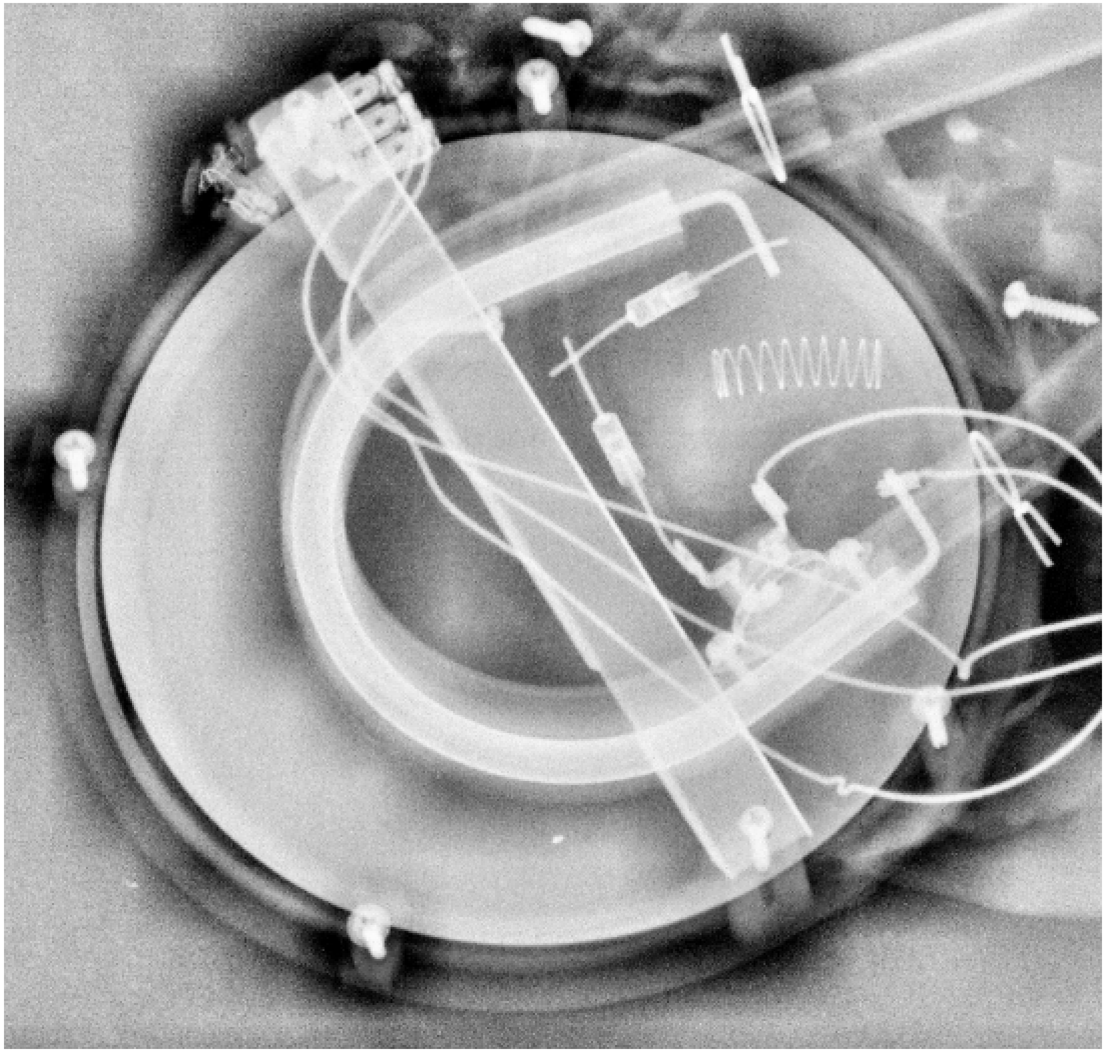
Series Connected Thermal Protection



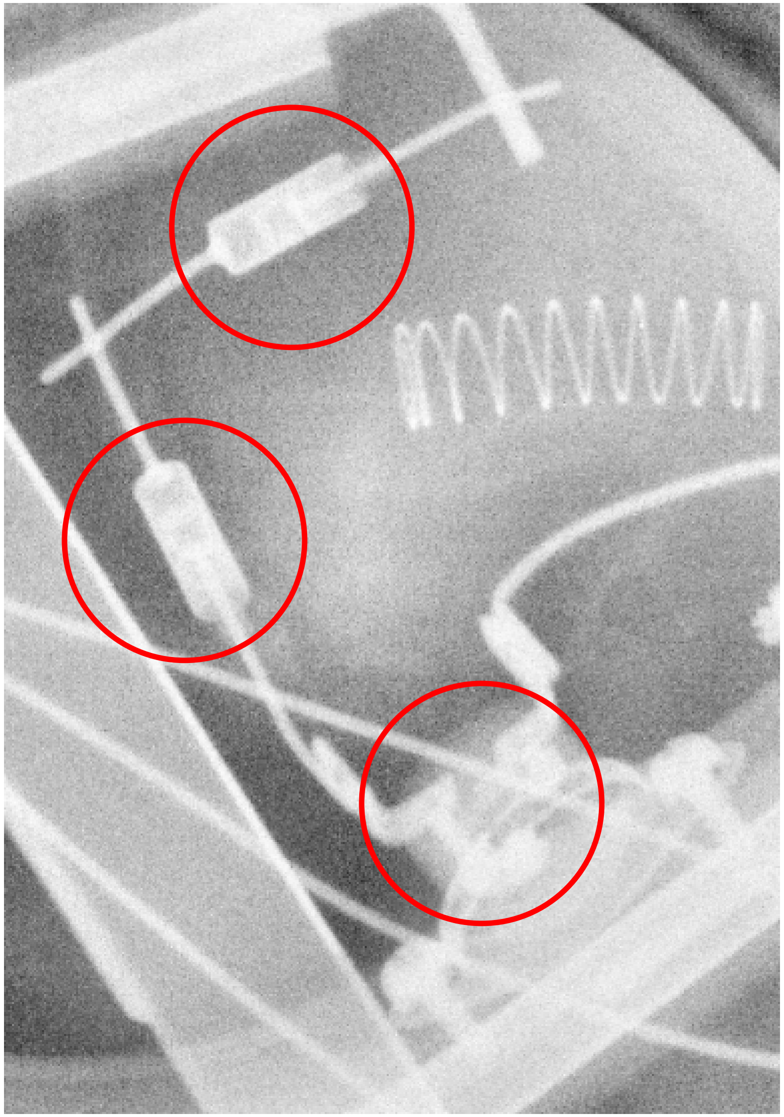
Electricity Flow



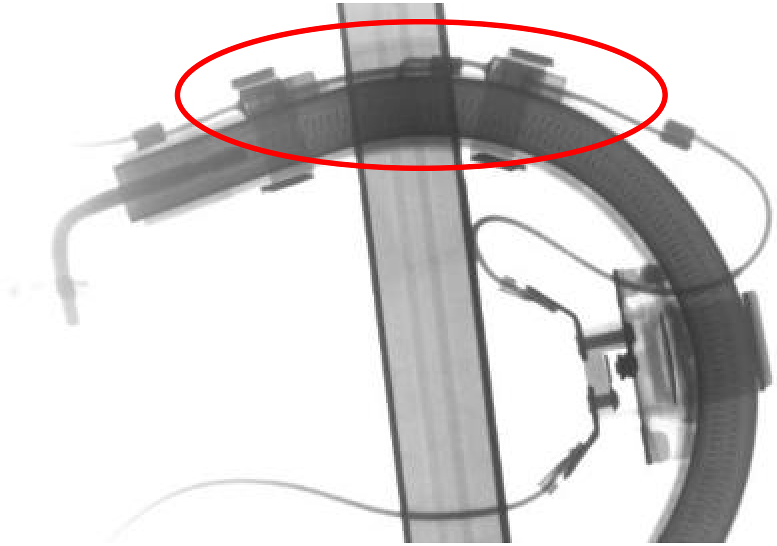
X-Ray Examination

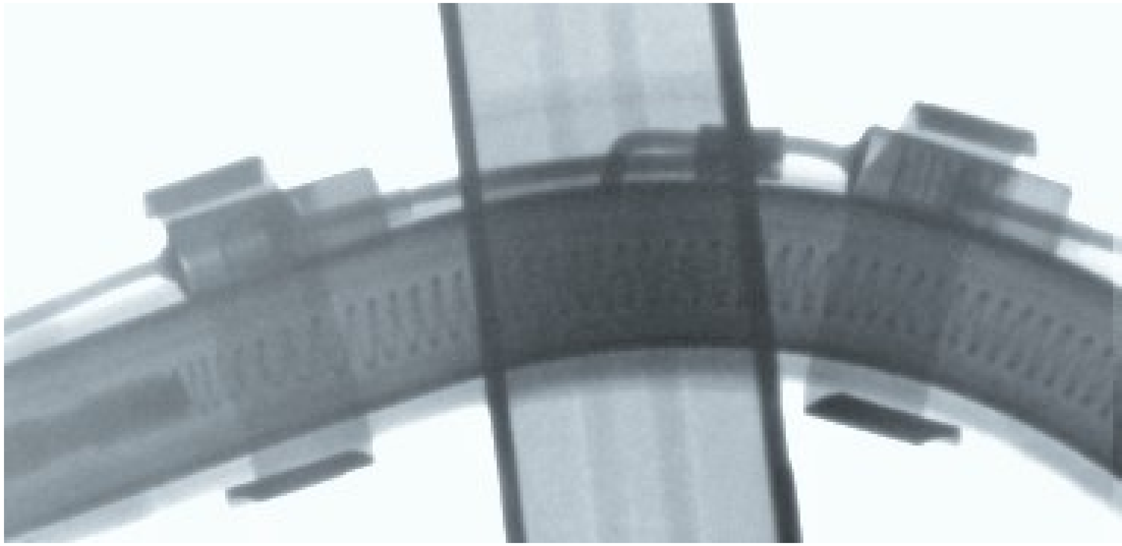


X-Ray Examination

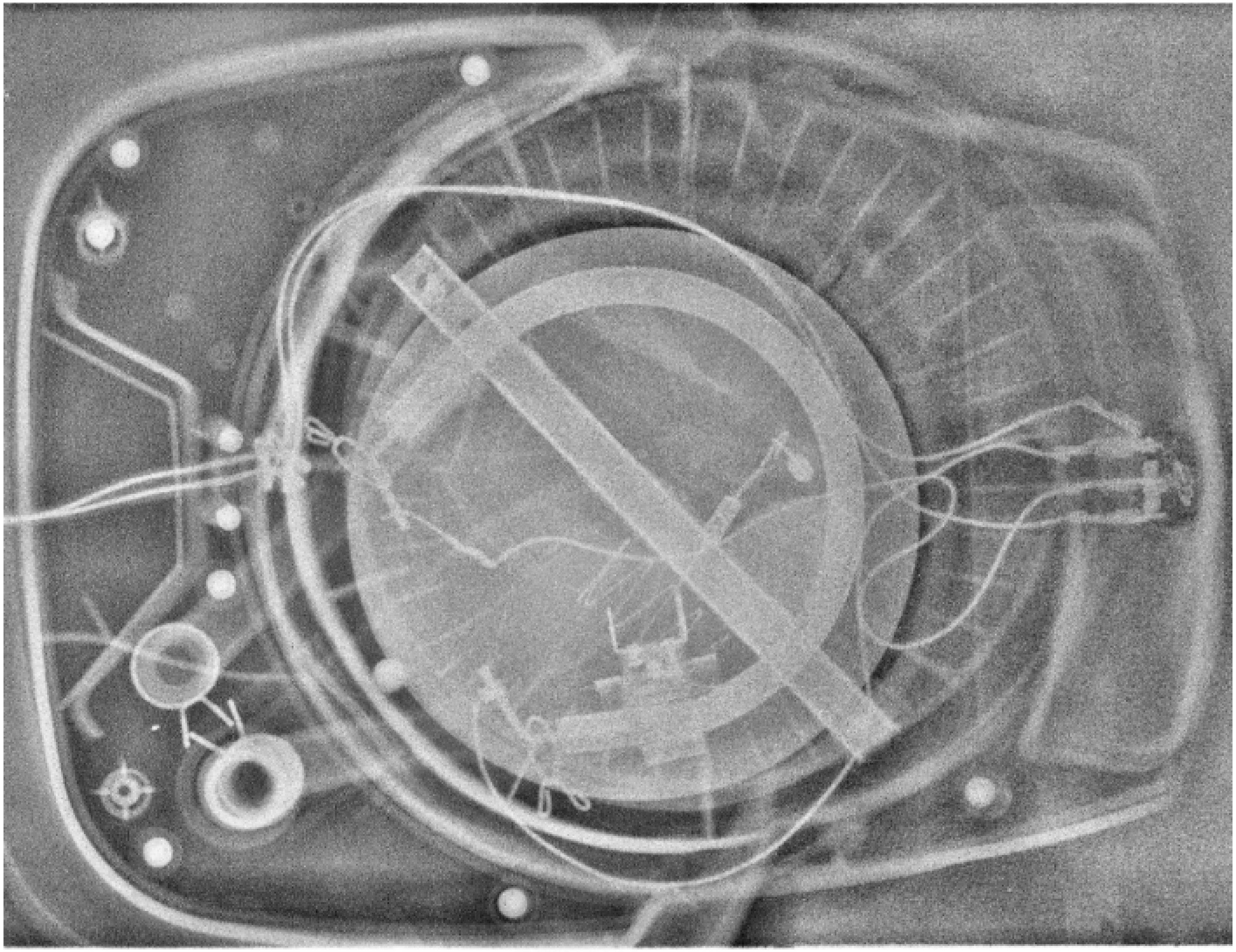


X-Ray Examination

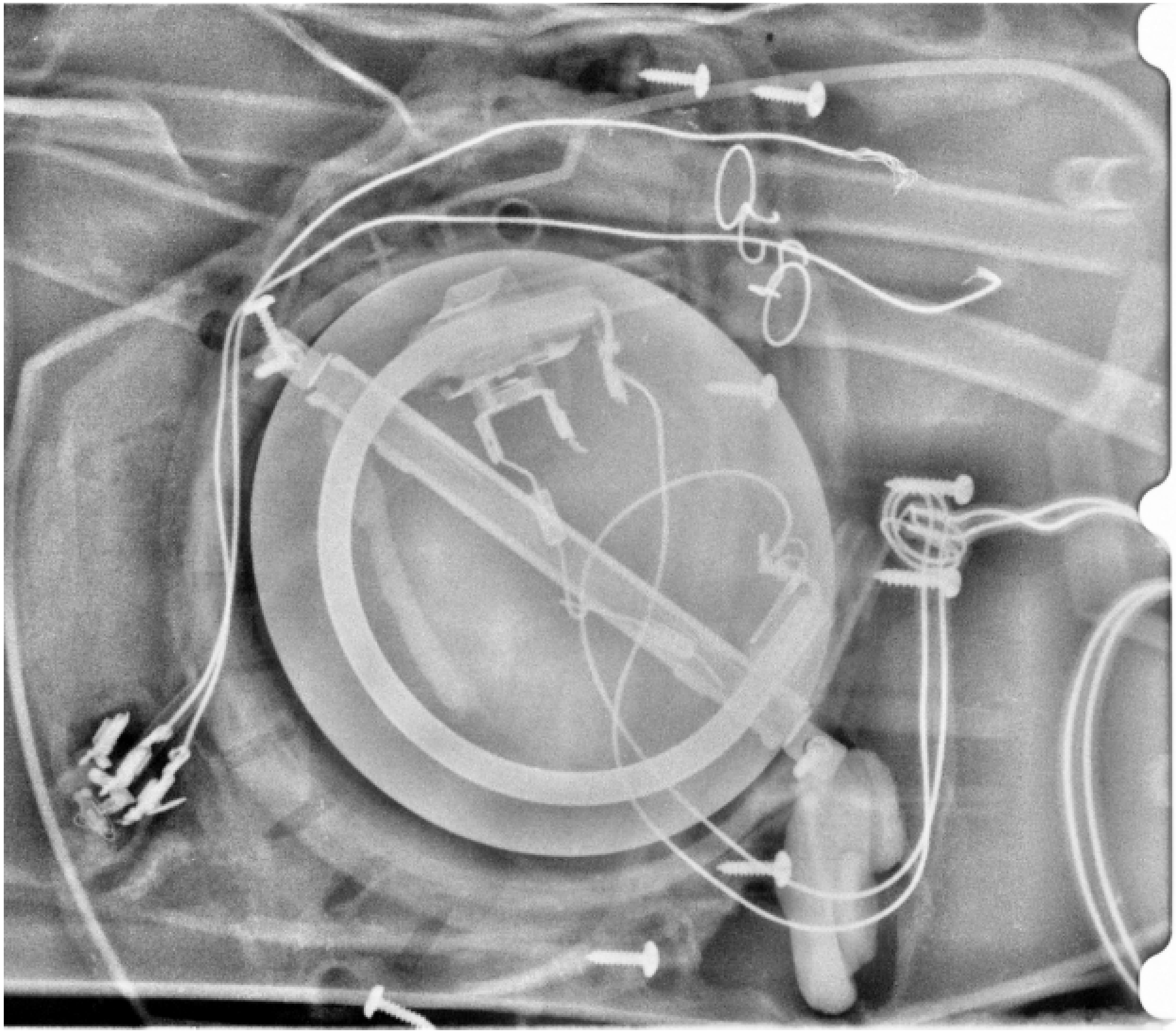


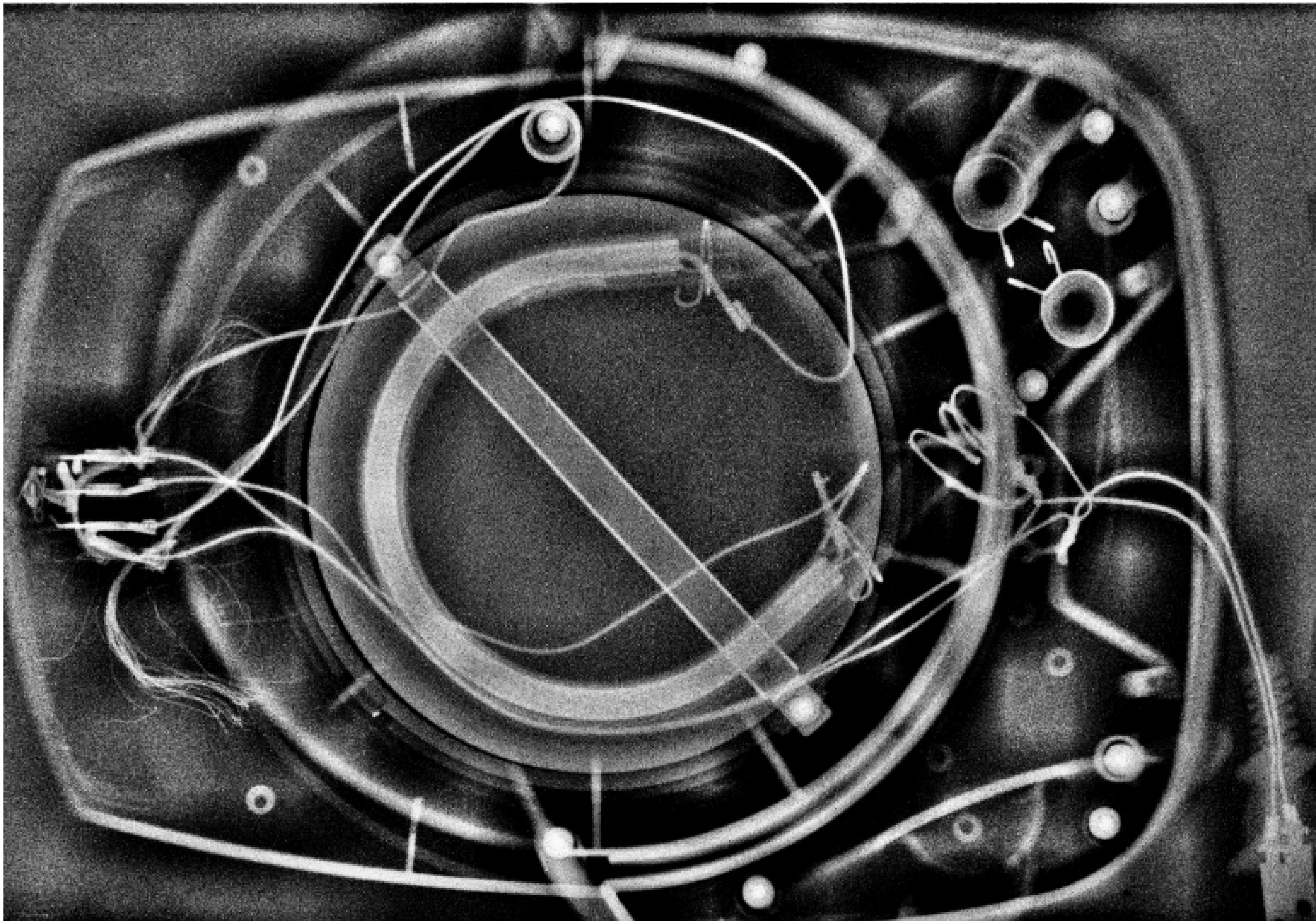


X-Ray: Exemplar



FIRE RESEARCH LABORATORY
ATF





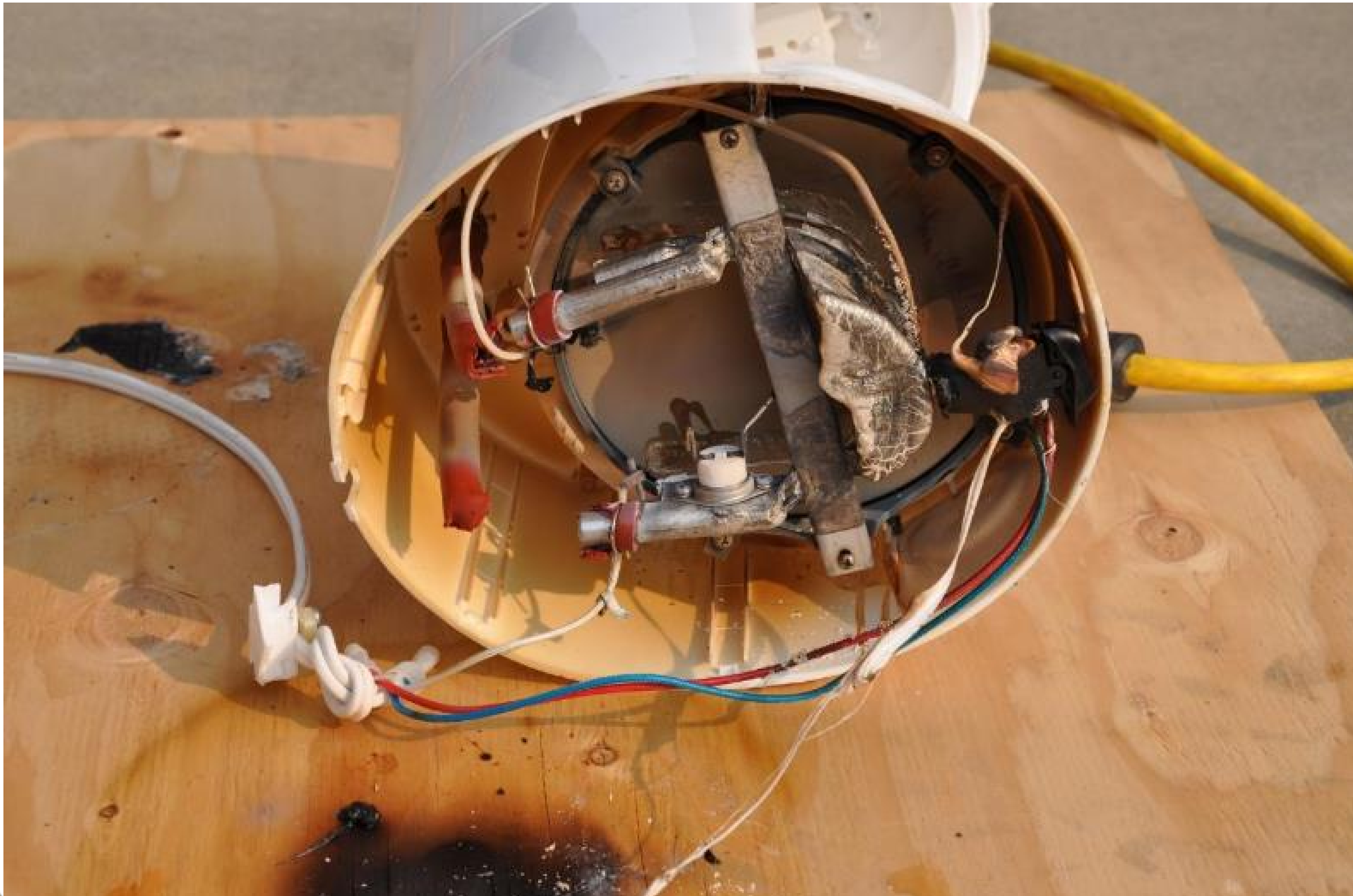
Coffee Maker Elements – Post Fire

Coffee Makers

- Failure Modes:
  - Multiple safety devices must fail for thermal runaway
  - Something jams contacts closed
  - High resistance connection

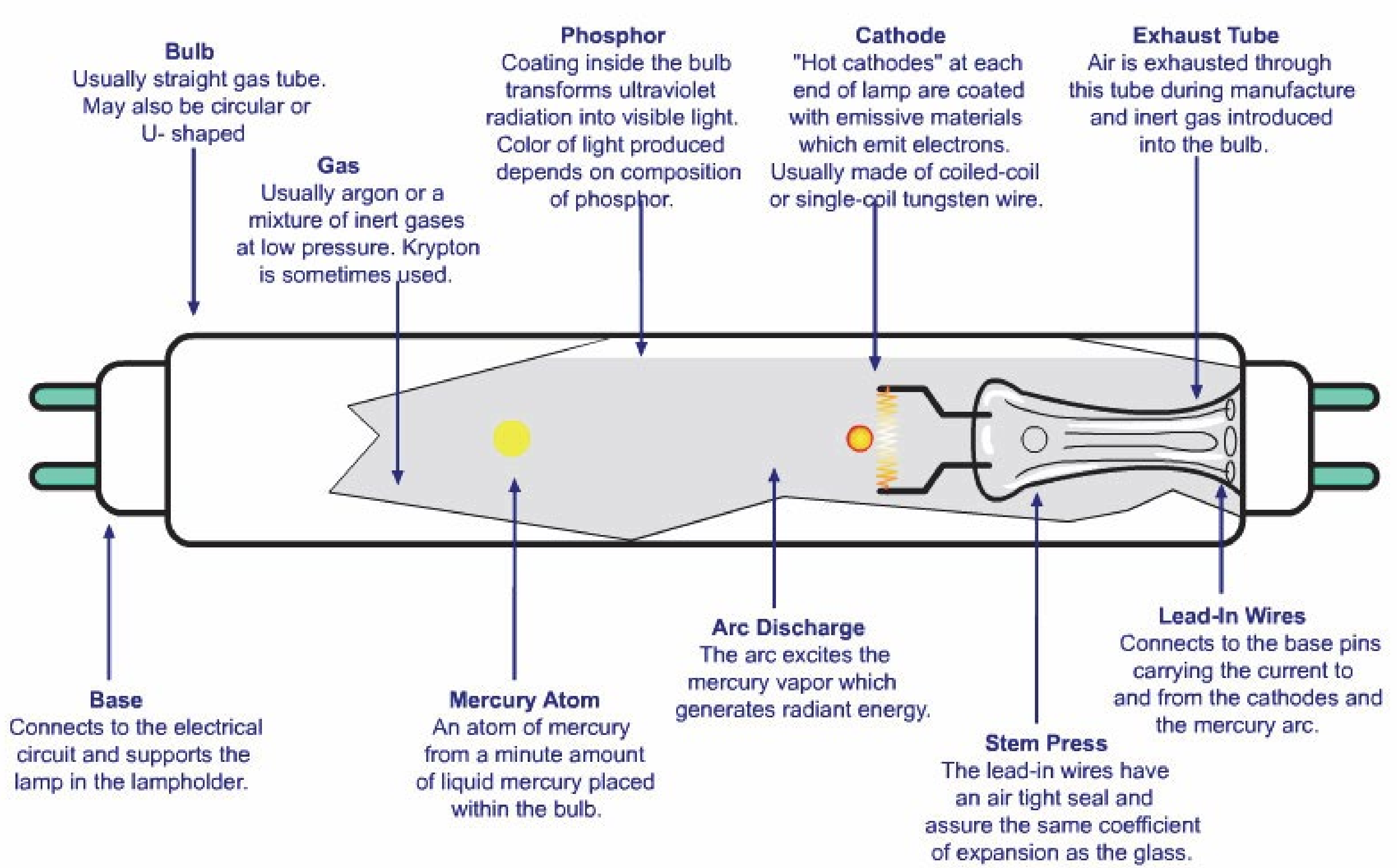
- Look For:
  - Debris inside of unit
  - Arc melting in immediate vicinity
  - Adjacent fuels


Proctor Silex

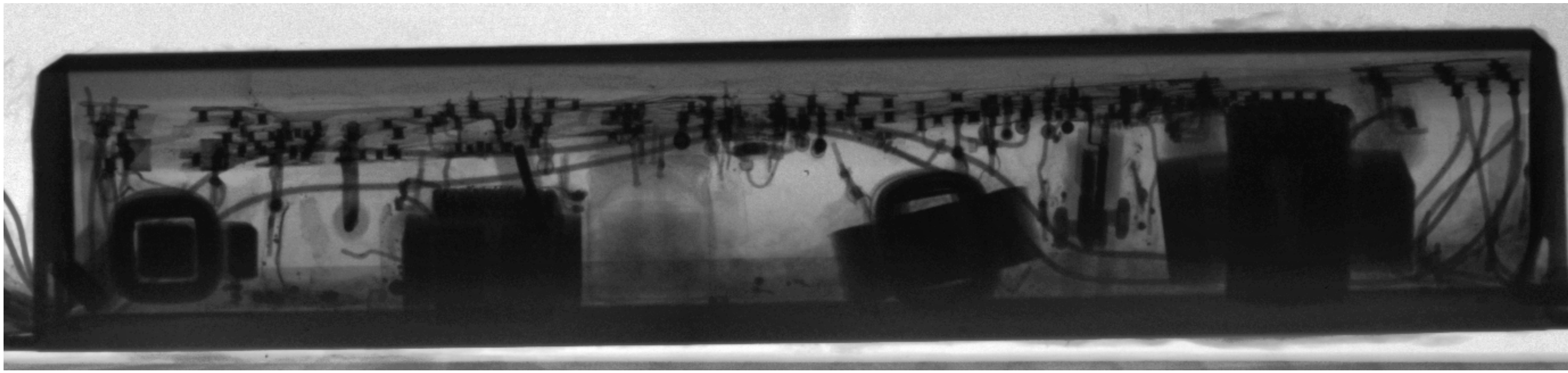


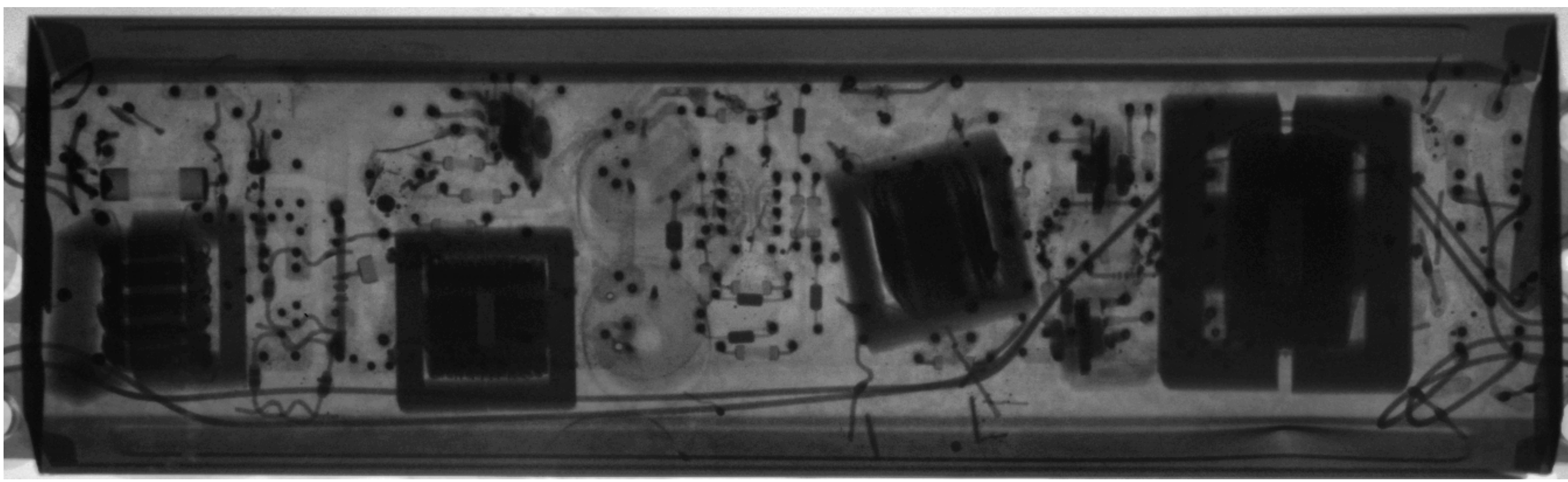
Fluorescent Light Fixtures

Fluorescent Lights

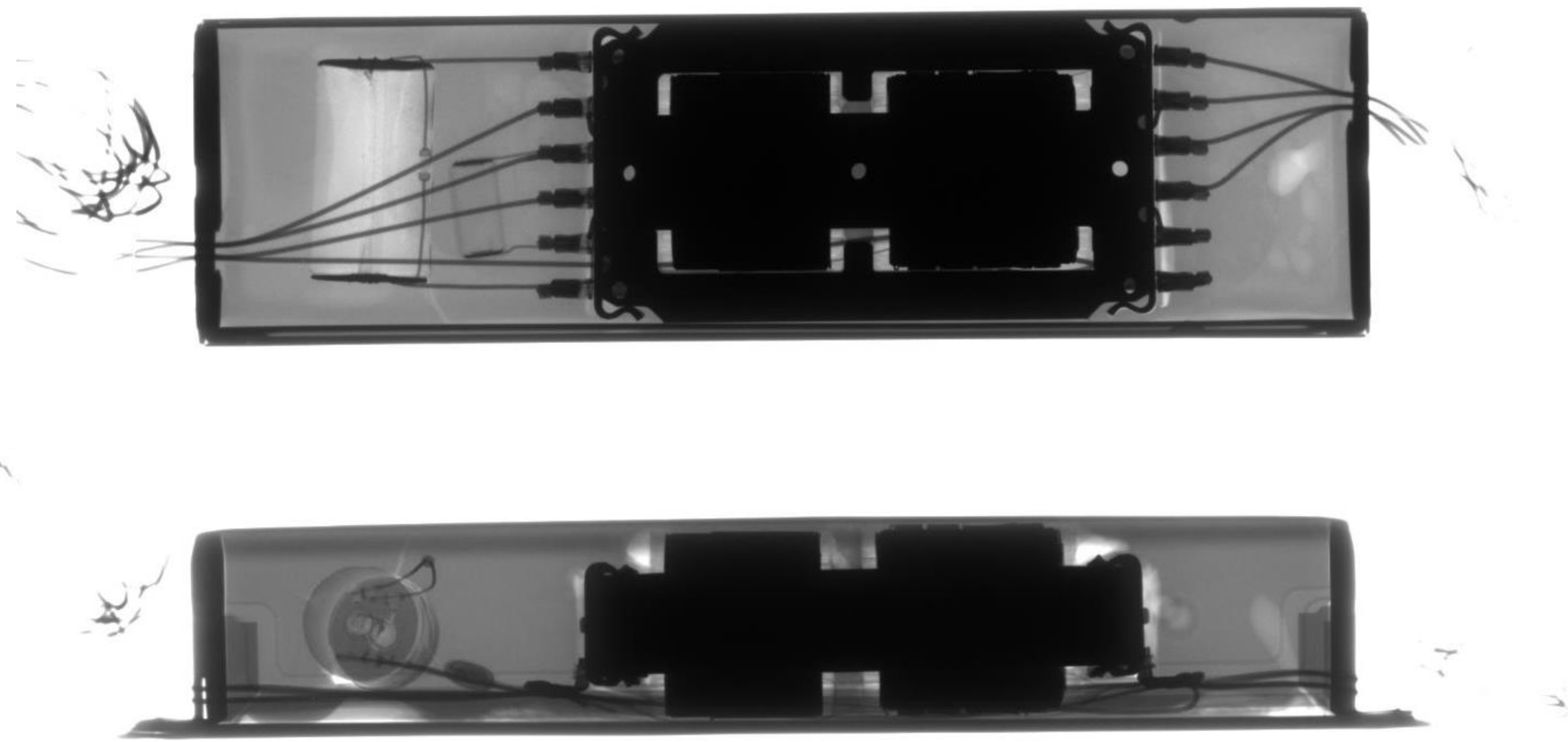


Fluorescent Light Fixture – Electronic Ballast





Fluorescent Light Fixture – Magnetic Ballast

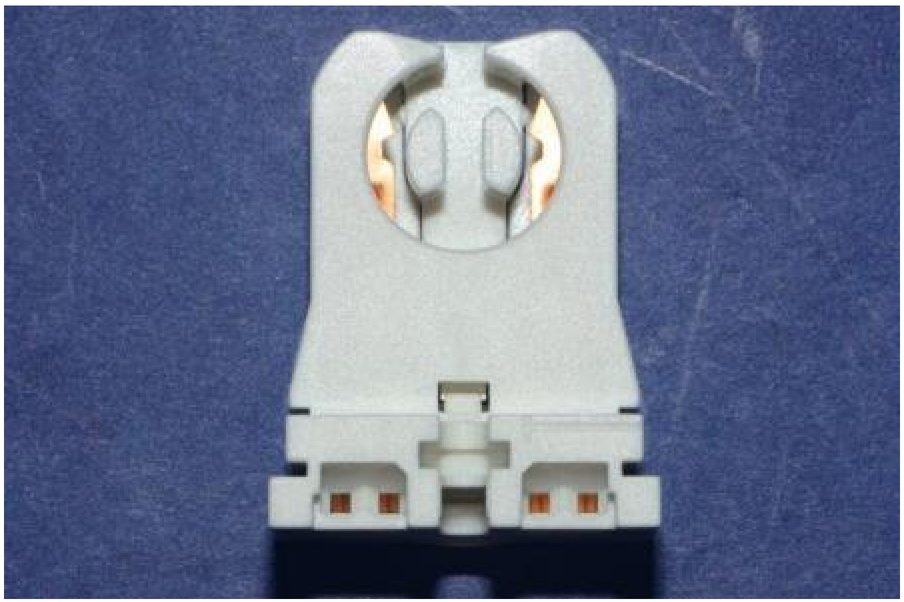


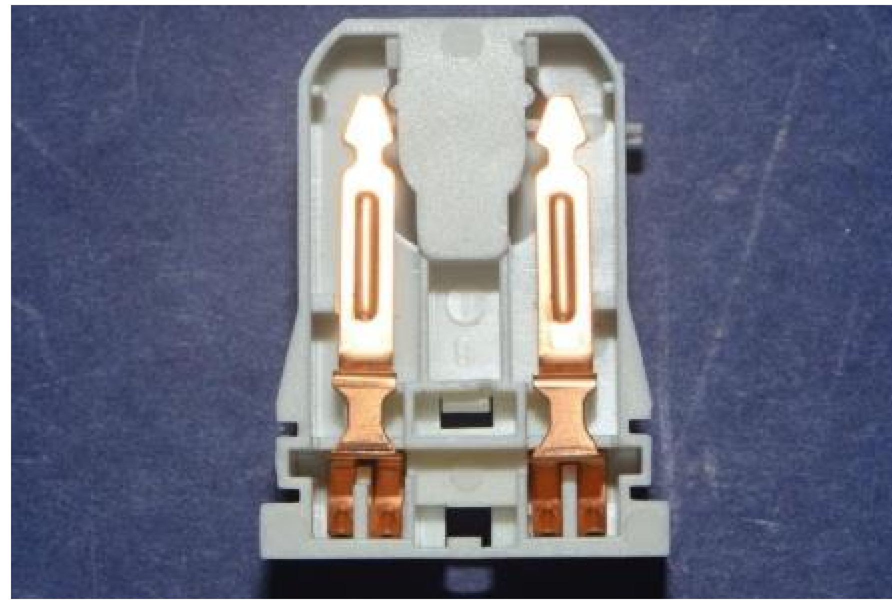
Ballast Failure

Courtesy Jamie Novak

Ballast Failure

Fluorescent Lamp Socket

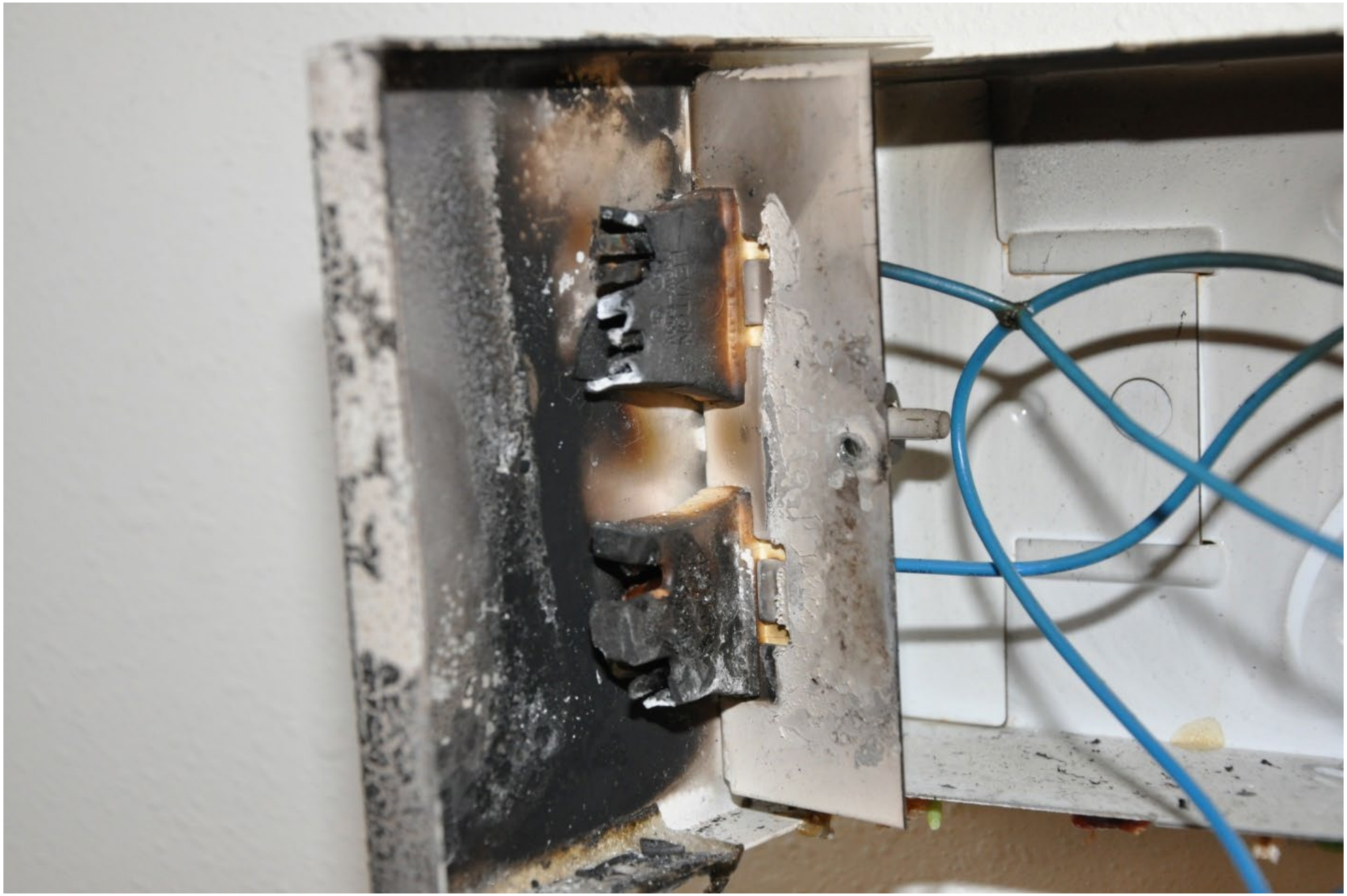




Fluorescent Light Fixture

Fluorescent Light Fixture

Fluorescent Light Fixture

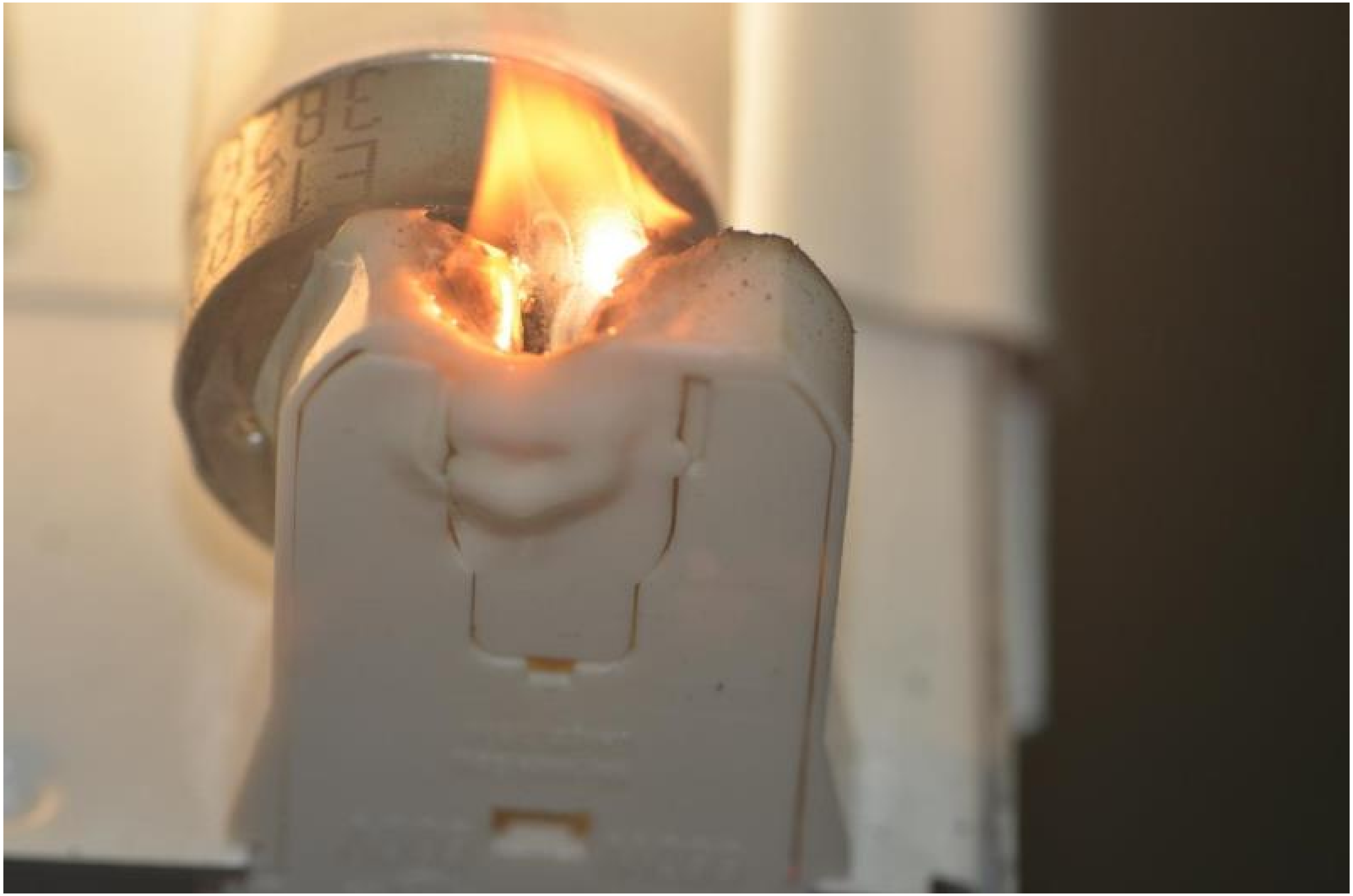


Fluorescent Light Fixture

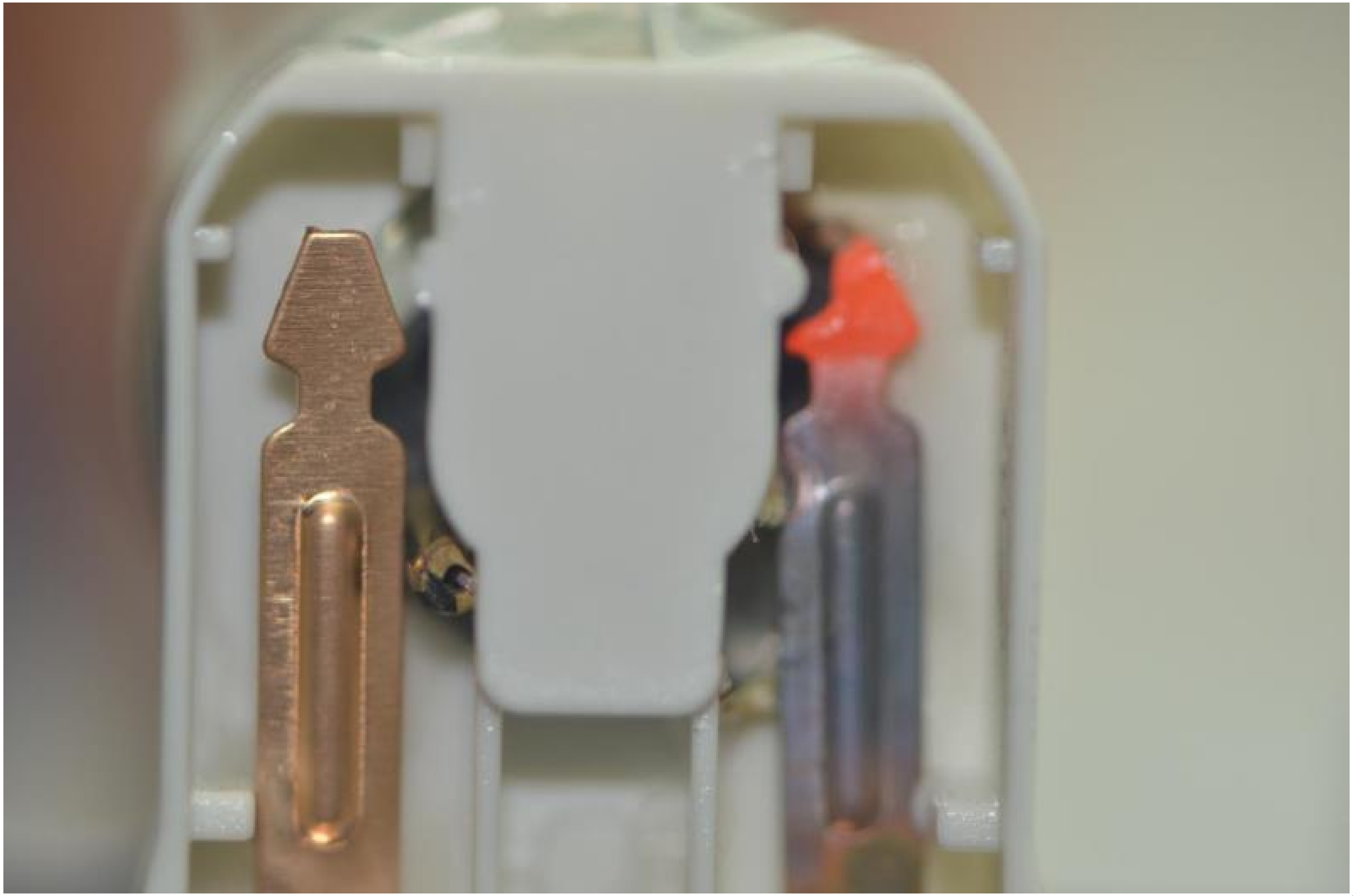
Fluorescent Light Fixture

Fluorescent Light Fixture

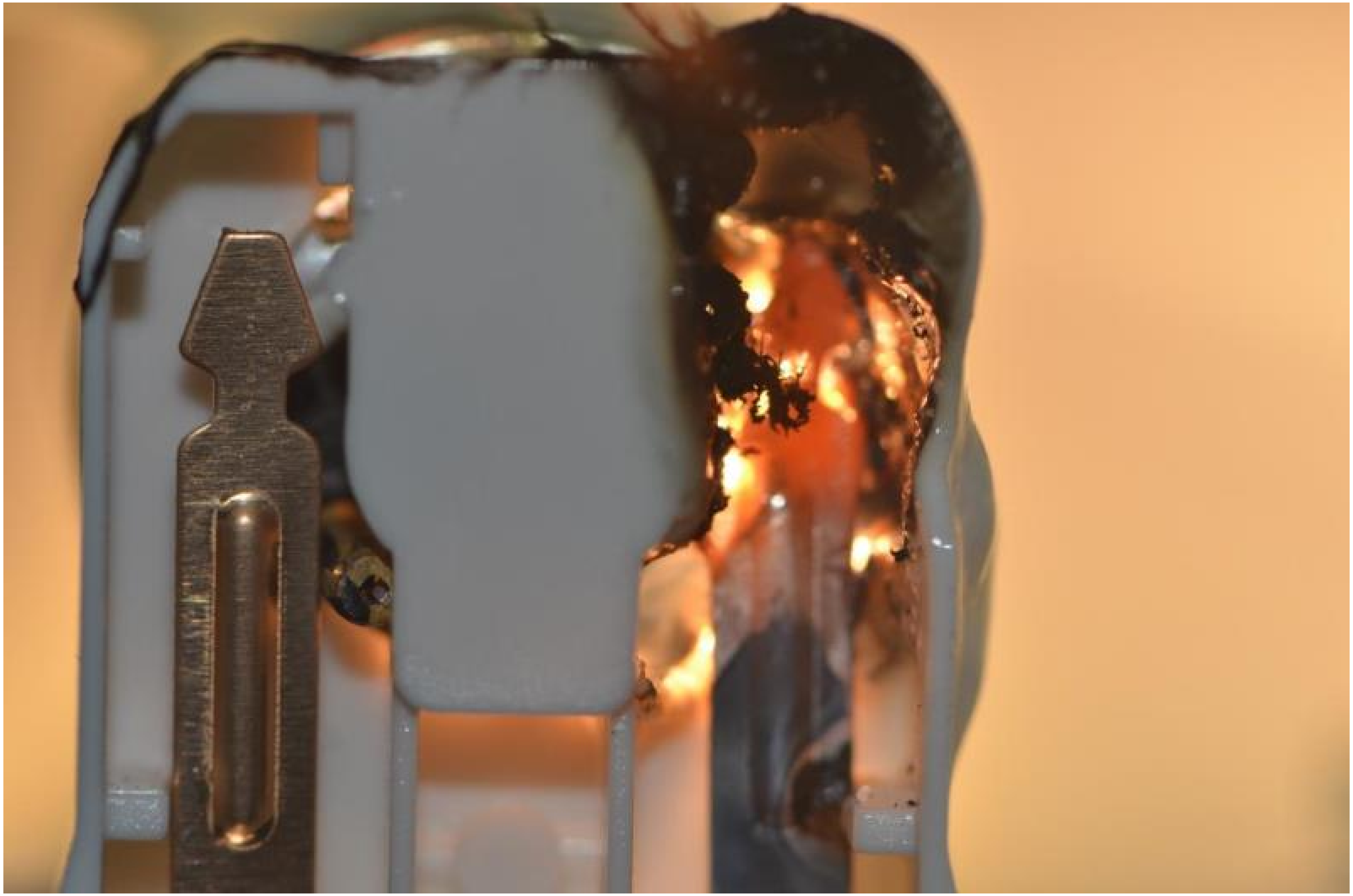
Lampholder Failure



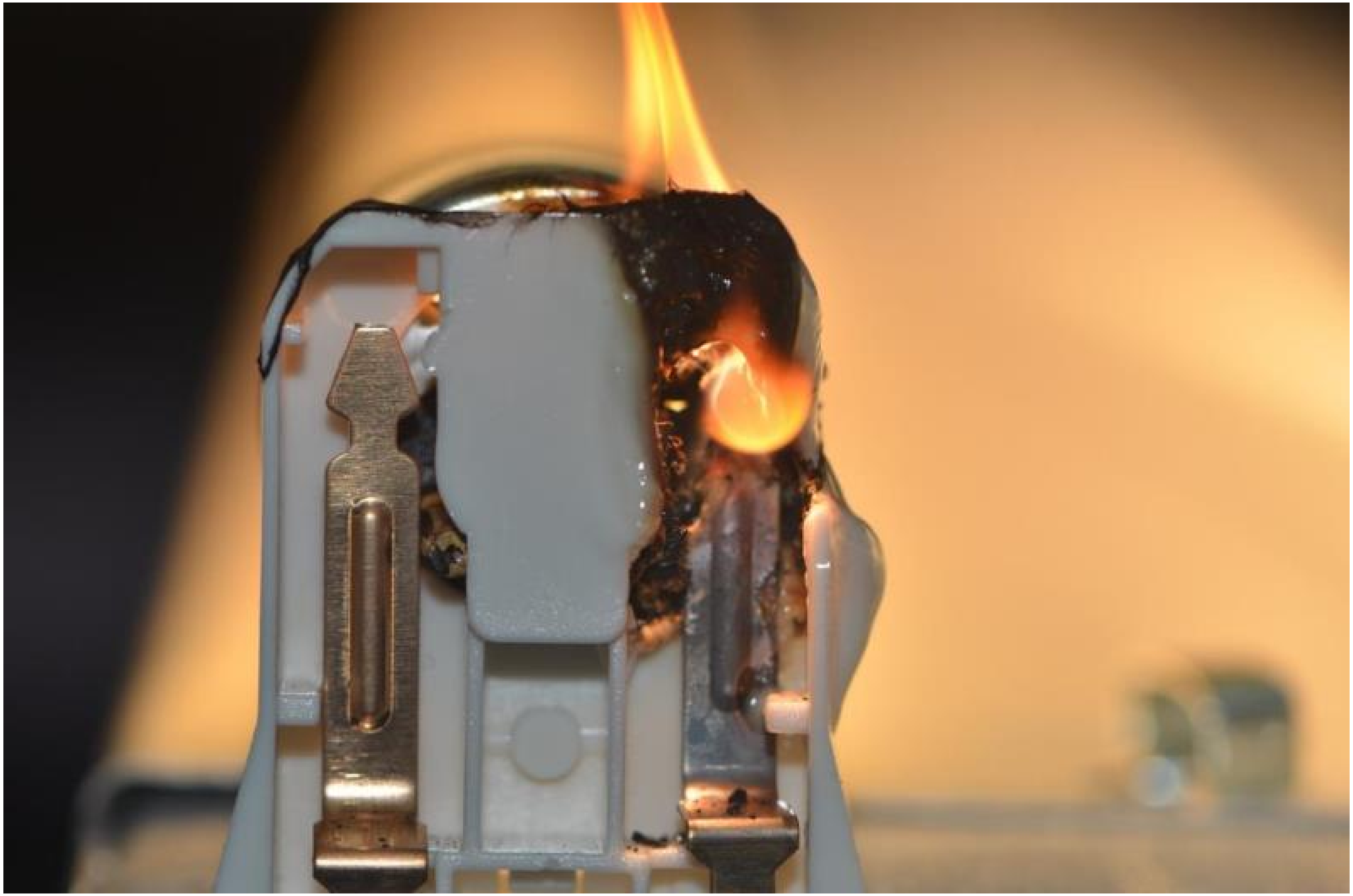
Lampholder Failure



Lampholder Failure



Lampholder Failure



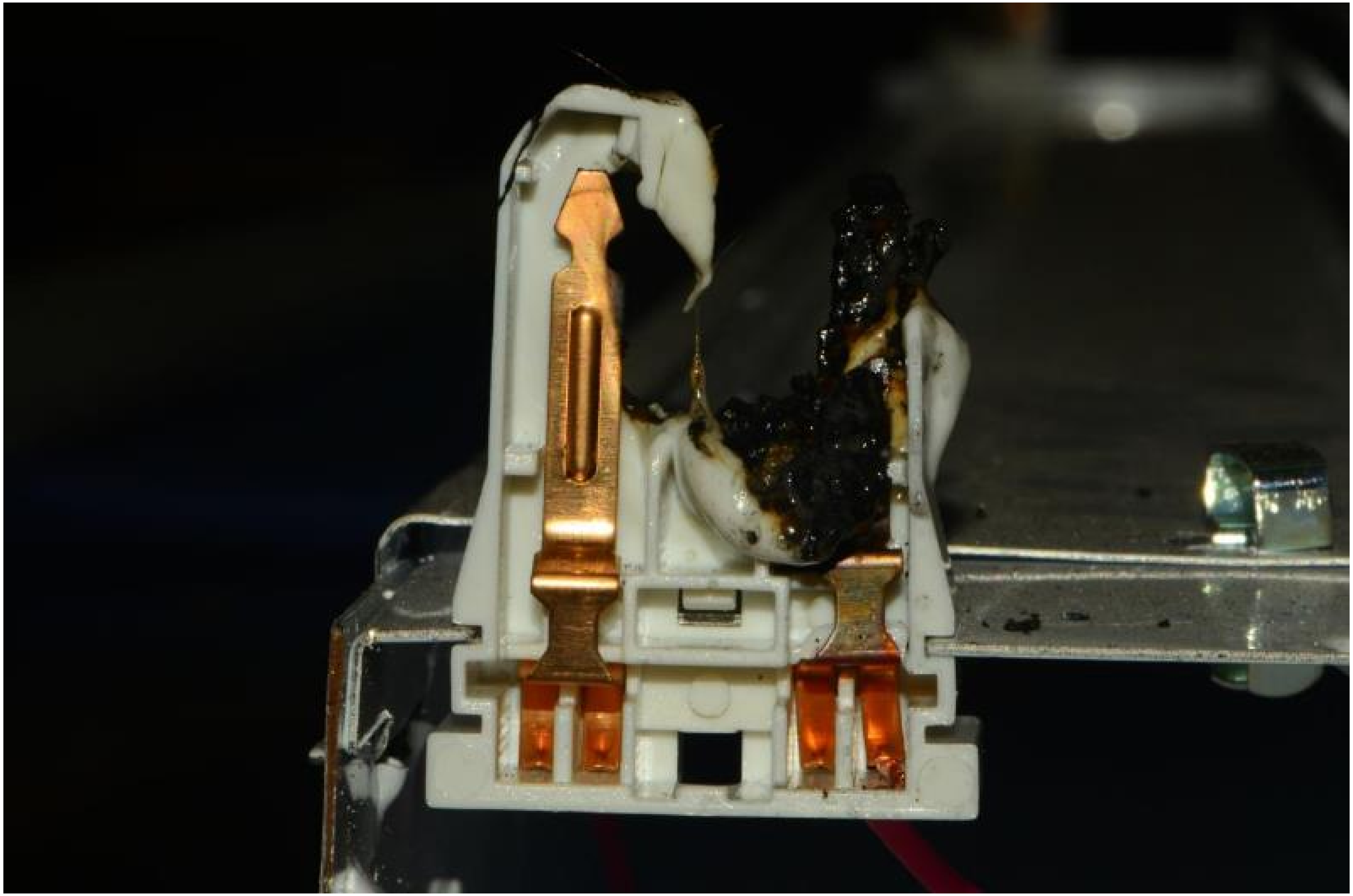
Lampholder Failure

Lampholder Failure

Lampholder Failure

Lampholder Failure

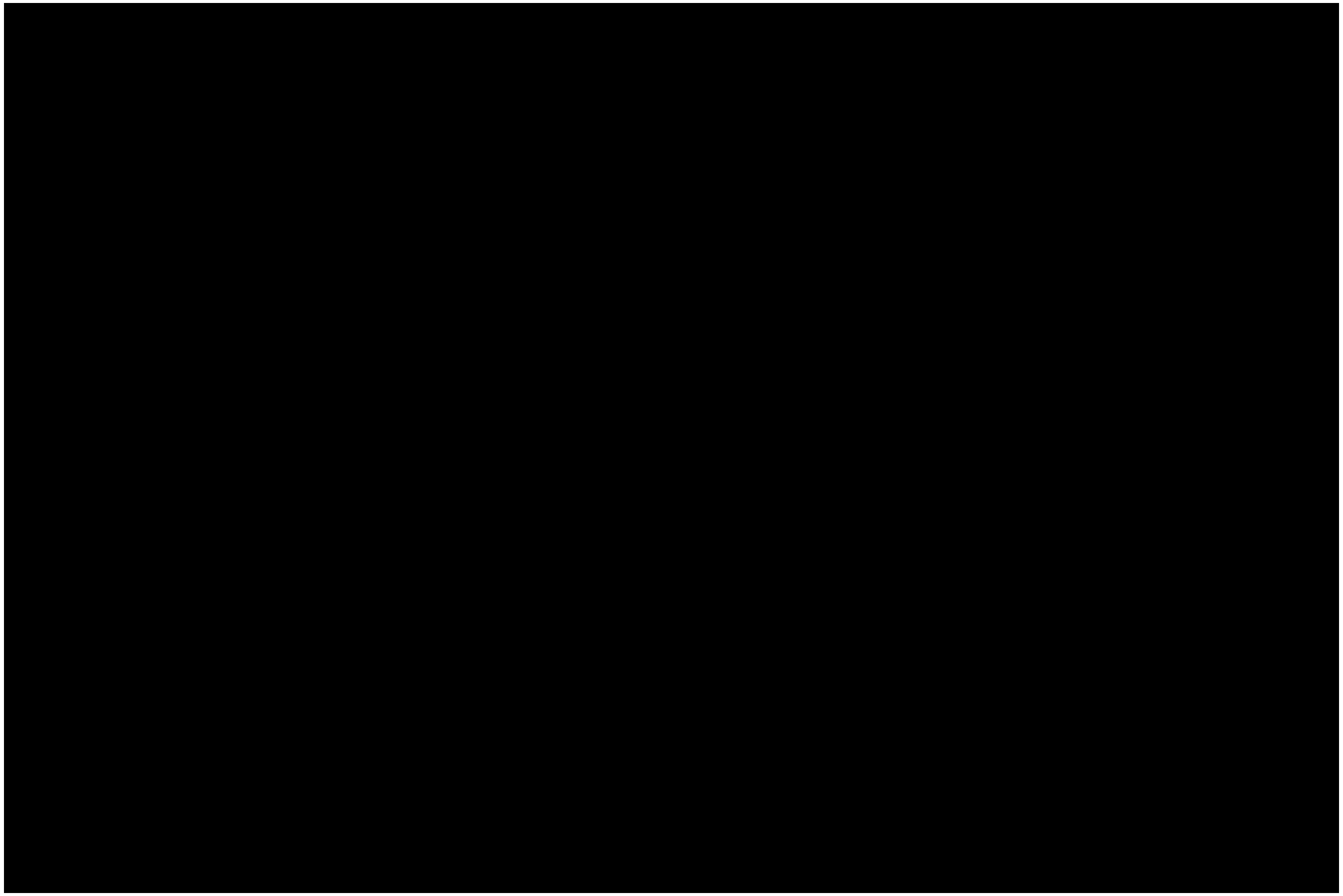
Lampholder Failure



FIRE RESEARCH LABORATORY
ATF

Fluorescent Lights

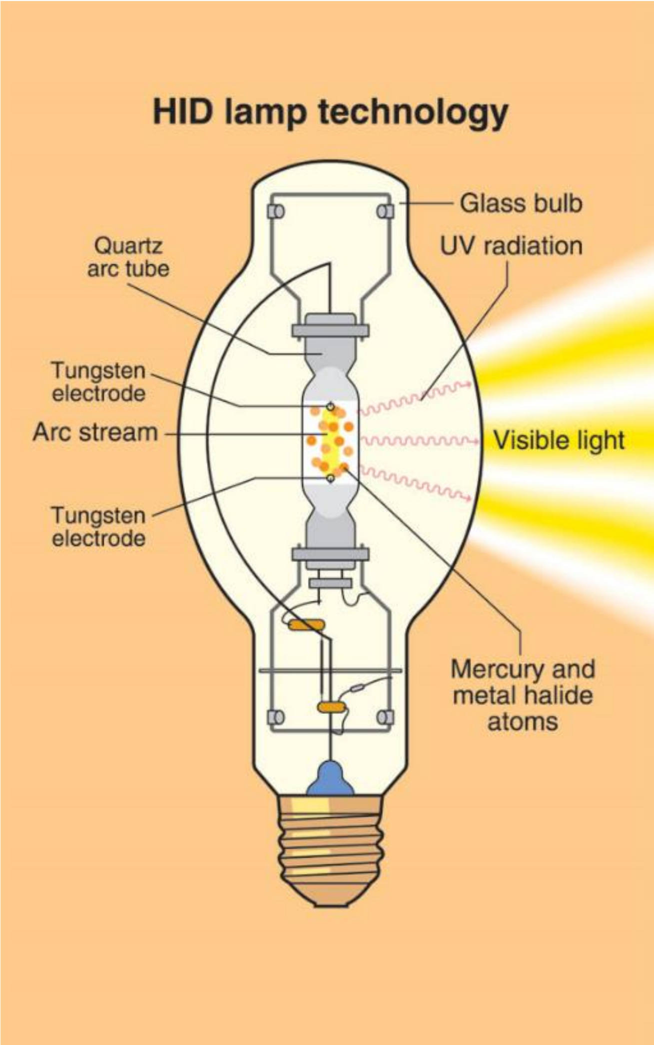
- Failure Modes:
  - Poor connection at lamp holder
  - Ballast failure
- Look For:
  - Arc melting inside/on fixture
  - Arc melting in close proximity
  - Localized melting at the lamp holder
  - Does it have a diffuser?
  - Fuel below?
  - If arc melting present, is it possible for spark to travel to adjacent combustibles?



Truck Fire

Truck Fire Surveillance Video

HID Lighting



HID Lighting

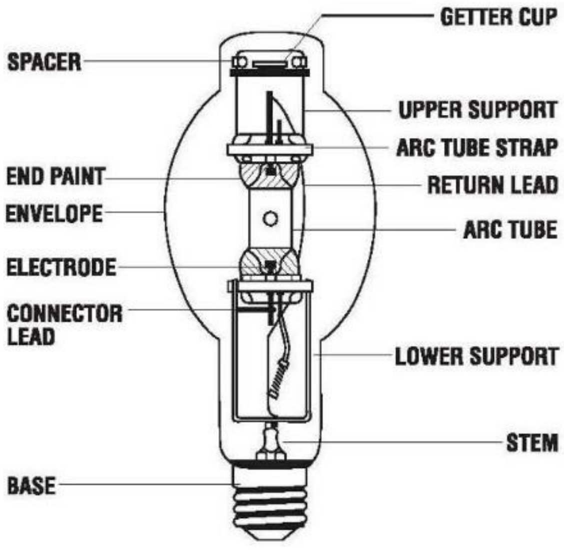
- Produces light by means of an electric arc between tungsten electrodes housed inside a translucent or transparent fused quartz or fused alumina arc tube.

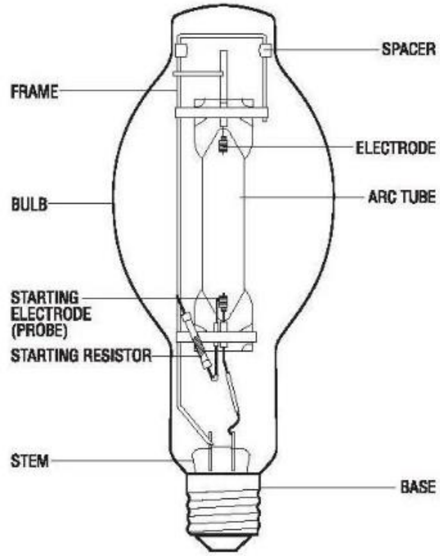
- Tube is filled with both gas and metal salts.

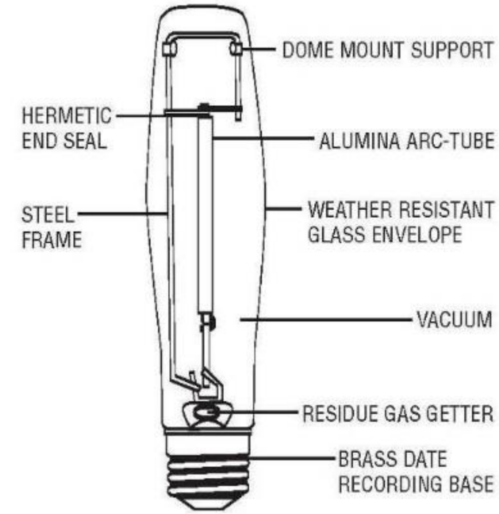
- The gas facilitates the arc's initial strike

- Once the arc is started, it heats and evaporates the metal salts forming a plasma, which greatly increases the intensity of light produced by the arc and reduces its power consumption.
  - High-intensity discharge lamps are a type of arc lamp.

- HID lamps have higher luminous efficacy since a greater proportion of their radiation is in visible light as opposed to heat.
  - They give a greater amount of light output per watt of electricity input.







Metal Halide

- Can be 75% more efficient than fluorescent lamps
- They have mercury, argon and metal halides, usually sodium iodide, scandium iodide and occasionally lithium iodide, in the gas filled tube.
- Often used inside buildings

Mercury Vapor

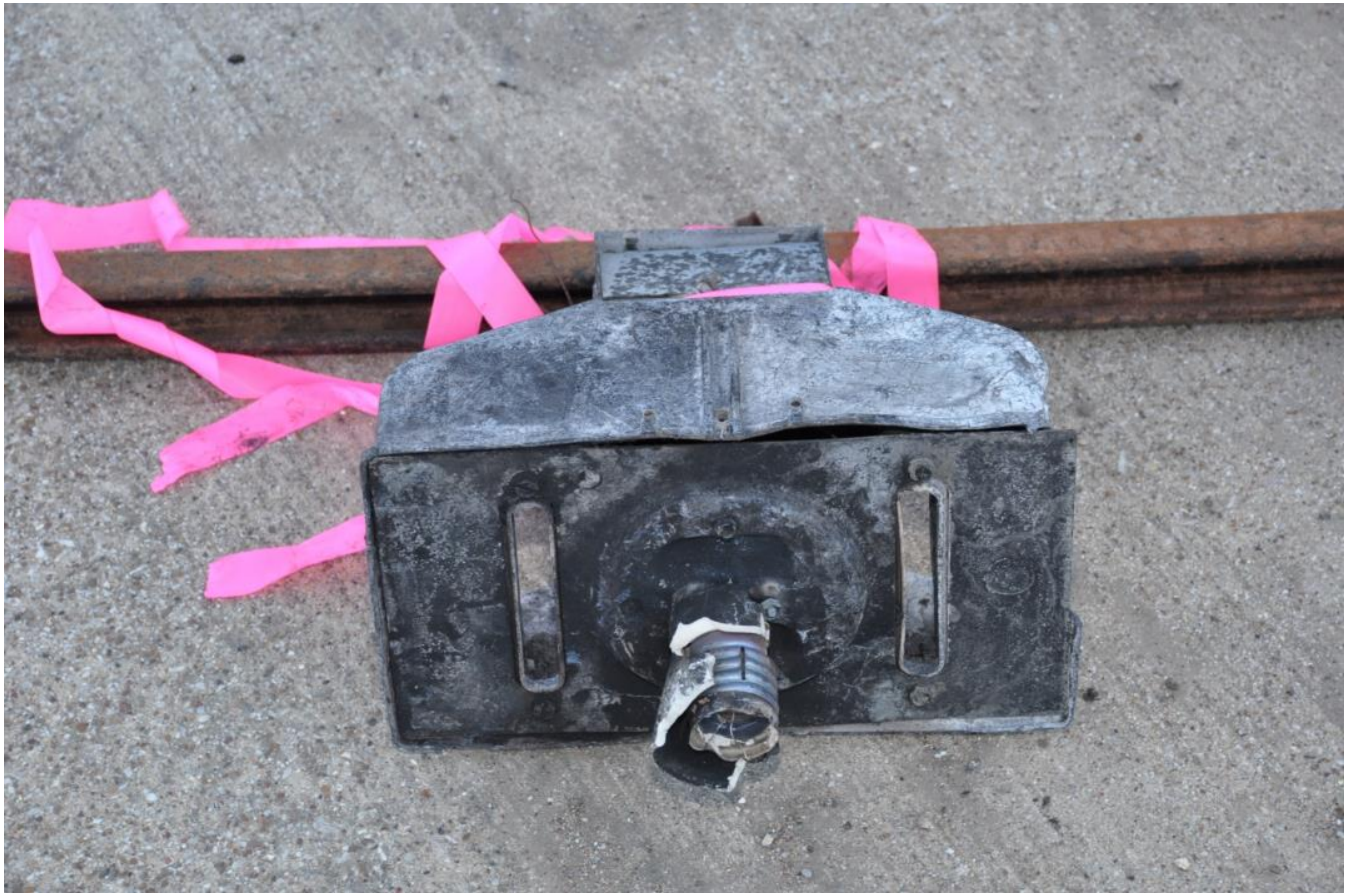
- Have existed since 1934 and have longest lasting lifetimes in this class of lights
- They are not as efficient as the other types
- Mercury is sealed in an argon filled quartz tube
- Emits a blue-white visible light, and Ultra Violet invisible light, that is corrected to a more natural light by the addition of phosphors.
- Used inside and outside.

High Pressure Sodium

- Utilize ceramic arc tube due to the high temperature (1300 0 C)
- inert gas filled arc tube within the outer glass envelope
- These produce an orange – white light with the highest luminance
- They are mostly used for exterior lighting

High Bay HID Fixture

Ballast



Ballast

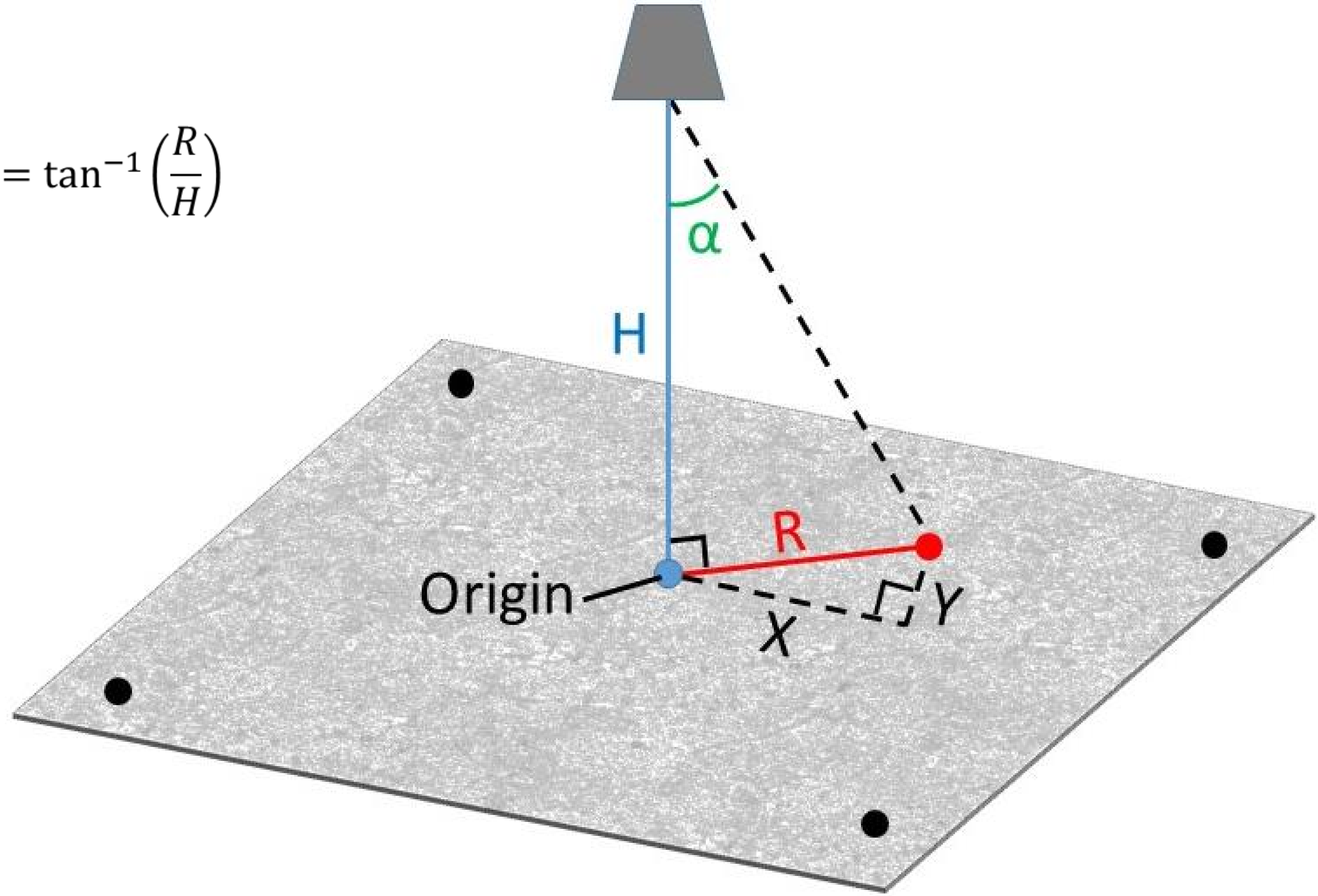
Arc Chamber

NOTE

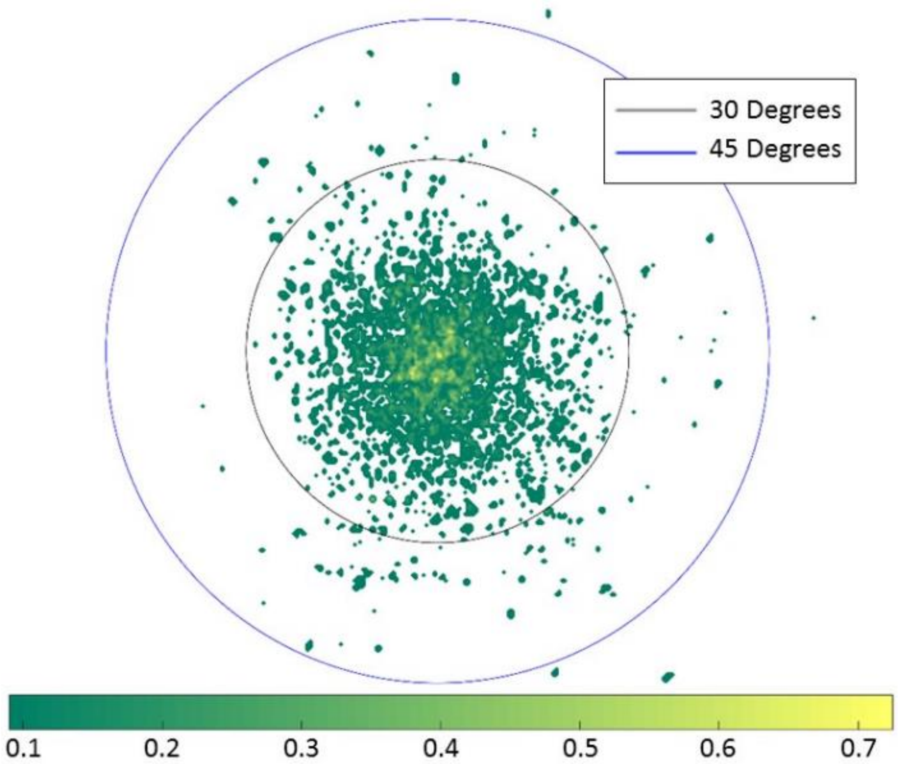
- Question:
  - How is this type of failure influenced by:
    - Type of hypothesized first fuel ignited?
    - Distance between the lamp and the hypothesized first fuel?

Debris Dispersion

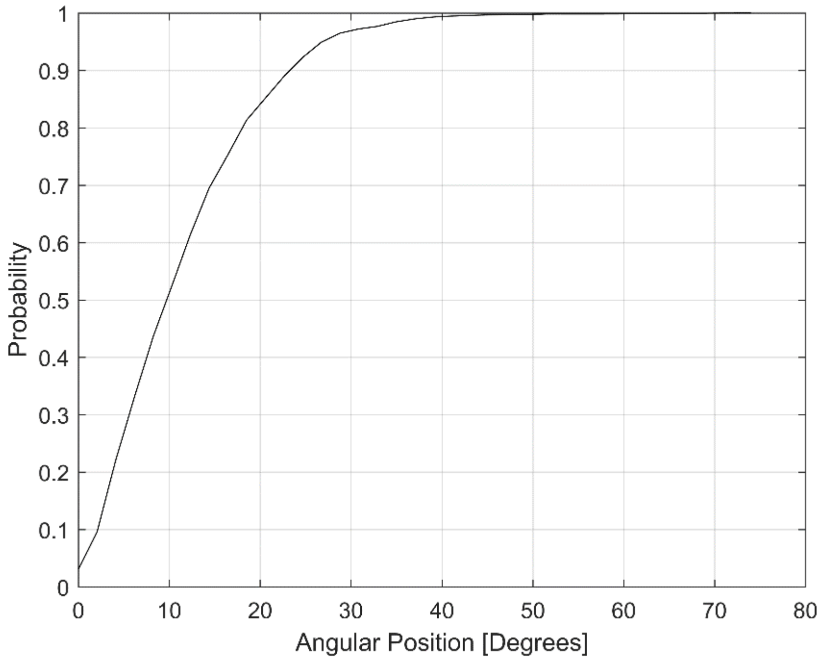
$$\alpha = \tan^{-1}\left(\frac{R}{H}\right)$$



Debris Dispersion

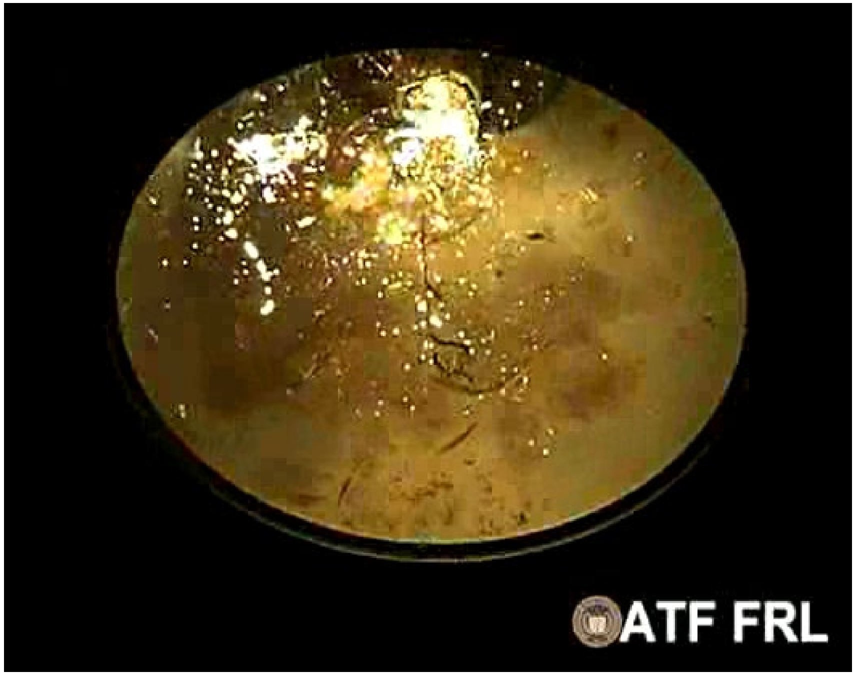


Contour plot of all debris resulting from electrical failures

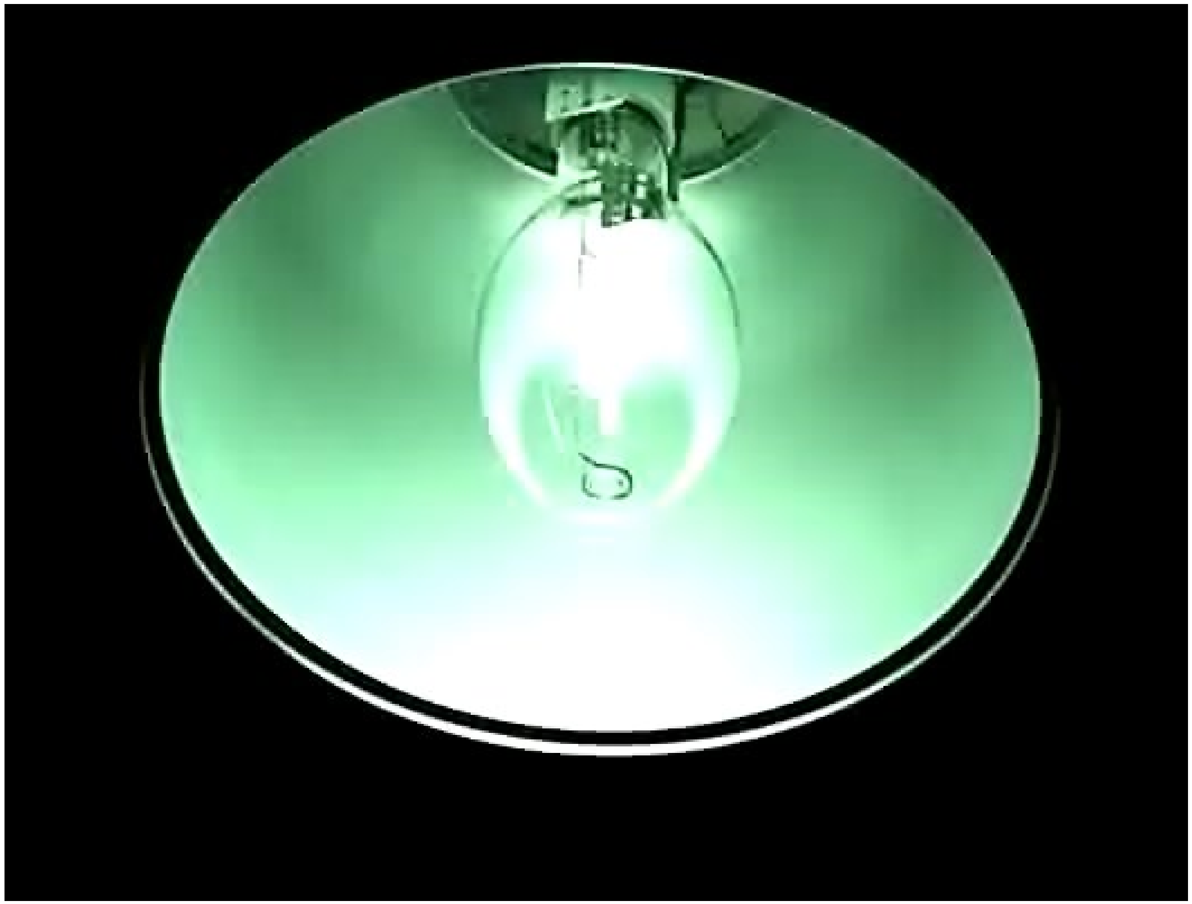


Cumulative Distribution Function plot of all debris resulting from electrical failures

HID Lights



- Failure Modes:
  - Poor maintenance/not replacing the lamps at the recommended time
  - Ballast failure
- Look For:
  - Arc melting inside/on fixture
  - Arc melting in close proximity
  - Correct lamp style for installation?
  - Arc melting on lamp components
  - Assume a 45 degree “cone of dispersion”



Lithium Ion Battery Failures

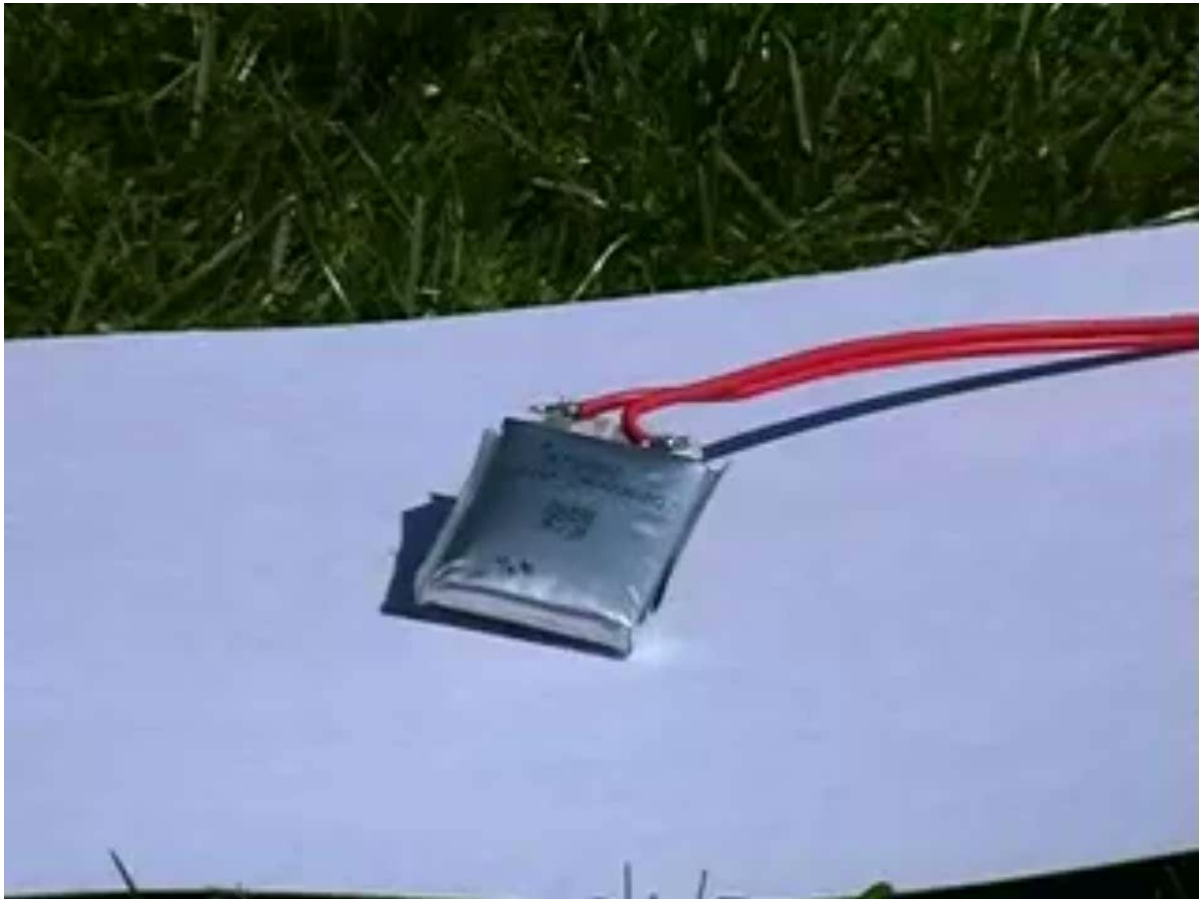
Lithium Ion Batteries

- With the widespread use of electronics, lithium ion batteries are everywhere.
- Because consumers want their devices to last longer, engineers are pushing the boundaries of what the current technology is capable of.
- And sometimes you just push too far…

Lithium Ion Batteries

- Most failures occur during the charging process.
- Many hobby shops sell “fire bags” to charge your batteries in.
- Many say that you should never leave the charging batteries unattended.
- Cells should always be charged with a cell balancer, so that one cell doesn’t reach the required voltage before the other, and then get overcharged.

18650 Cell in Ceiling Tile




www.pcpitstop.com/pcsafety

Lithium Ion Battery Failure Modes

- Causes of a catastrophic failure can include:
  - Mechanical damage
  - External heat
  - Overcharging
  - Over discharging
  - Internal short/manufacturing defect

Lithium Ion 18650

Lithium Ion 18650 CT Scan

Lithium Ion 18650 CT Scan

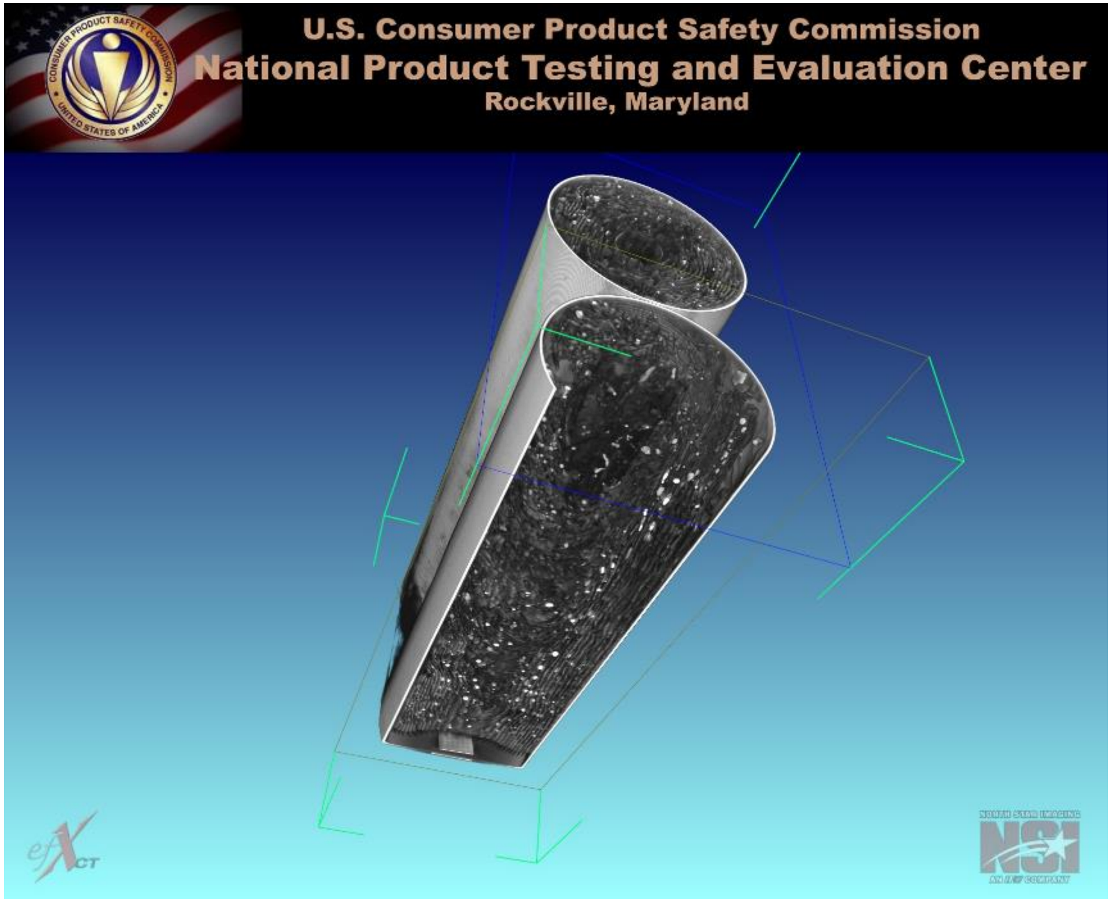
Lithium Ion 18650 CT Scan

Lithium Ion 18650 CT Scan

Lithium Ion 18650 CT Scan

Lithium Ion 18650 CT Scan

Lithium Ion 18650 CT Scan



Lithium Ion 18650 CT Scan

Cell Phone

Lithium Polymer Battery

Lithium Polymer Battery

Lithium Battery Failures

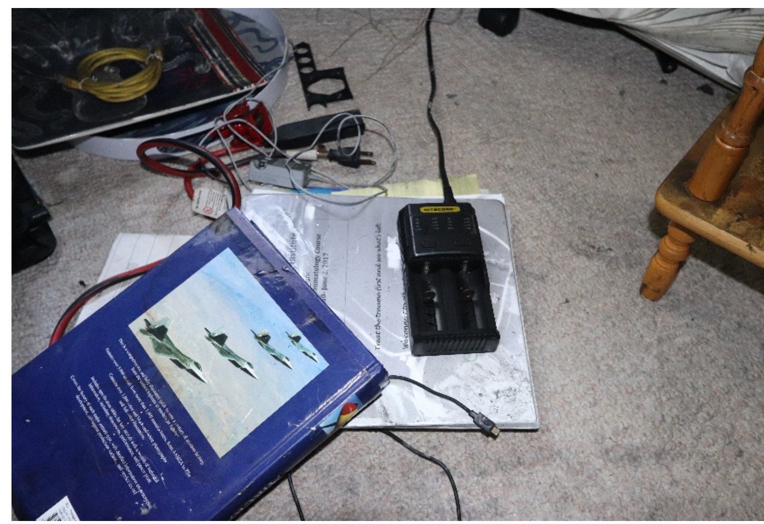
- Failure Modes
  - Internal short circuit due to manufacturing defect
  - External short circuit across terminals
  - Over-charging/discharging
  - Physical damage
  - Environmental heating
- Look for:
  - Identify the total number of cells
  - Bulged vs intact housings
  - Cells that stay in place
  - Internal mass loss or arc perforations

BUREAU OF ALCOHOL, TOBACCO, FIREARMS AND EXPLOSIVES 1972

FIRE RESEARCH LABORATORY ATF

Dog Induced 18650 Failure…

…Resulting Fire



BUREAU OF ALCOHOL, TOBACCO, FIREARMS AND EXPLOSIVES
1972

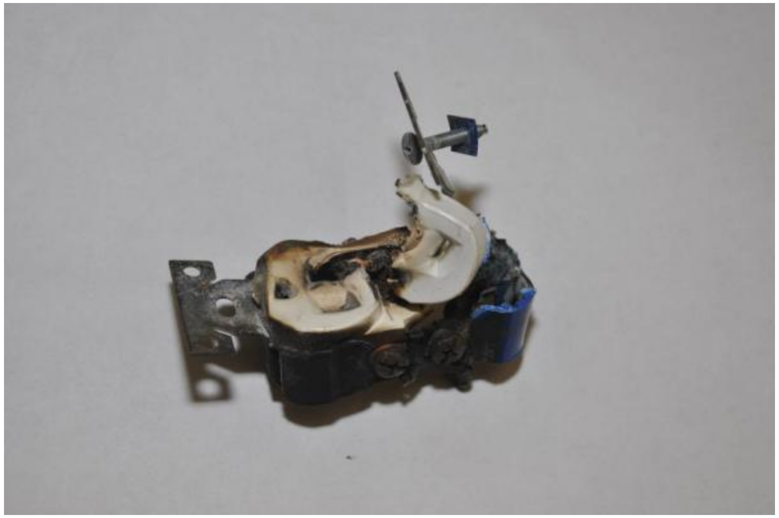
FIRE RESEARCH LABORATORY
ATF

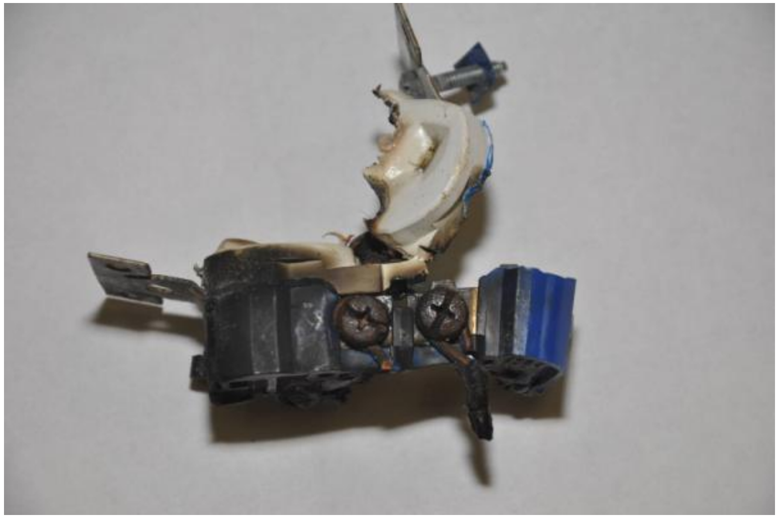

INR18650-25
SAMSUNG

Electrical Failure

Failure Point #1
Conductor Entry Points

Failure Point #2
Connection Points





Failure Point #3:
Transition Points

Service Entrance Area

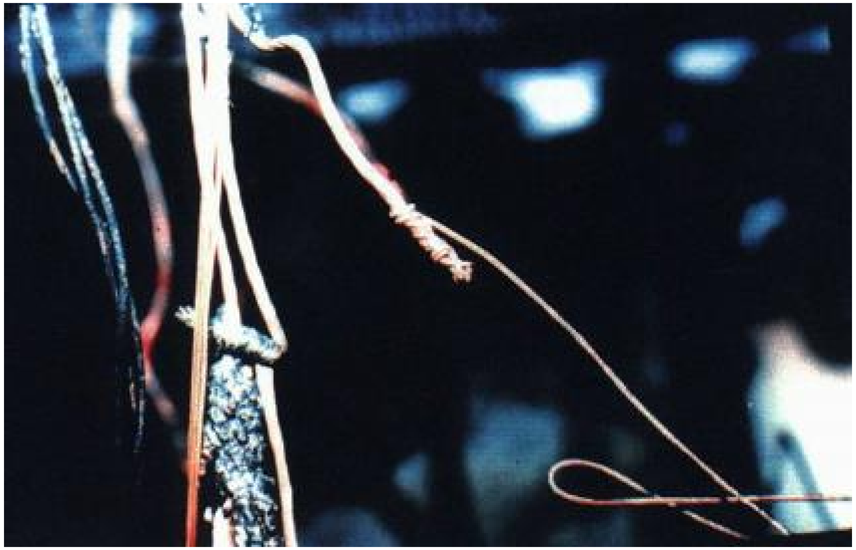
Branch Circuit

How does any of this Fail and Start a Fire?

- Wiring in conduit or behind walls normally will not fail in the middle of a run without some sort of mechanical event.

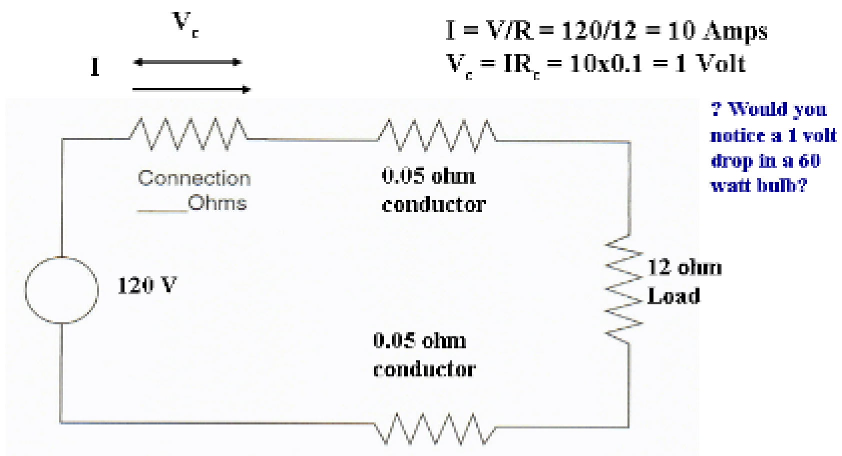
- Focus on:
  - Entry Points
  - Connection Points
  - Transition Points

Loose Connections



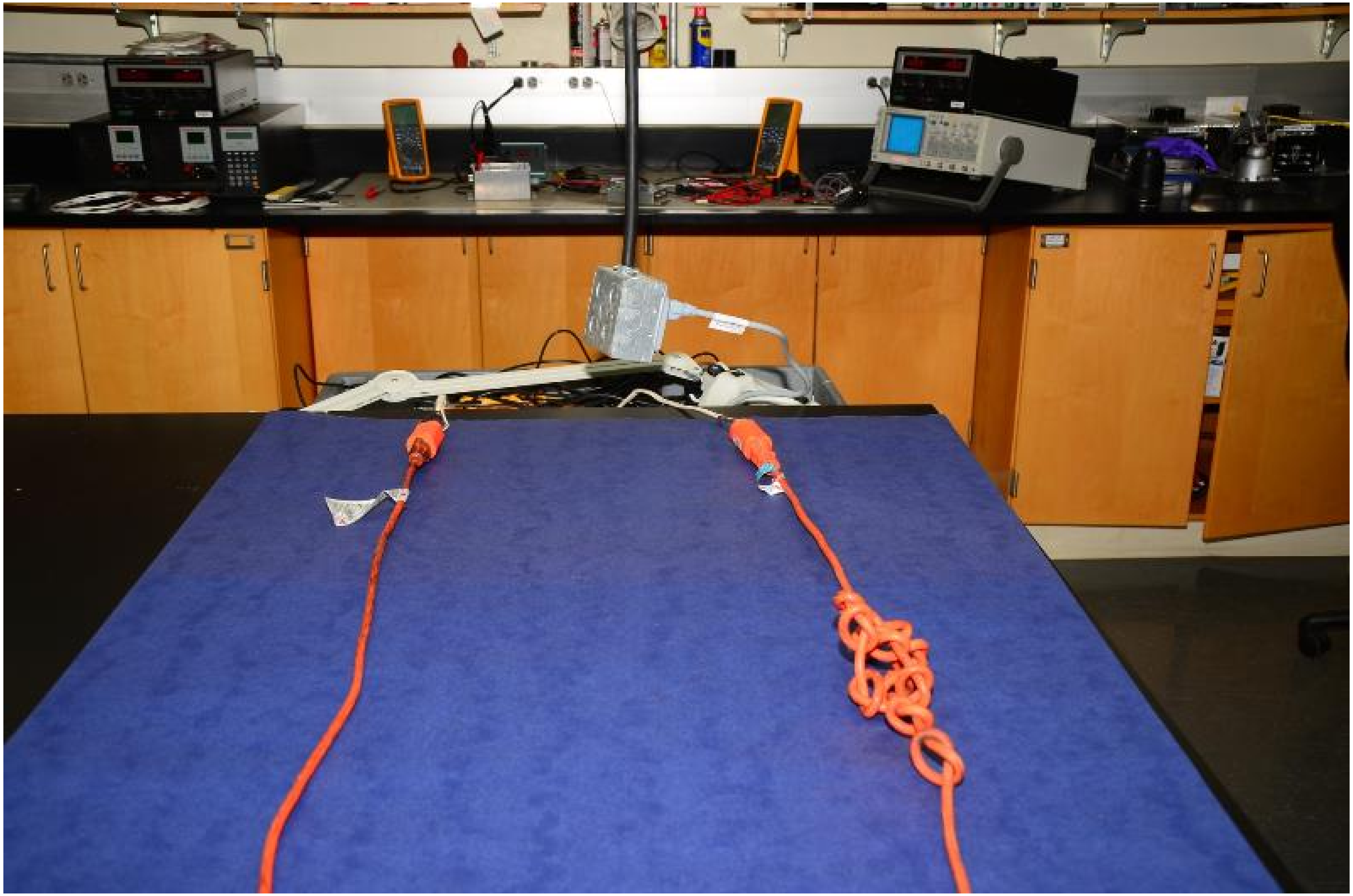
- A splice requires electrical continuity and mechanical security

Why do Loose Connections Cause Fires?



- The connection only has 0.1 ohms of resistance.
  - Seemingly very small and no problem - Right?
- The power dissipated at the loose connection is: Pc = I x Vc = 10A x 1V = 10 Watts
- This 10 watts is only spread over the 1/4 inch diameter screw head

Two Identically Loaded Identical Extension Cords



What is the Difference *Electrically*?

Time = 0

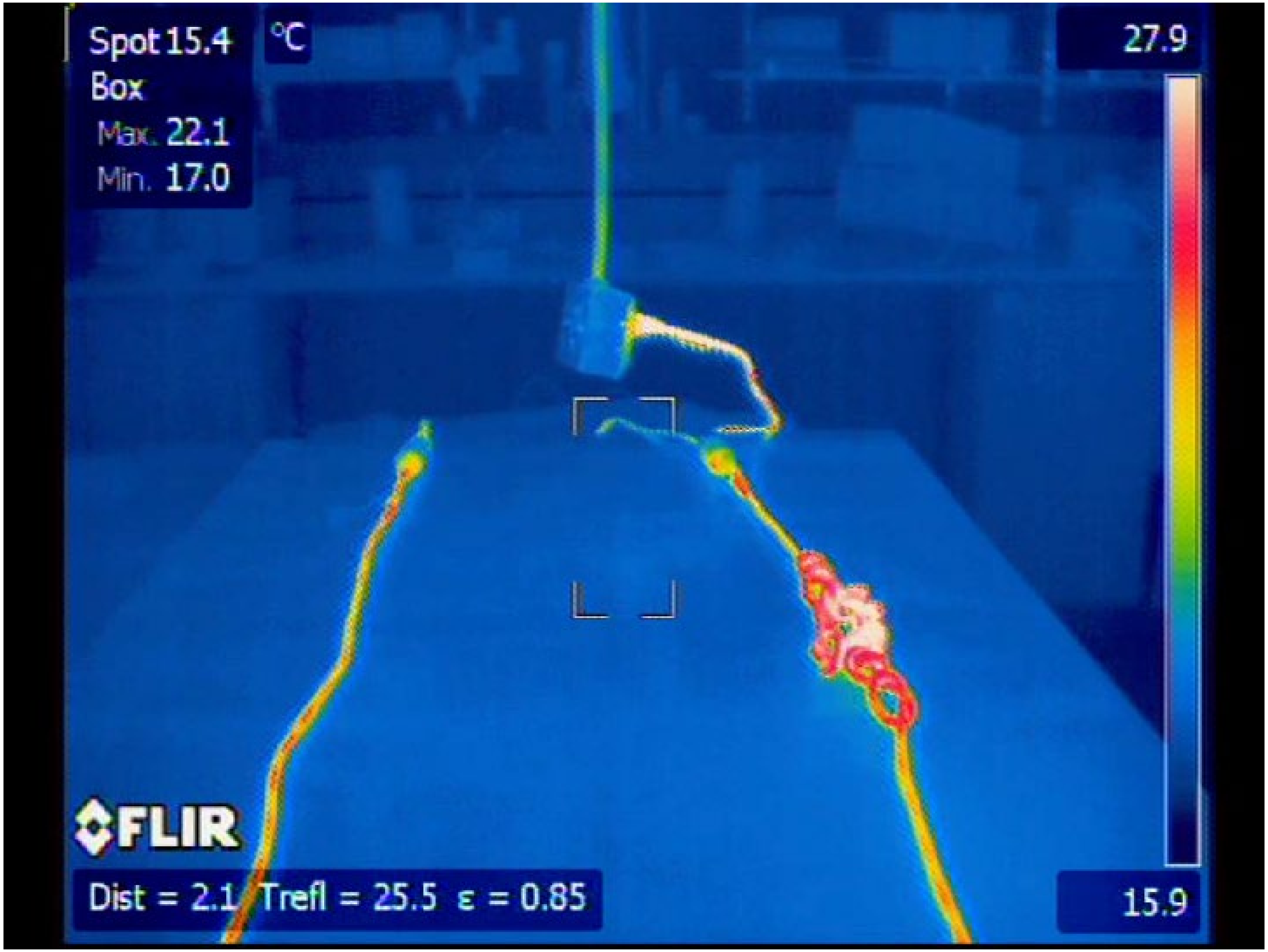

Spot 15.8
°C
Box
Max. 18.3
Min. 16.6
23.5
FLIR
Dist = 2.1 Trefl = 25.5 ε = 0.85
11.4

Time = 2.5 Minutes

Time = 5.0 Minutes

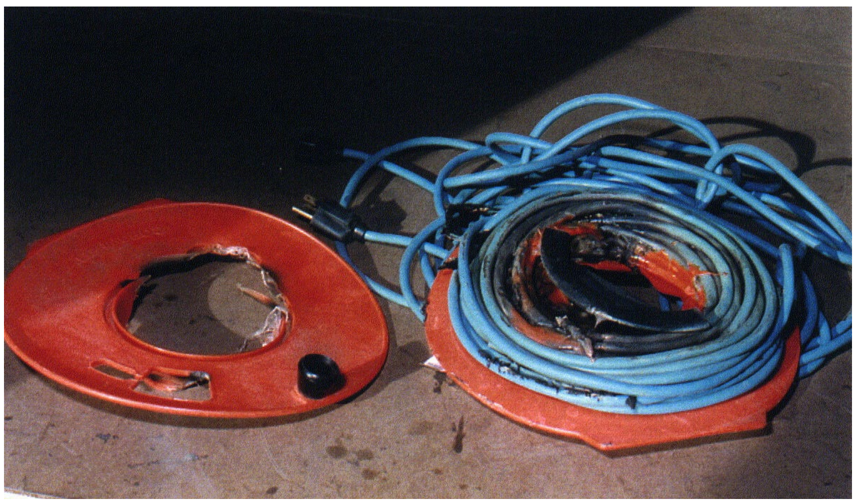
Time = 7.5 Minutes

Time = 10.0 Minutes



Time = 10.0 Minutes

Overloaded Conductors Don't Always Cause Fires



- 16 AWG extension cord
  - 10 amp rating
  - 25 Amp load
  - Wrapped 80% around the plastic reel to trap heat
- Results:
  - melting and light charring
  - heavy smoke
  - No flame
- With more time, insulation between conductors would have melted and caused an arc fault between conductors
  - would have tripped the circuit breaker

Arcing Melting

Arcing Through Char

- Arcing through char starts when an energized conductor is attacked by fire and the wire’s insulation begins to char, deteriorate, and lose its insulating properties.
  - The insulation begins to turn into carbon
- The charring results in the presence of a sufficient quantity of carbon between the adjacent ungrounded conductor, and a grounded conductor or grounded enclosure, to create a current path between the points of contact.

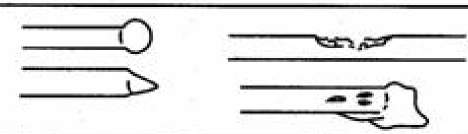
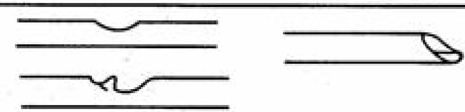
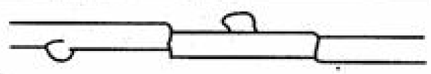
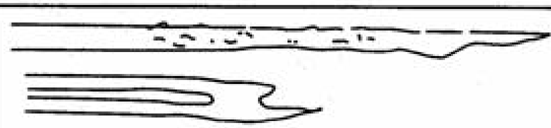
FIRE RESEARCH LABORATORY
ATF

Arcing Through Char

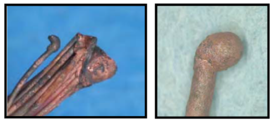
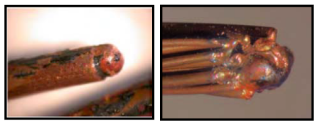
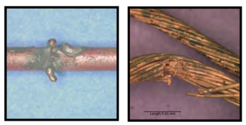
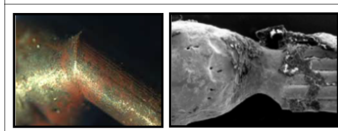
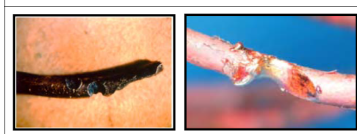
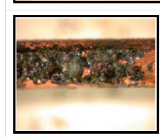
- As the current increases, the resulting heat also increases as a result of this high resistance connection.
- The resistance in this carbonized path begins to drop, due to the increase in heat, raising both the current and the heat.
- This process continues until the amount of current flowing increases to the point that an arc is formed.
- The arc produced will possess a sufficient amount of heat to: melt and sever a conductor; burn a hole in an enclosure; trip a circuit breaker; or open a fuse.
  - You may have more than one arc on an individual branch circuit before opening a circuit breaker or fuse.

Excerpt from *Users Manual for NFPA 921*

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

ATF Tech Bulletin

Table 1 Characteristics of Arc Beads	
	Sharp Line of Demarcation between damaged and undamaged area (Photos by Kevin Lewis / E. C. BUC)
	Round Smooth Shape (Photos by Nick Cary / Kevin Lewis)
	Localized Point of Contact (Photos by Kevin Lewis / E.C. Buc)
	Identifiable Corresponding Area of Damage on Opposing Conductor (Photo by Kevin Lewis)
	Copper Drawing Lines Visible Outside the Damaged Area (Photos by Kevin Lewis)
	Localized Round Depressions (Photos by David Reiter / Kevin Lewis)
	Small Beads and Divots Over a Small Area (Photo by Nick Carey)

Arc-melting Identifiers:

- Sharp line of demarcation
- Rounded smooth shape
- Localized point of contact
- Identifiable corresponding area of damage
- Copper drawing lines
- Localized round depressions
- Small beads and divots over a limited area

ATF Tech Bulletin

Table 2 Characteristics of Melt Globules	
 	Extended Area of Damage Without a Sharp Line of Demarcation from Undamaged Material (Photos by Yasuki Hagimoto / E. C. Buc)
	Visible Effects of Gravity in the Artifact (Photo by Stephen Andrews)
 	Blisters on the Surface (Photos by E. C. Buc)
	Gradual Necking of the Conductor (Photo by Jeremy Neagle)
	Non-Localized Loss of Integrity of Individual Strands on a Stranded Conductor (Photo by Michael Keller) (NOTE: This characteristic was not included in Dr. Babrauskas' proposal but is included here since it is part of the ATF training curriculum.)

Thermal-melting Identifiers:

- Extended area of damage
- Visible effects of gravity
- Blisters on the surface
- Gradual necking of conductors
- Loss of strand integrity

NFPA 921

Arc-Melting:

- Localized arc damage
- Sharp line of demarcation between damaged and undamaged area
- Corresponding area of damage on the opposing conductor
- Round, smooth shape of artifact
- Rounded or irregular-shaped beading on the ends of severed conductors
- Resolidification waves
- Copper drawing lines visible outside the damaged area
- Notches in the sides of the conductors
- Molten particles sprayed from the arc location collected on nearby surfaces
- Localized, round depressions
- Small beads and divots over a limited area
- Locally enlarged grain size
- High internal porosity when viewed in a cross-section

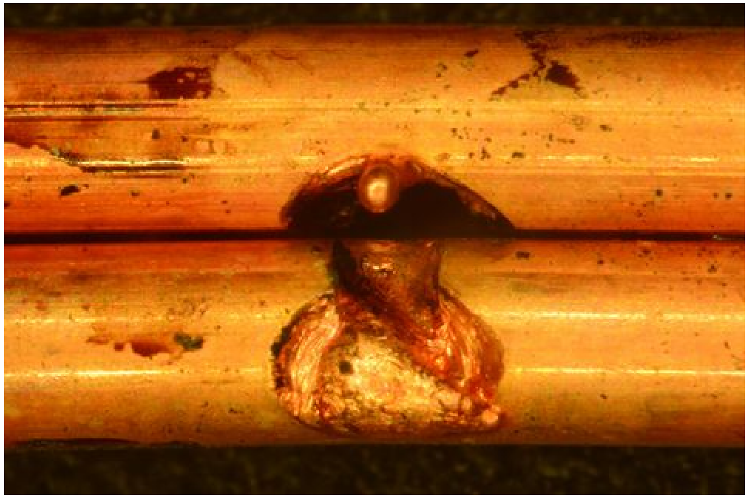
NFPA 921

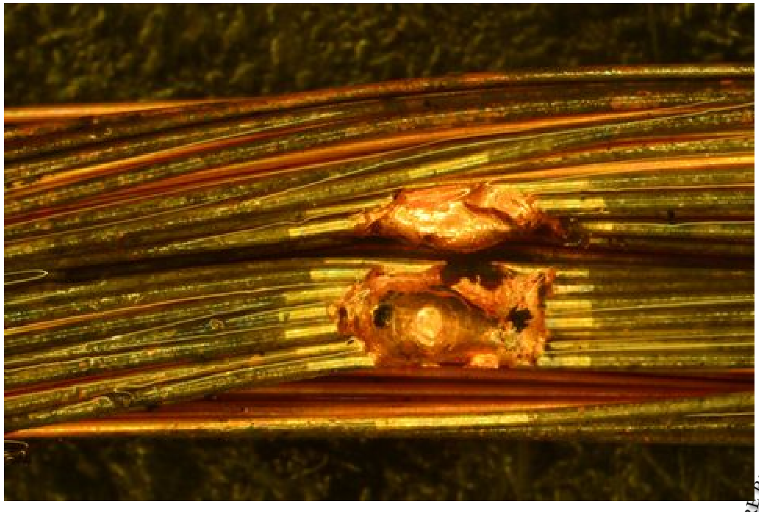
Thermal Melting:

- Damage is spread over a larger area
- No distinct line of demarcation
- Irregular or rounded globules
- Smooth or rough tapered ends
- Visible effects of gravity on the artifact
- Extended area of damage without a sharp demarcation from undamaged material
- Gradual necking of the conductor (assuming this is not due to mechanical break)
- Low internal porosity when viewed in a cross-section

Localized damage/ Sharp line of demarcation

- The wire's size, shape and surface are pristine everywhere except at the artifact…how can general heating in a fire cause this pinpoint damage???



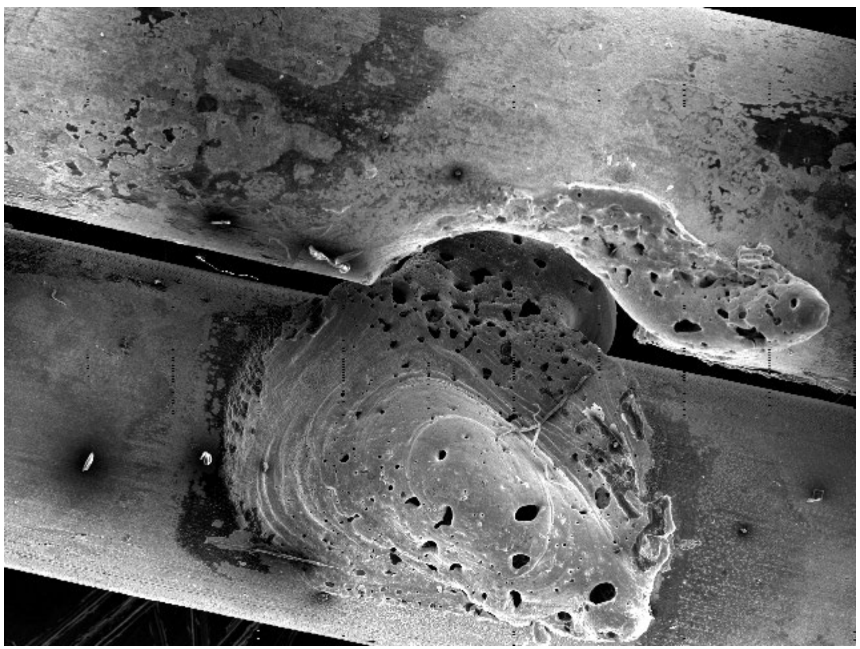


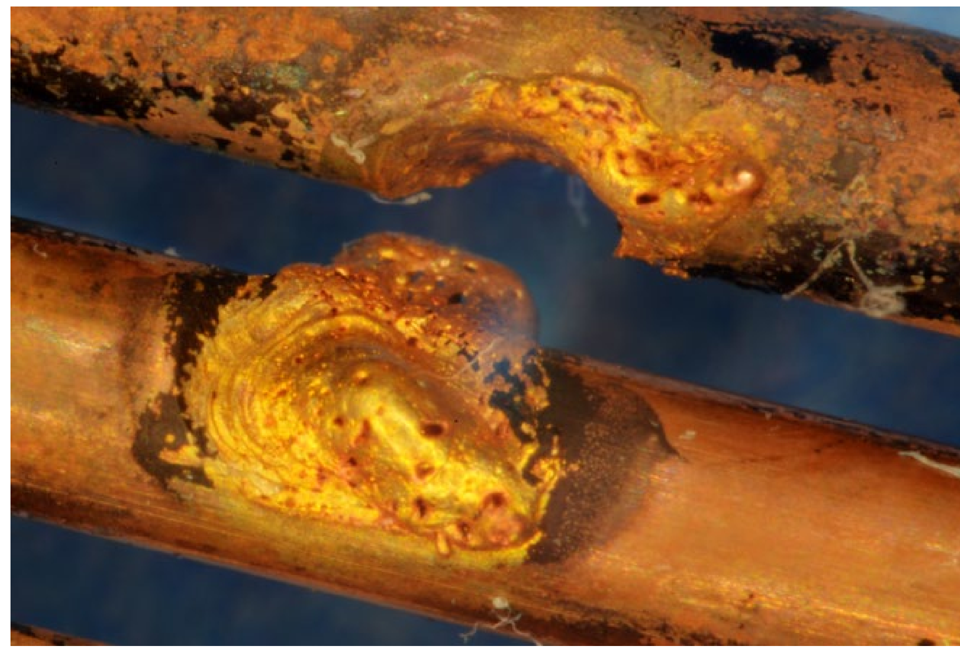
Resolidification waves

- Similar to the semi-circular waves formed in a weld bead
- Caused by cooling of the molten metal as the arc is extinguished

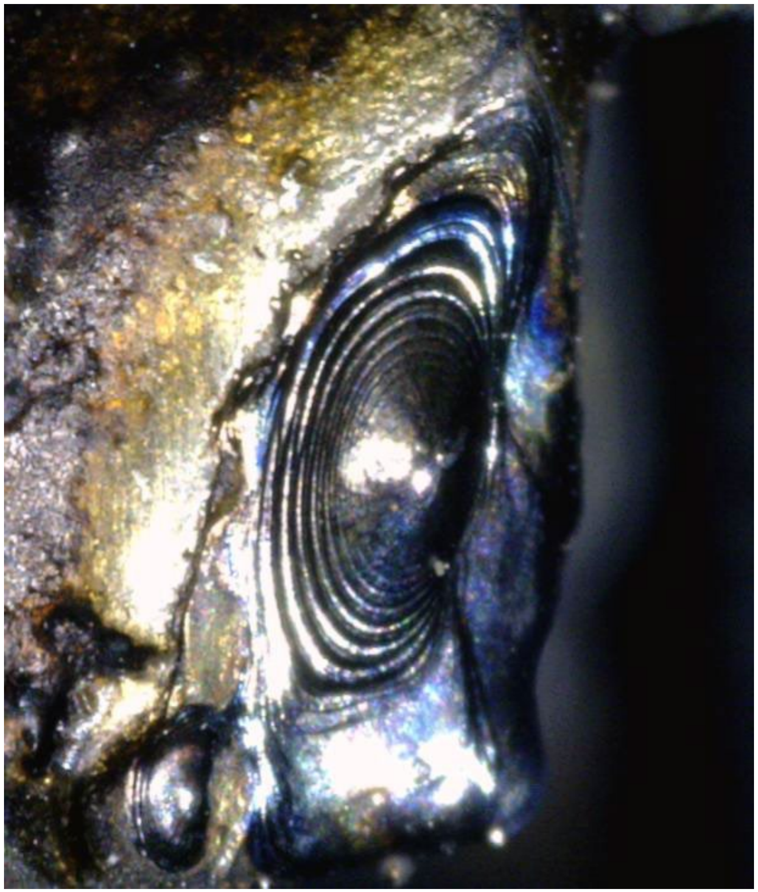
Resolidification waves

- Resolidification waves are an indicator that the metal was once molten and cooled quickly, effectively ‘freezing’ the waves in the metal

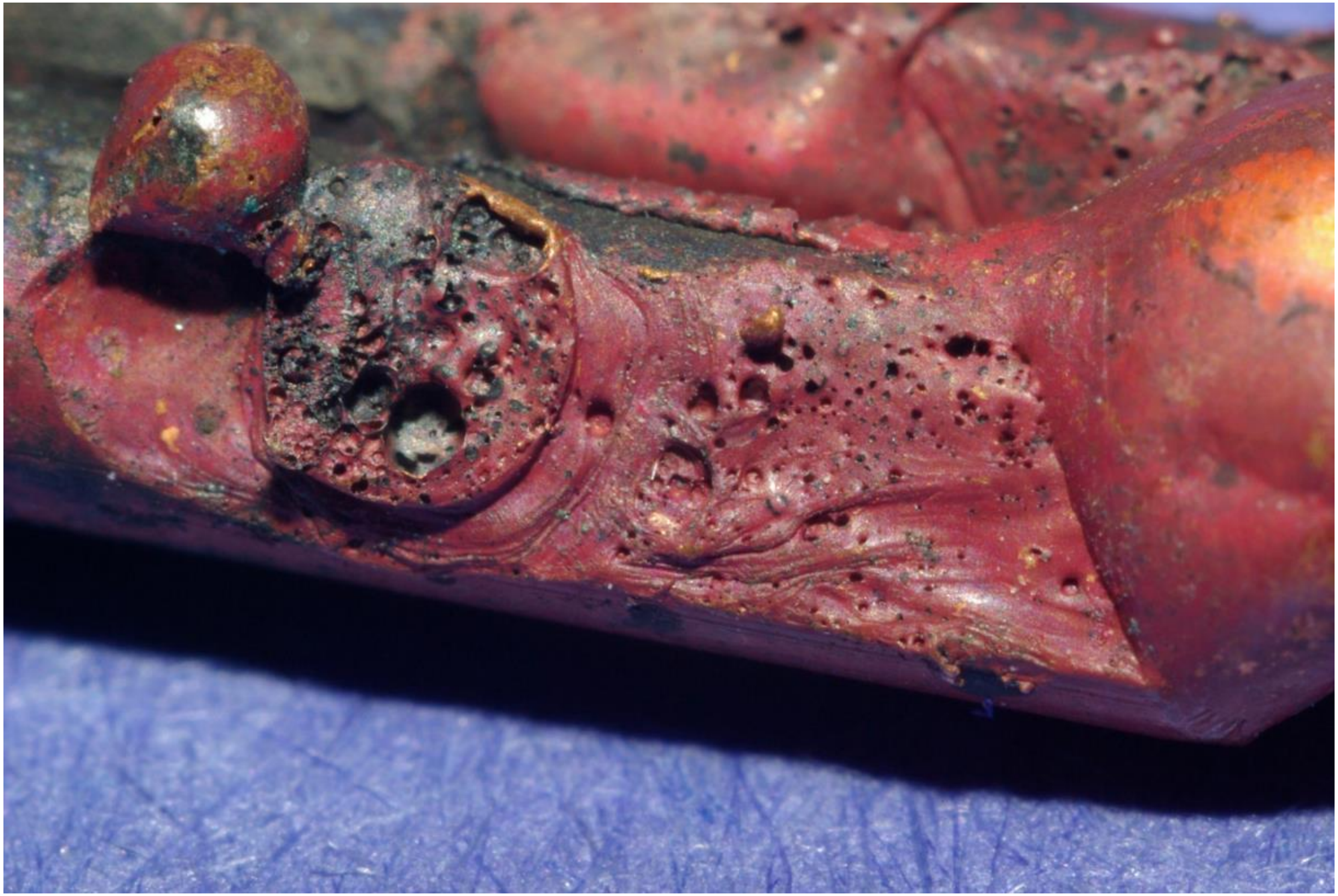




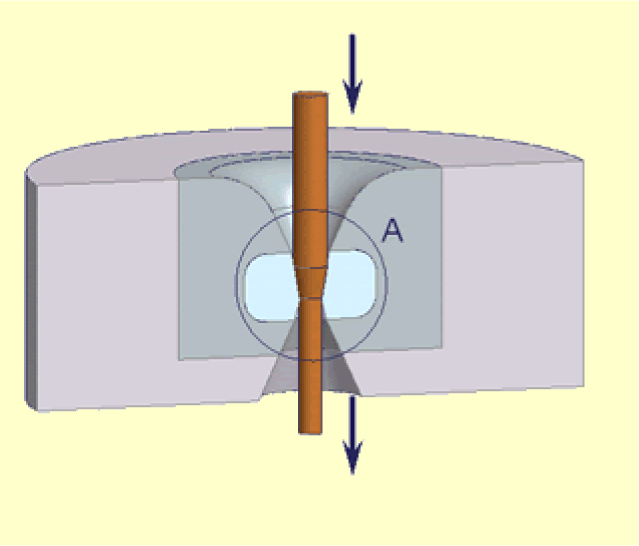
Resolidification waves



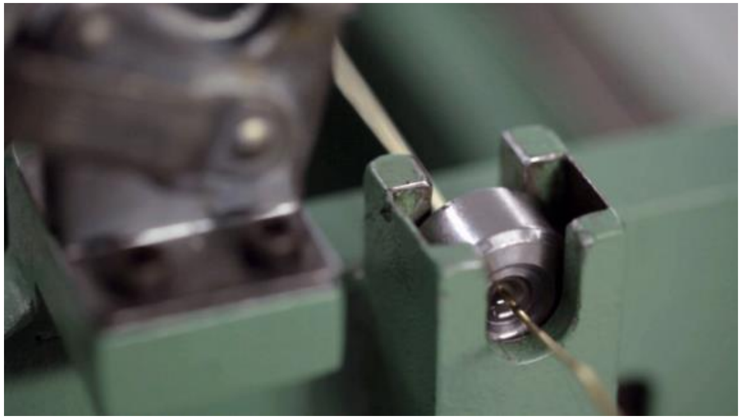
Resolidification waves



Drawing lines



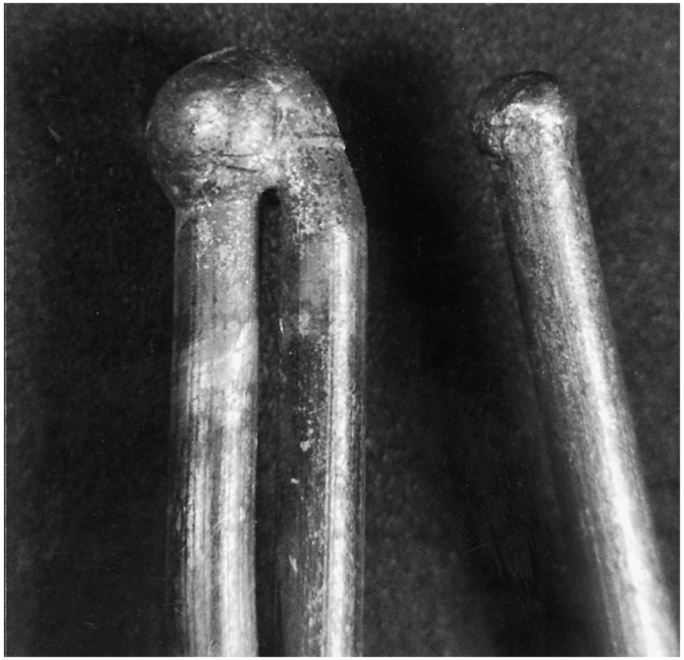
Wire is made by pulling or ‘drawing’ thicker wire through a set of dies until it reaches the proper diameter.



Drawing lines

- During this process, scratches known as ‘drawing lines’ are left on the surface of the wire.

- As a wire begins to heat, its surface will melt first…obliterating the drawing lines.



Small Beads and Divots

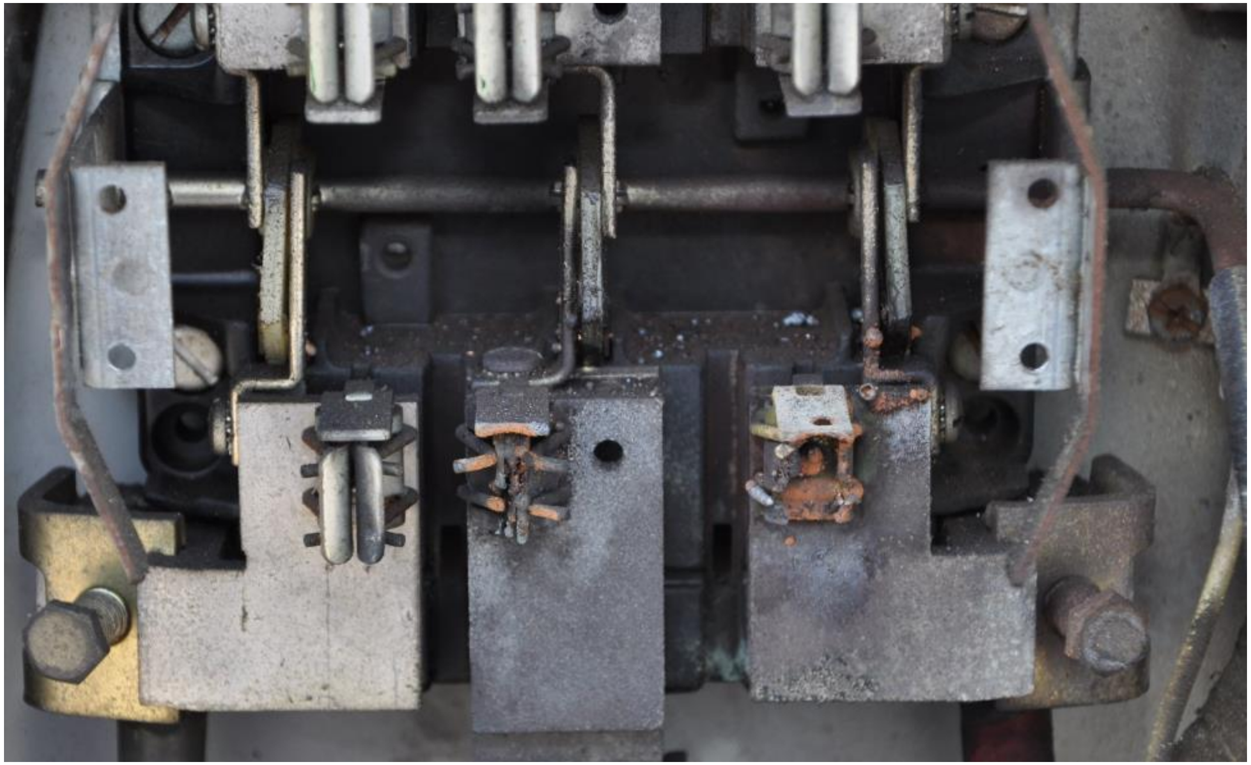
- In some cases, arcing may not result in a low-resistance fault causing immediate opening of a protective device.
- In these cases, prolonged arcing may result in small beads and divots over a limited area of the conductor
- This is more common at low voltages and where charred insulation is the primary current path.

Sprayed Particles

- Sparks ejected during the arcing process may adhere to adjacent areas of the conductor or nearby objects

Sprayed Particles

- ‘Mass transfer’ indicates movement of the molten material as a result of the pressure created by the extreme temperature of an arc.



Irregular (amorphous) globules

- These globules may indicate that the whole mass of conductor has been molten for a period long enough for physical forces act on the molten metal.

- Arc-melting may have been present on these conductors, but the evidentiary artifact has been obliterated by gross melting.

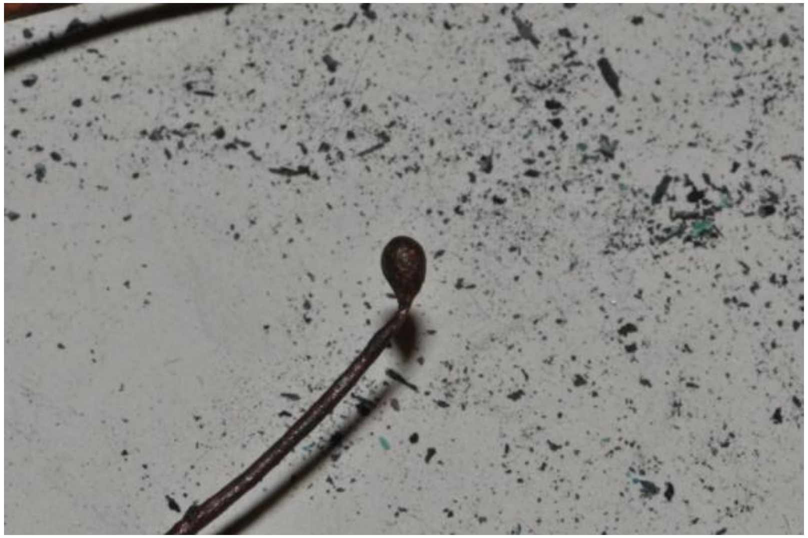
Loss of strand integrity

- **As fire impinges on the conductors, the smaller strands begin to melt and fuse together.**

VS

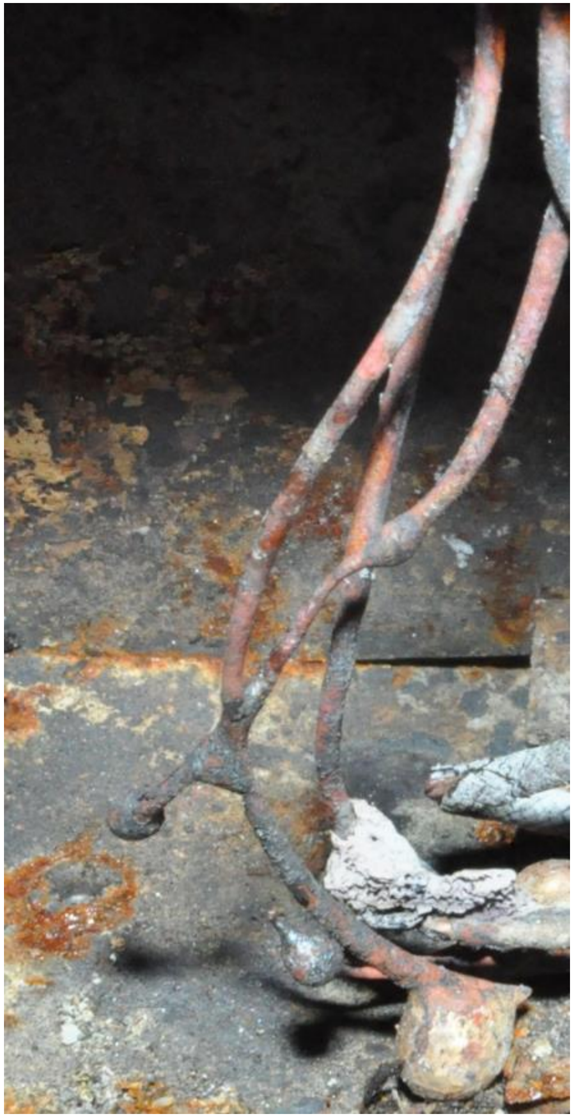
Effects of gravity

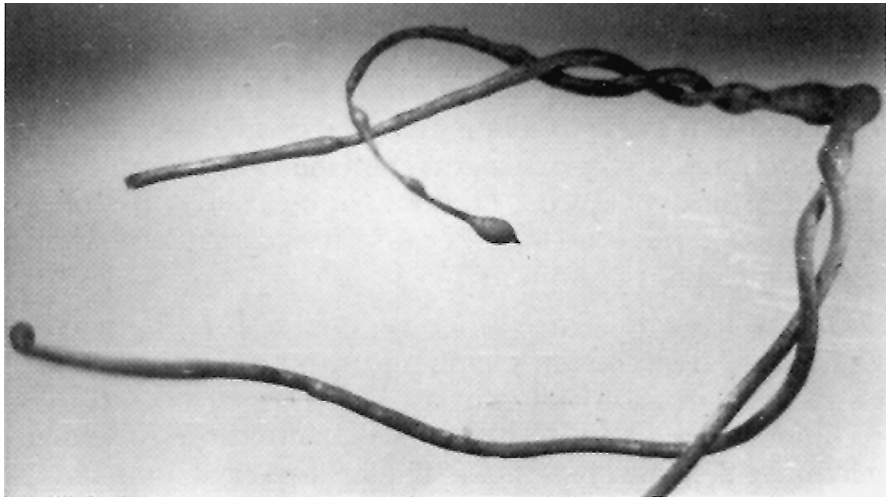
- Arcs are typically extinguished quickly by fuses or circuit breakers opening. Molten metal will cool and solidify quickly…often before gravity has time to act on it.
- Metal melted by the heat of a fire typically remains molten longer. Gravity may begin to act on the molten metal causing it to drip…if it cools during this process the 'drips' can be frozen in the artifact.



Gradual Necking

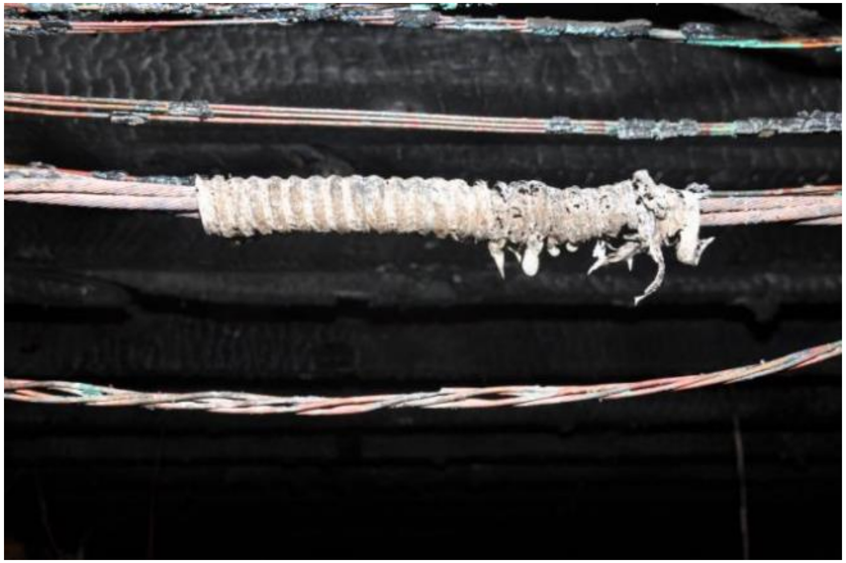
Similar to the obliteration of drawing lines, further melting of the conductor surface may cause the molten metal to 'run' down the conductor (effect of gravity). The result may be changes in the cross sectional area of the conductor…thinner where the metal has melted and 'run', and thicker or 'drips' where the molten metal has collected.



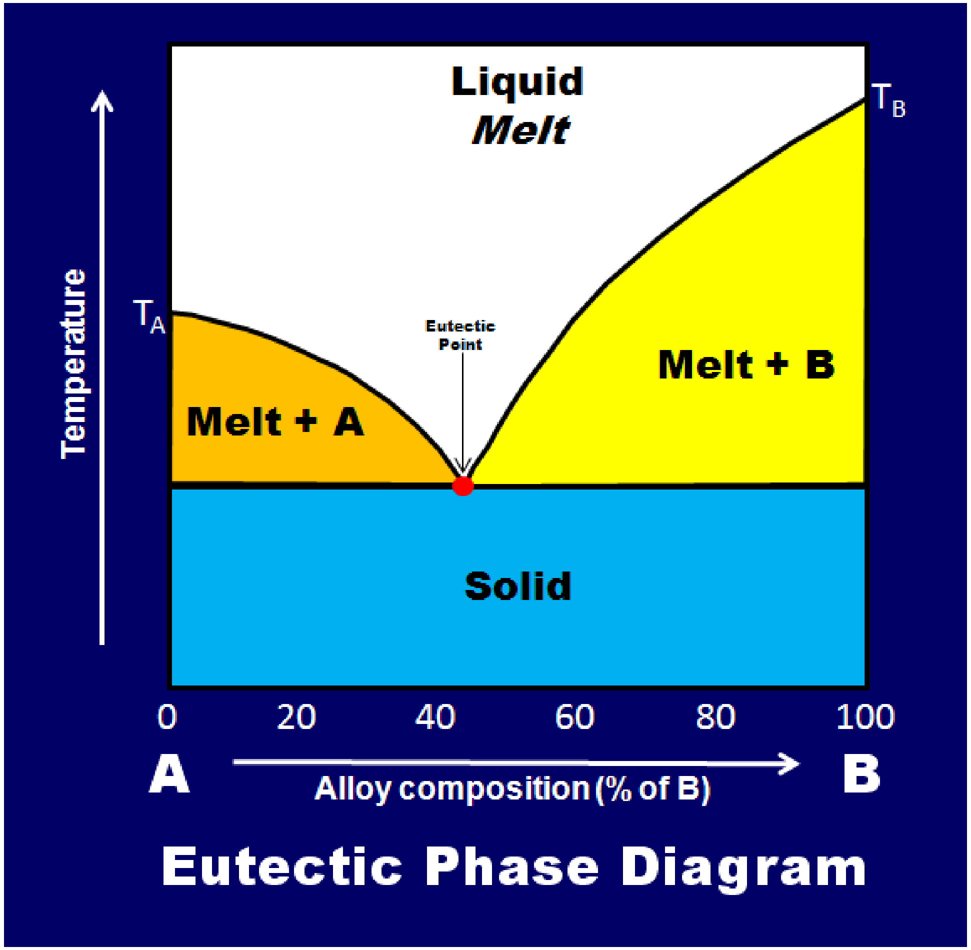


Alloying

- Alloying, or eutectic melting, results from the mixing of two different metals.
- Alloying may cause metals to melt at temperatures below their normal melting point.
- In order to make a determination that alloying occurred you must ensure that you know the source of the second metal.



Alloying / Eutectic Melting



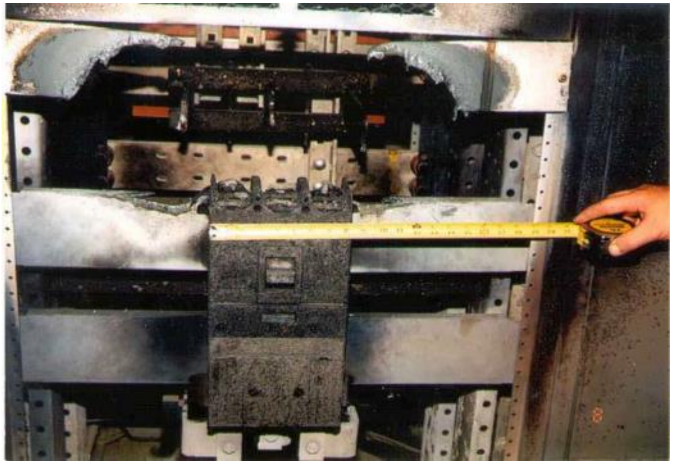
- Alloying refers to the mixing of, generally, two or more metals in which one or more of the metals is in a liquefied state, resulting in an alloy. Metals such as copper and iron (steel) can be affected by alloying with lower melting point metals such as aluminum, zinc, and lead.

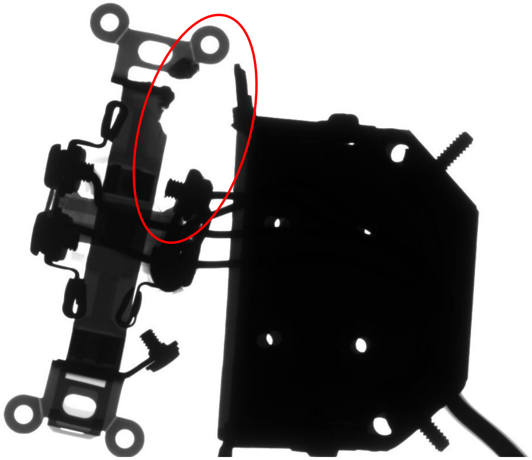
Alloying Aluminum & Steel

Alloying Aluminum & Steel

Alloying Aluminum & Copper

Non-wire Conductors





Other factors that affect arcing

- Materials
- Ground Fault Circuit Interrupters (GFCI's)
- Arc Fault Circuit Interrupters (AFCI's)
- Circuit breakers tripping to OFF
- Available fault current and conductor resistance

Materials

- Does the damage fit with the fire?
  - Did the fire have sufficient intensity and duration to melt the metals involved?
- How does the type of metal affect the assessment?

Melting Points of Metals Found in Electrical Systems

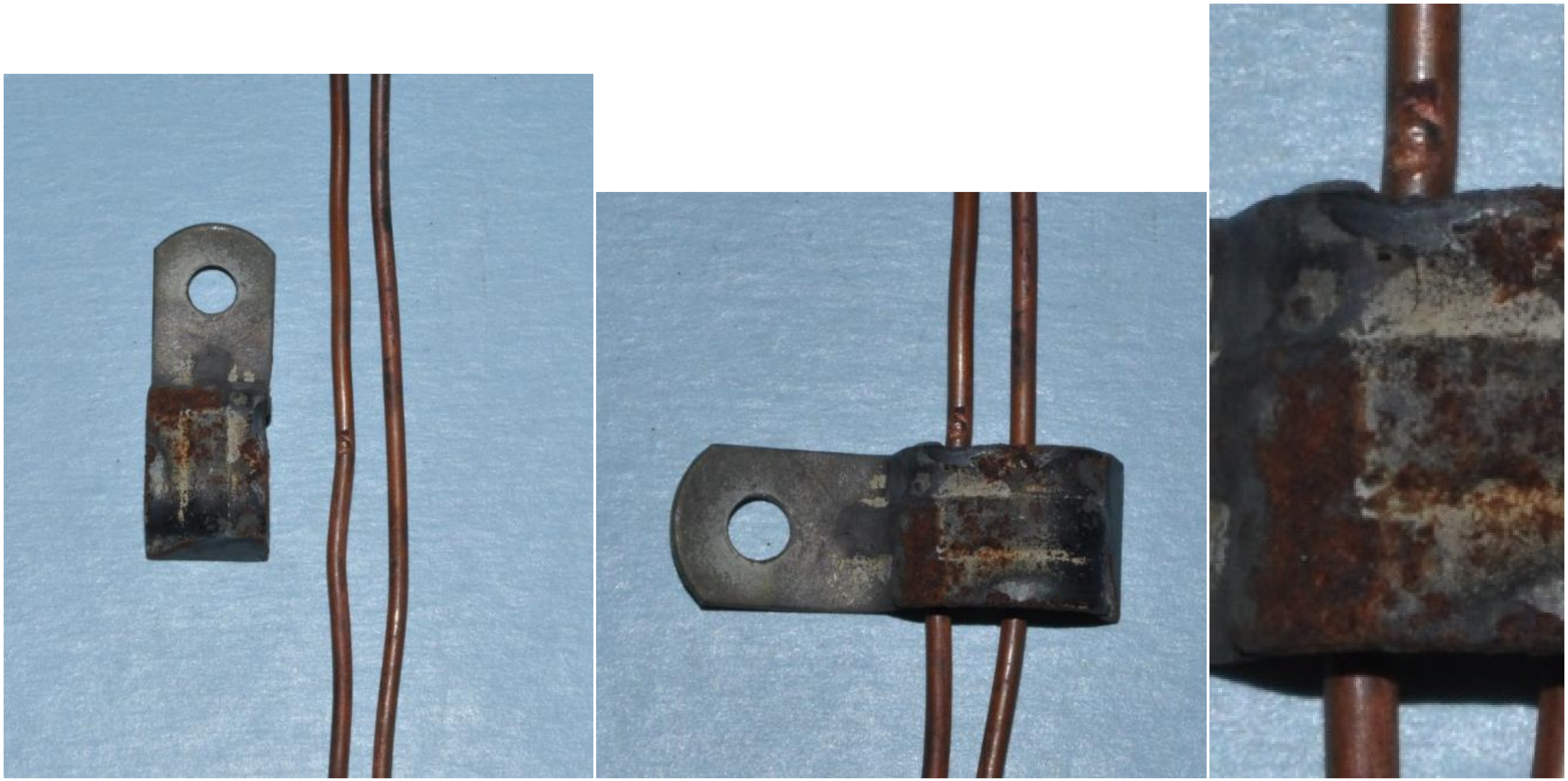
- Solder ~ 360°F (183°C)
  - Connections on printed circuit boards
- Zinc ~ 707°F (375°C)
  - connectors and coatings
- Aluminum Wire ~ 1,218°F (659°C)
- Yellow Brass ~ 1,710°F (932°C)
  - receptacle and switch components
- Copper Wire ~ 1,981°F (1,083°C)
- Carbon Steel ~ 2,760°F (1,516°C)
  - conduit, boxes, and enclosures

Materials

- If aluminum is involved be aware that it's very common to find melted aluminum after even a moderate fire. Melted aluminum may look very different from melted copper…regardless of how it was melted.
- If copper is involved (which it almost always is), it may melt in some long duration or very intense fires.
- If steel is melted it's almost always the result of arcing…it would be extremely rare to melt steel in a residential fire. If you find melted steel you may want consider what factors caused this.
- Watch out for alloying and corrosion!!!

Materials

- **Carefully consider what may have been involved in the fault…finding arcing on a steel cable strap can be very useful (especially if aluminum wire is involved).**



Conductor Size

Use caution when assessing damage on small diameter conductors or conductors made up of small diameter strands.

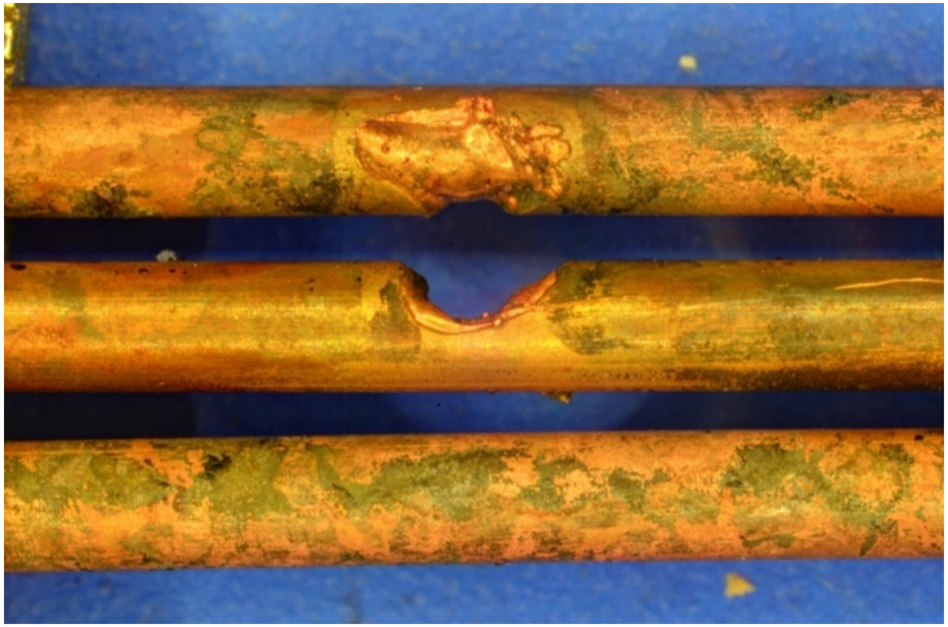
- Damage to smaller conductors and strands can be misleading.
  - The reduced mass of smaller conductors allows them to melt more easily during a fire.
  - Arc-melting and thermal melting still follow the same basic rules, but it may be tougher to interpret the damage on a smaller scale.

- What is 'small'? Typically <14 AWG or larger conductors comprised of smaller strands

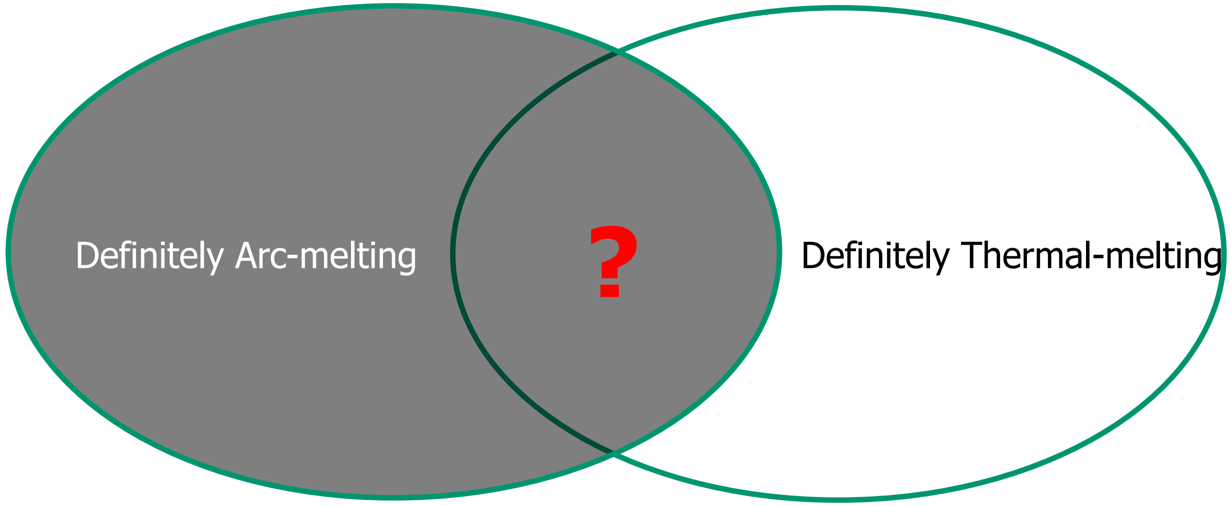
Reliability???

← Do you feel comfortable making the call based on this?

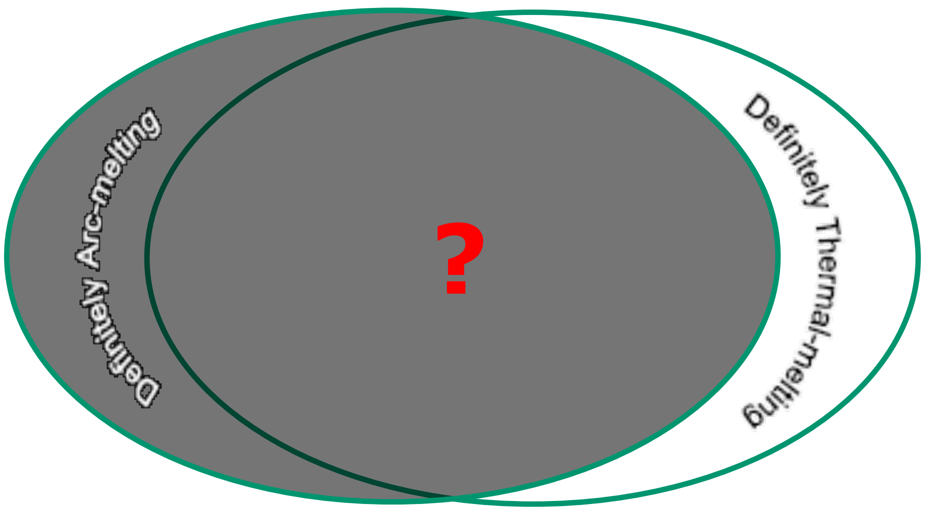
How about this? →



How some see the world…

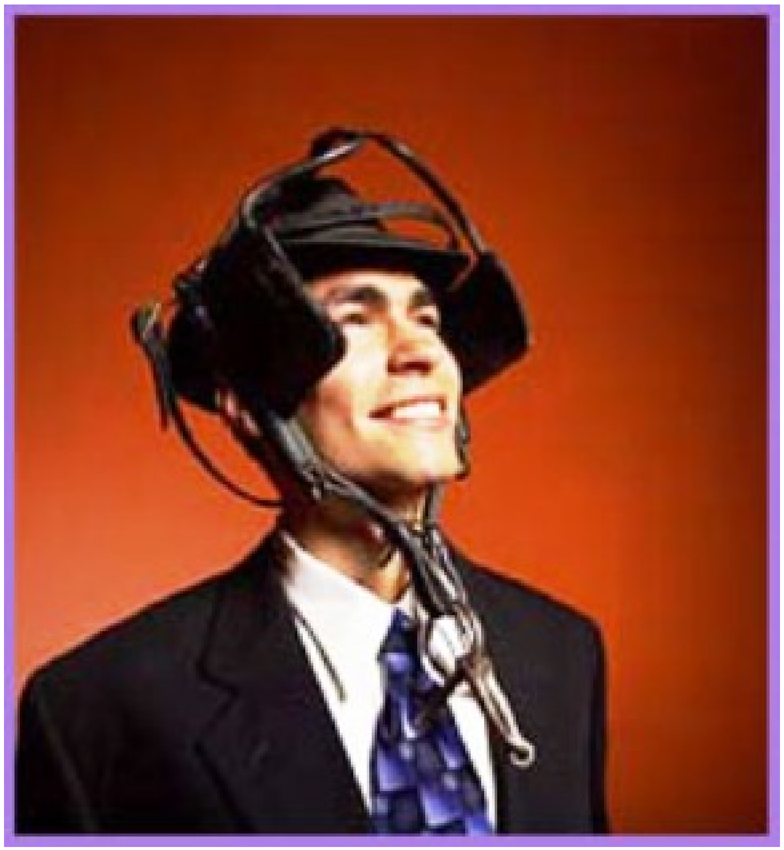


…probably a little more realistic



Scene Processing

Conducting an Electrical Scene Examination



- The electrical scene examination will only focus on the electrical systems and NOTHING else.
  - In effect, act like it is a separate investigation.

Conducting an Electrical Scene Examination

- If something is observed that looks like an electrical failure: wait and see how it fits with the remainder of the scene before drawing a conclusion.

Arc Melting

- The only conclusion that can be drawn from looking at arc damage to conductors, devices, appliances, or equipment is that it was energized at the time of the fire.
  - A forensic examination of the damage alone will not tell you if the arc melting is a cause or result of the fire.
  - We need to practice identifying arc melting to be able to identify arc melting.

Before You go Inside…
Basic Interview Questions

- DO NOT forget that witness interviews are also part of the electrical investigation
- The following are questions for the owner / maintenance manager / electrician / employees:
  - How is the facility wired?
  - Are there any drawings?
  - Who did the maintenance for the facility?
  - Where are the distribution panelboards?
  - What was on?
  - What was off?
  - How are different pieces of equipment turned on or off?
  - Is machinery turned off at the panelboard or at the equipment?
  - What was acting "funny"?
  - What kind of problems have happened in the past?
  - What has recently been changed in the facility?
- The main goal is to understand what should have been energized at the time of the fire.

FIRE RESEARCH LABORATORY
ATF

Basic Interview Questions

- The following are questions for the first in firefighters:
  - What lights did you see on?
  - At what point did you see the lights go out?
  - Did you hear something that sounded like a shotgun?
  - Did you hear anything shorting out?
  - Did you hear any motors running?
  - Did you hear any alarm horns?

Arc Mapping

NFPA 921 - 2017

- 18.4.5 Arc Surveys or Arc Mapping

  …a technique in which the investigator uses the identification of arc locations or "sites" to aid in determining the area of fire origin...

- 18.4.5.1 Suggested Procedure*
- 18.4.5.2 Arc Survey Diagram

  The drawing used to plot the arc sites should be as detailed as possible…

- 18.4.5.3 Documenting Arc Sites

  To document arc sites, attach visible markers such as colored ribbon, colored cable ties…

- 18.4.5.4 Arc Site Evidence Collection

  …The conductors are sometimes brittle and can be quite fragile. Handling may result in fractures…

- 18.4.5.5 Arc Survey Utilization

  The utility of arc mapping is primarily the analysis of the data to determine the sequence of events…

- 18.4.5.6 Arc Survey Limitations

  …The accuracy of the effort, however, is directly dependent upon the investigator correctly identifying arc damage on the wires…

Arc Fault Mapping

- What is arc fault mapping?
  - Locating and mapping all faults that occurred in the electrical wiring

- Why arc fault map?
  - Using arc fault mapping techniques, the area of origin can sometimes be narrowed to a very specific area that may not have been possible using conventional means
    - Fire progression through a structure can be verified using this technique
    - In some cases the location or absence of faults can disprove that a particular area was the fire origin

Our Interpretation

- Arc mapping is one of several tools that are available to aid in determining the origin of the fire. Arc mapping is NOT a stand alone technique.

NFPA 921 - 2017

18.4.5.1 Suggested Procedure

(1) Identify the area that will be surveyed.

(2) Sketch and diagram the area as completely and accurately as possible.

(3) Identify zones within the survey area, such as ceiling, floor, north wall, south wall, etc.

(4) Identify all conductors of the electrical circuits passing through the zone, noting, when possible, loads on each circuit, direction of power flow (upstream versus downstream), locations of junction boxes, outlets, switches (or any such control), size of each conductor, and the overcurrent protection size, type, and status.

(5) Select a zone for examination and begin the process of systematically examining each of the conductors in that zone.

(6) Examine and feel each conductor, for the purpose of identifying surface anomalies or damage, such as beads and notches. When it is necessary to remove conductors from conduits, take care to prevent damage to the conductors.

(7) Determine if the surface anomaly occurred from arcing, environmental heat, or eutectic melting (alloying of metals).

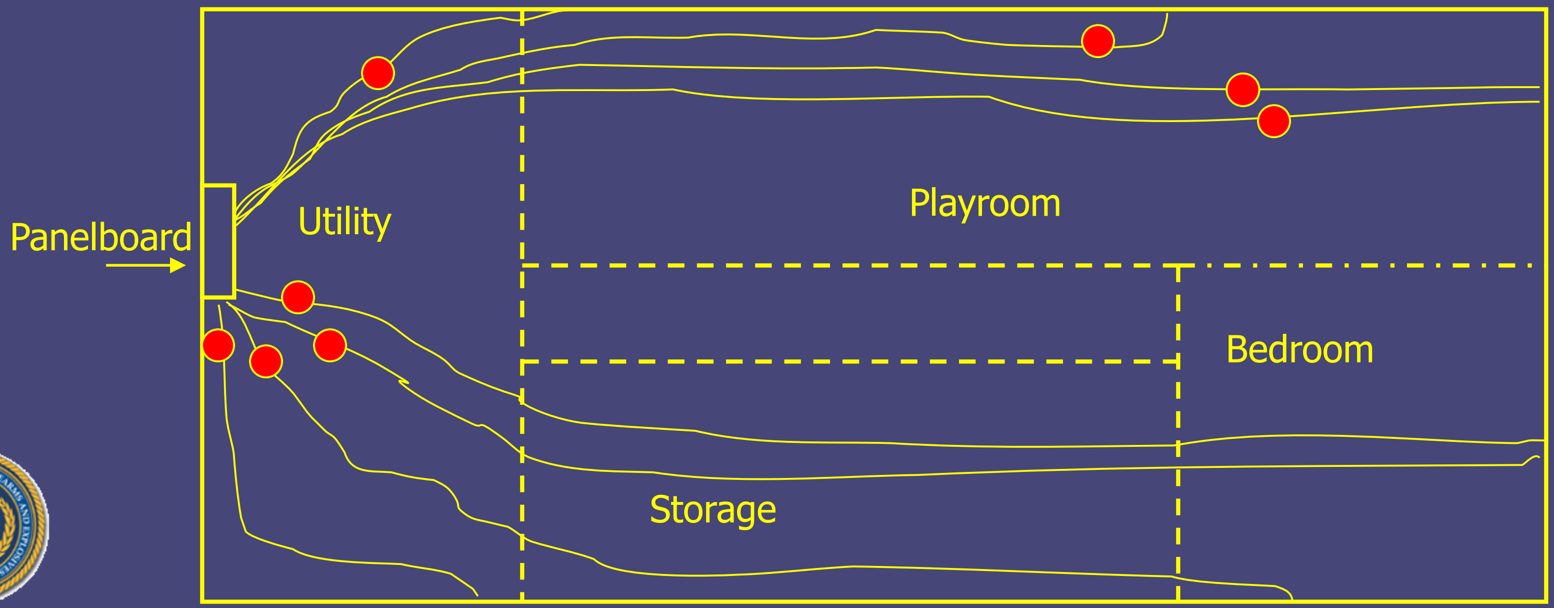
(8) Locate the arc site on the sketch and document its physical characteristics (faulted to another conductor in same cable, faulted to conductor from another cable, completely severed conductor, partially severed conductor, faulted to grounded metallic conduit, or a conductive building element).

(9) Flag the location of the arc site(s) with a suitable marking and document such location(s).

(10) Preserve the items as evidence, when warranted.

Arc Fault Mapping

- Knowing how many tripped breakers or blown fuses can give an idea of how many circuits have faults – but not always
- Locate all faults and tag with tape then plot the locations 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, the conductors would have been de-energized there and no downstream arcing would have been found in the playroom.



Keys to Success

- Understand the electrical service and specifics on how it was distributed throughout the facility
- Use the interview process to identify what circuits should have been energized or were observed to be energized
- Start the evaluation at the primary distribution system and follow it to the end regardless of the fire dynamics
- Compare all observations with the remaining investigative tools before making a final conclusion
  - Arc mapping needs to support the entire investigation

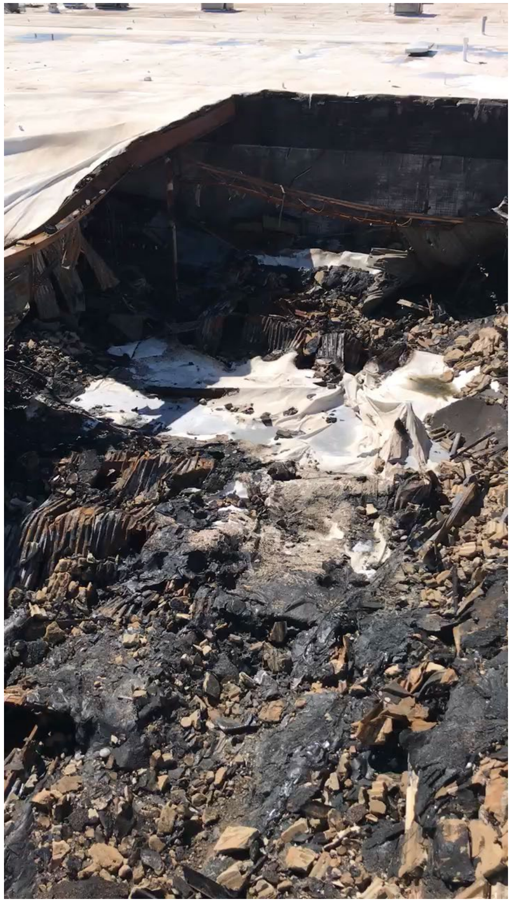
Limitations of Arc Fault Mapping

- Failure to identify the key components of the distribution system
- Failure to identify arc damage on conductors
- Complete destruction of the branch circuits
  - Can be impacted by collapse or extreme heat
- Inability to trace circuits back to the source
  - Multi-story building with collapse makes this very difficult
- Melting of conductors from fire exposure
- Post-fire re-energizing of the electrical system

Can You Arc Map This?

Can You Arc Map This?

How About This?



Maxim Egg Farm Fire

- Boling, TX
- July 3, 2010 – 9:41 PM
- 58,000 SF facility
- $30 Million in damage

Aerial View

Service Entrance Area

3 Phase Feeder

Arc Melting

More Arc Melting

Arc Melting Locations

Light Fixture

Arc Melting Locations

Switch

Arc Melting Locations and Lighting Branch Circuits

Arc Melting Locations and Lighting Branch Circuits

Inside the Storage Area

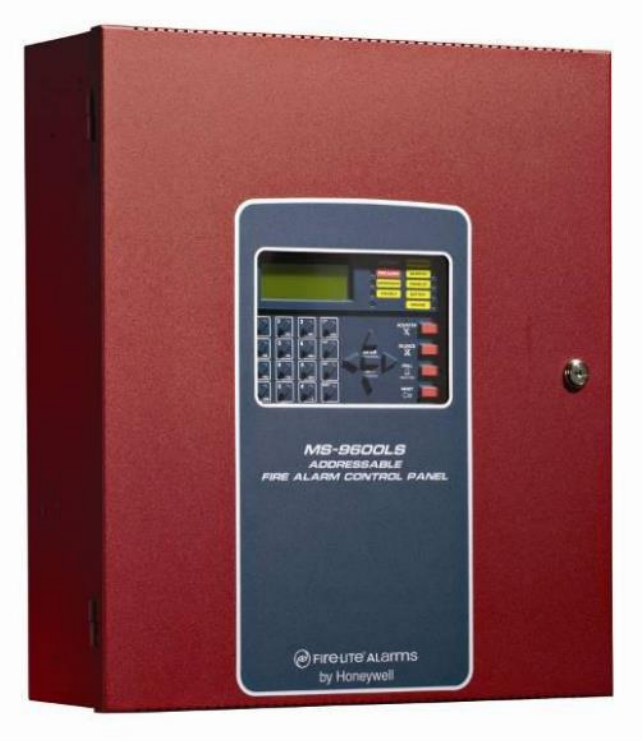
ALARM SYSTEMS

System types

- Fire Alarm
  - Detection and annunciation of fire conditions
  - Fire protection system monitoring
  - Building egress
- Security
  - Premises monitoring
  - Access control
  - Auxiliary functions

Simple Systems

- Single control panel with limited circuits and devices
- Self contained systems with wireless sensors and no centralized control panel

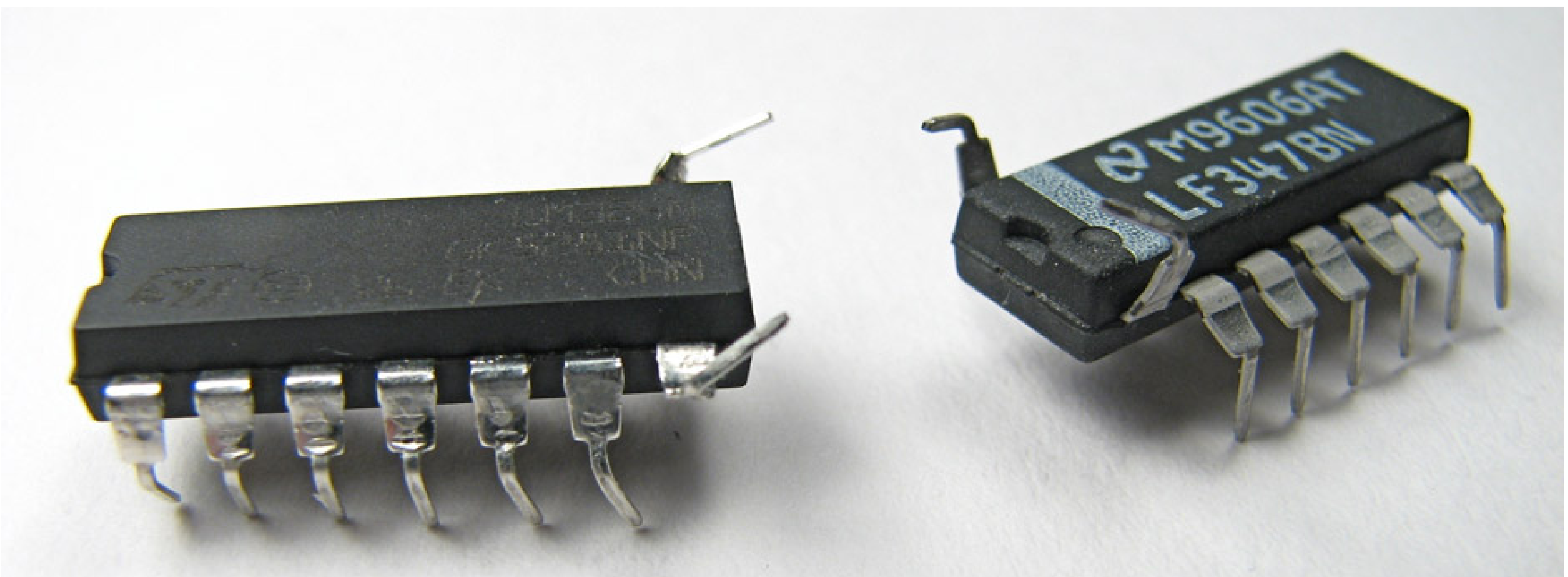


Complex Systems

- Large control panels or Interconnected control panels/modules with numerous circuits and devices serving large buildings

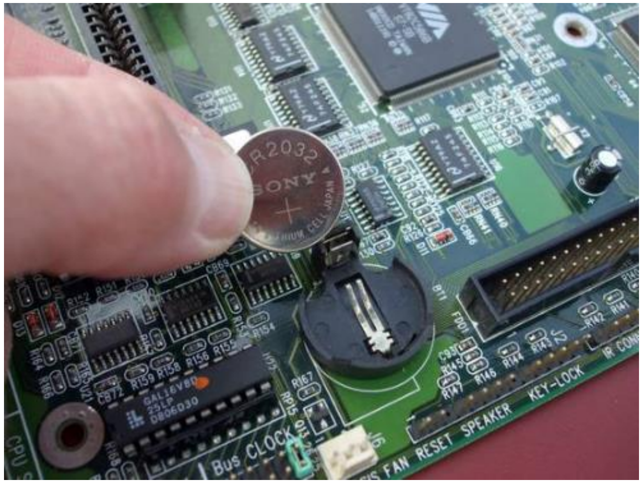
Memory

- How much?
  - 100’s to 1000’s of events
- What kind?
  - Volatile or Non-volatile



Volatile Memory

- Random-Access-Memory (RAM)
  - DRAM
  - SRAM



ALARM MEMORY
The sensor number display can be viewed to determine if there are any alarms in memory. If STATUS is pressed, the system will give an audible indication of its current protection level and the displays will show the sensor number of any sensors which were in alarm during the previous arming period. Sensors which were in alarm are retained in the alarm memory for six hours after the system is disarmed. The alarm memory will be cleared immediately by arming to Level 9.

Non-volatile Memory

- Read-Only-Memory (ROM)
  - EEPROM
- Flash memory

3.4 Programming and Passwords

There are two factory set programming passwords which will access the Programming screens as indicated in the following examples. From either of the screens, access to specific system and device features or programming may be obtained. All user programming entries are stored in non-volatile memory. The factory set passwords can be changed by the user as described in "Password Change" on page 92. If an invalid password is entered, the blinking cursor will return to the first password character position. To exit Programming or Read Status mode at any time, press the *ESC* (Escape) key repeatedly. Note that Programming mode must be exited using the *ESC* key in order to store the program data entered during this mode. If the *Reset* key is pressed or power is lost before exiting Programming mode, the data just entered will not be saved.

Memory

- Alarm systems typically store 100's to 1000's of events in their memory logs.
- The events are stored in a First-in-First-out configuration, where old events are 'pushed out' of the memory by newer events.
- An alarm system which continues to log new events may 'push' the evidentiary data out of the memory.
- It is critical to secure the system to minimize data loss

Alarm System Power

- Fire and Security alarm systems are provided with both AC power and battery backup.
- AC power is likely to be lost during a fire, either due for fire impinging on the power circuit or the scene being de-energized.
- The alarm system will automatically switch to battery power.

Alarm System Power

- Battery life depends on:
  - The power consumption of the panel
  - The power consumption of the connected devices (e.g., if the horns/strobes continue to go off, the battery will die sooner)
  - Damage to the control panel, devices and circuits (e.g., a shorted output circuit will cause the battery to drain quickly)

Alarm System Power

- An alarm technician should be called to the scene ASAP to download the memory
- The alarm system manual or manufacturer should be consulted to determine the best course of action
- When faced with a decision of powering down a panel versus allowing it to log additional events, powering it down is more likely to have positive results

FA CENTRAL STATION DATA

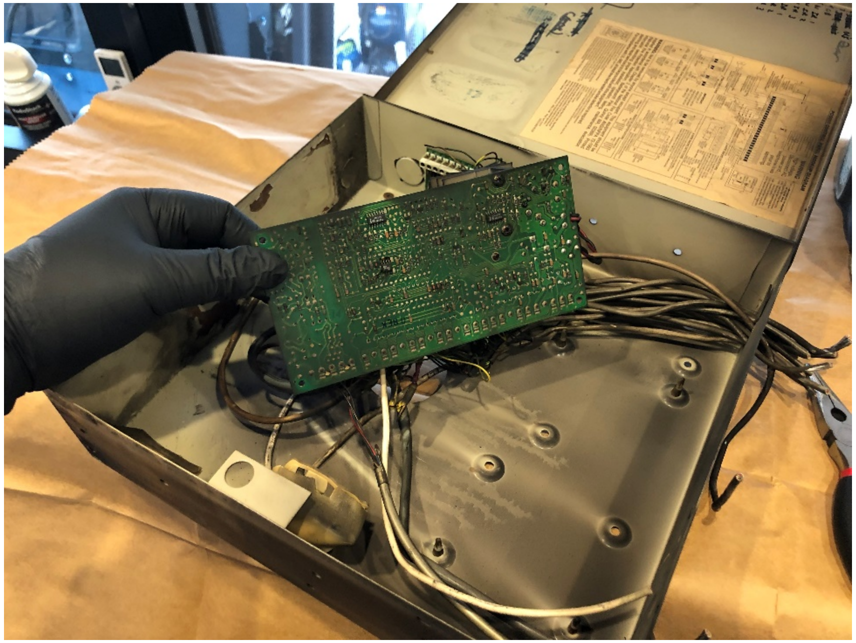
```
02/15/17          A l l   A c t i v i t y   R e p o r t          Page: 574

 Date      Time       Signal          Information          Account:    615522
-------- -------- ------------------------------------------------------------
02/13/17 MON
                  RESTORAL AREA 00 FIRE SUPERVISORY
         10:00:39 SIGNAL RECEIVED:  (R140 ) R140   002    00               SYS
                  RESTORAL AREA 00 FIRE TROUBLE
         10:00:52 SIGNAL RECEIVED:  (E140 ) E140   002    00               AP
                  TROUBLE AREA 00 FIRE TROUBLE
                      > MULTIPLES/DUPLICATES RCVD 1/0
         10:01:00   VIEWED MULTIPLES                                       AP
         10:01:03   ADDED MESSAGES                                         AP
                      PER NOTES - DISREGARD
         10:01:04   ALARM RESOLUTION                                       AP
                      MULTIPLE/DUPLICATE ALARM
02/14/17 TUE
         08:51:32 SIGNAL RECEIVED:  (E602 ) E602   000    00               SYS
                  TEST AREA 00 TEST TIMER
         08:51:33 SIGNAL RECEIVED:  (P140 ) P140   002    00               SYS
                  LOG ONLY AREA 00 PRIOR ALARM STILL ACTIVE
02/15/17 WED
         02:20:12 SIGNAL RECEIVED:  (E140 ) E140   001    00               SM
                  FIRE ALARM AREA 00
                      > MULTIPLES/DUPLICATES RCVD 2/1
         02:21:01   CALLED ANCHORAGE FIRE DEPT. DIALED (907) 565-1623      SR1
                      CONTACTED
                      AUTHORITIES CONTACTED
         02:22:23   ADDED MESSAGES                                         SR1
02/15/17 WED
                      AFD STATED THERE IS AN ACTUAL FIRE.
         02:22:45   ADDED MESSAGES                                         SR1
                      STATED THEY ARE ALREADY IN ROUTE.
         02:22:50   CALLED PREMISES            DIALED (907) 563-3114      SR1
                      CALL ABORTED
         02:23:08   CALLED THOMAS YOON         DIALED (907) 229-0114      SR1
                      CONTACTED
         02:23:35   THOMAS YOON - PASSCODE VERIFIED                        SR1
         02:23:54   ADDED MESSAGES                                         SR1
                      THOMAS IS ON SITE, AND CONFIRMED THERE
                      IS AN ACTUAL FIRE.
```

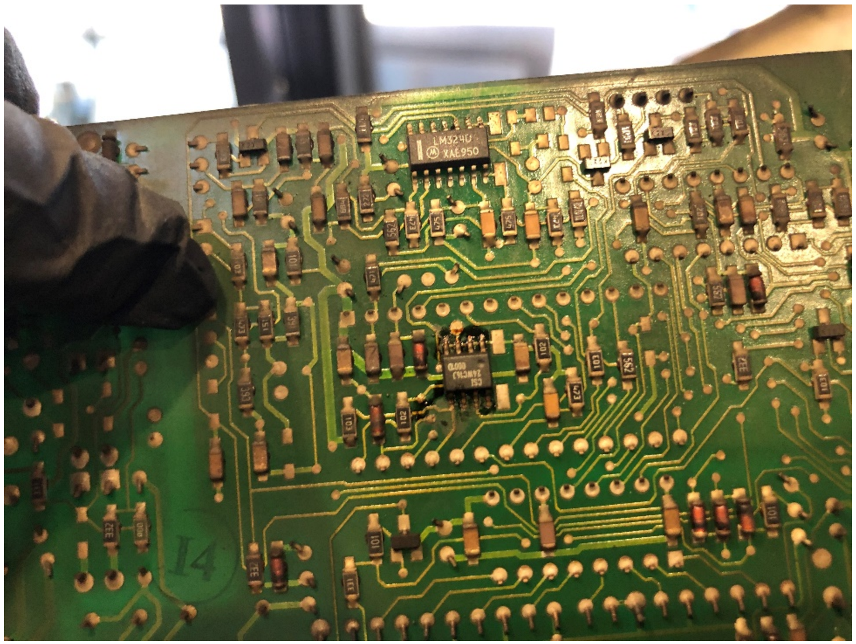
FACP LOCAL DOWNLOAD

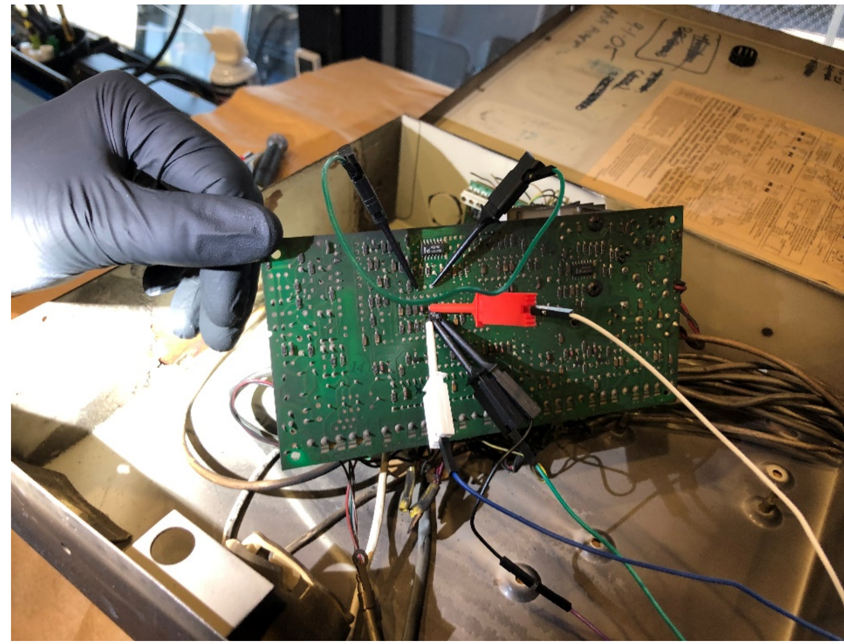
Intrusion Alarms

- Magnetic and infra-red sensors usually act as "normally closed" switches. When they are activated, they open.
- Generally, they will act as an "open" or "alarm" when impinged by flame.
- Wiring to the devices is normally lightweight and surface mounted. It will also act as an "open" when it is impinged by flame and fails.

Burglar Alarm Memory Download

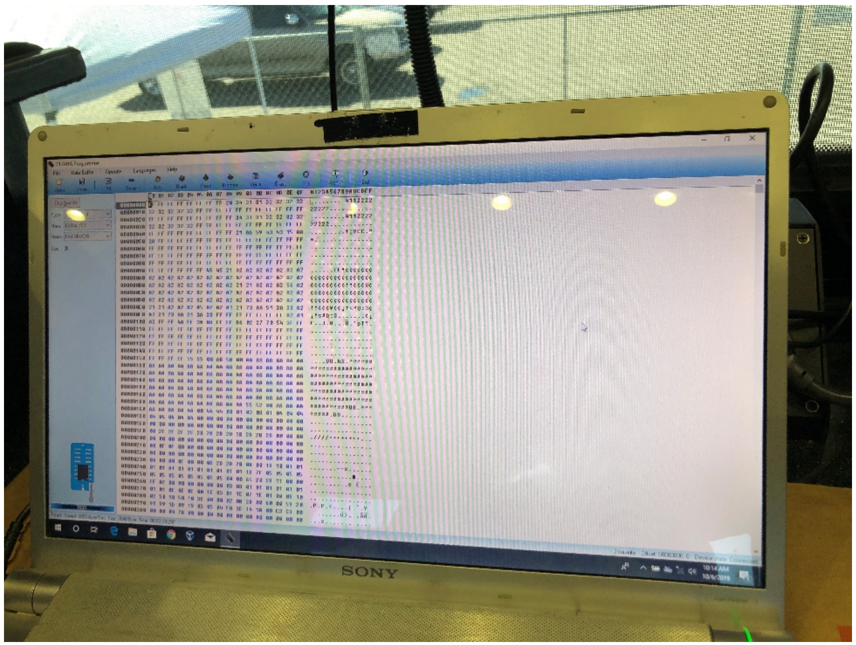


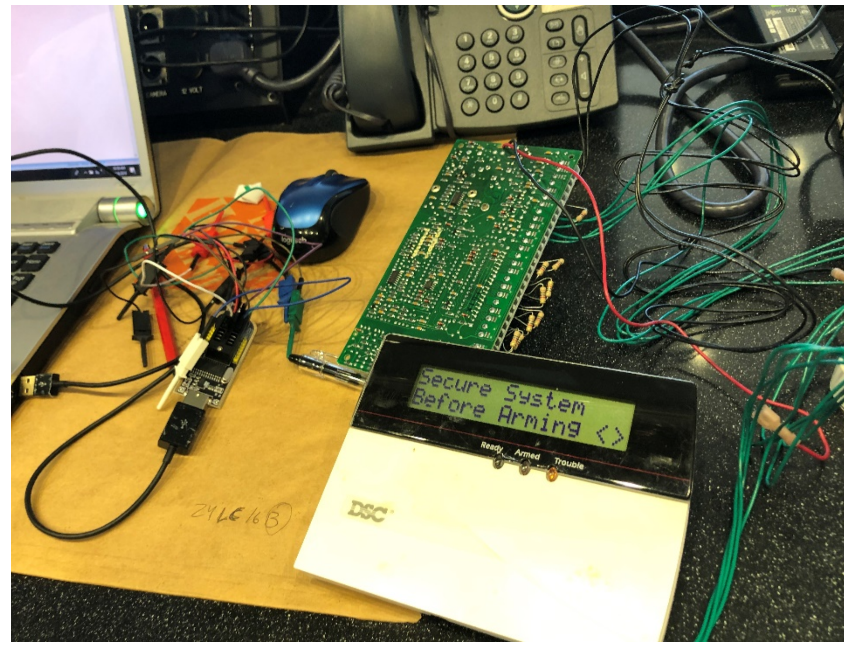




BUREAU OF ALCOHOL, TOBACCO, FIREARMS AND EXPLOSIVES
1972

FIRE RESEARCH LABORATORY
ATF


SONY


Secure System
Before Arming <>
Ready
Armed
Trouble
DSC
24LC16B

Fatal Explosion/Fire

Fatal Explosion/Fire

Fatal Explosion/Fire

Fatal Explosion/Fire

Fatal Explosion/Fire

Fatal Explosion/Fire

Fatal Explosion/Fire

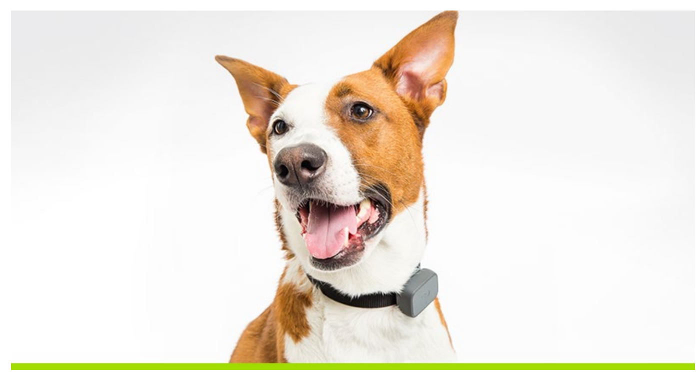
Fatal Explosion/Fire

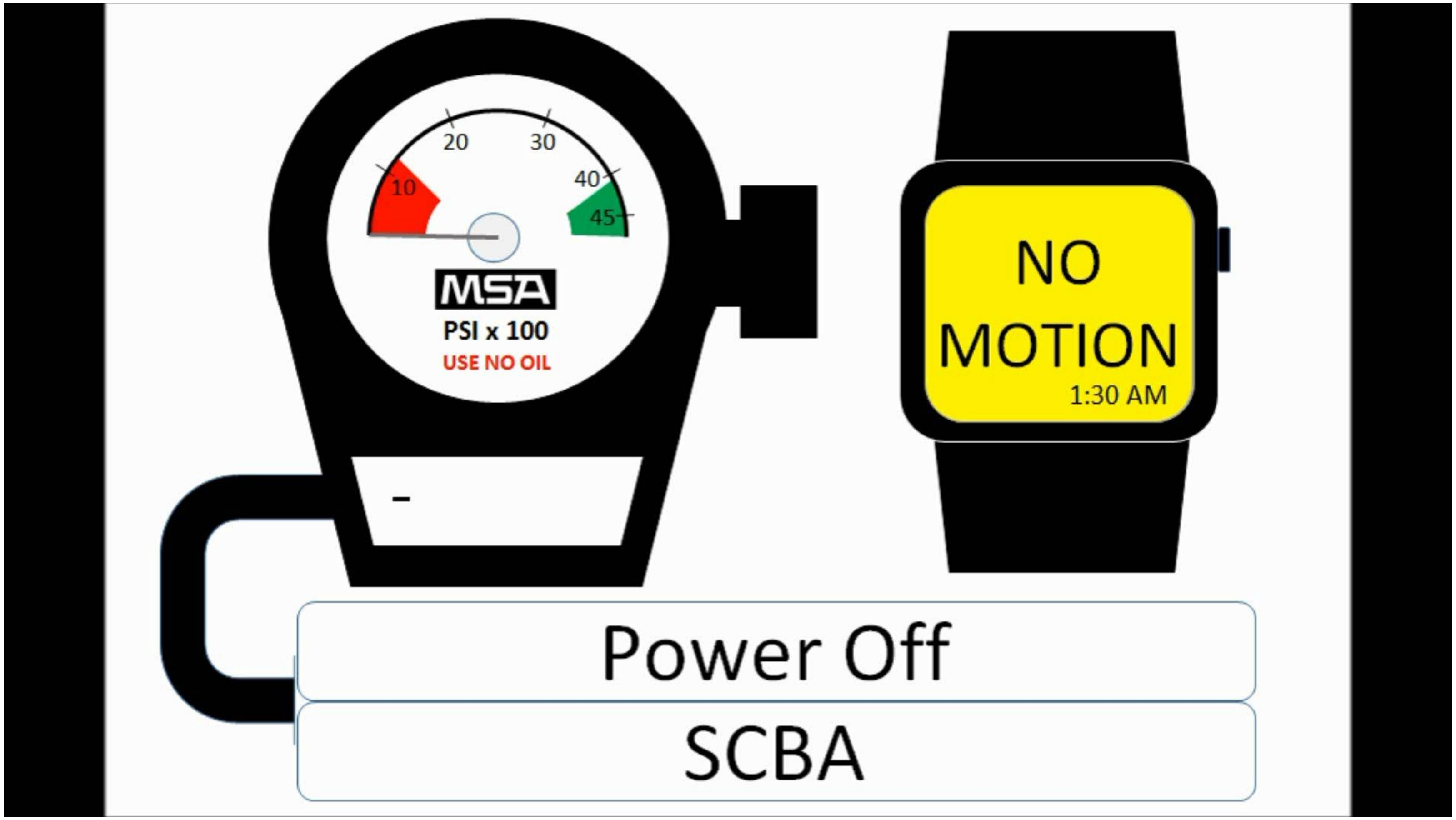
Zone	Response Type	Input Type	Description
9	3 - Perimeter	3 - RF (Supervised)	Storage Door
10	1 - Entry/Exit 1	3 - RF (Supervised)	Shop Side Door
11	3 - Perimeter	3 - RF (Supervised)	Front Office Door
12	3 - Perimeter	3 - RF (Supervised)	Rear Office Door
13	3 - Perimeter	3 - RF (Supervised)	Shop Laundry Door
14	4 - Interior Follower	3 - RF (Supervised)	Office Motion Detector
15	4 - Interior Follower	3 - RF (Supervised)	Hall Office Motion
16	6 - 24 Hour Silent	4 – UR (Unsupervised)	Panic
Additional zones were present for keypad emergency buttons			

Event Log Type --All 11:37:11 08-16-2016						
Event #	Date	Time	Event	Point	User	Partition
8	8/11/2016	10:12 AM	E-132-Interior	14	0	1
9	8/11/2016	10:02 AM	E-132-Interior	14	0	1
10	8/11/2016	05:50 AM	E-132-Interior	14	0	1
11	8/11/2016	12:34 AM	E-354-Failure to communicate event	0	0	0
12	8/11/2016	12:25 AM	E-134-Entry/Exit	10	0	1
13	8/11/2016	12:19 AM	E-354-Failure to communicate event	0	0	0
14	8/11/2016	12:11 AM	E-301-AC Loss	0	0	0
15	8/11/2016	12:08 AM	E-132-Interior	14	0	1
16	8/10/2016	11:59 AM	E-132-Interior	14	0	1
17	8/10/2016	11:59 AM	E-354-Failure to communicate event	0	0	0
18	8/10/2016	11:58 AM	R-132-Interior	14	0	1
19	8/10/2016	11:50 AM	E-132-Interior	14	0	1
20	8/10/2016	08:42 PM	R-401-O/C by user	0	02	1
21	8/10/2016	08:40 PM	E-401-O/C by user	0	02	1
22	8/10/2016	08:32 PM	R-401-O/C by user	0	02	1
23	8/10/2016	08:30 PM	E-401-O/C by user	0	02	1
24	8/10/2016	06:04 PM	R-401-O/C by user	0	02	1
25	8/10/2016	06:42 AM	E-401-O/C by user	0	02	1

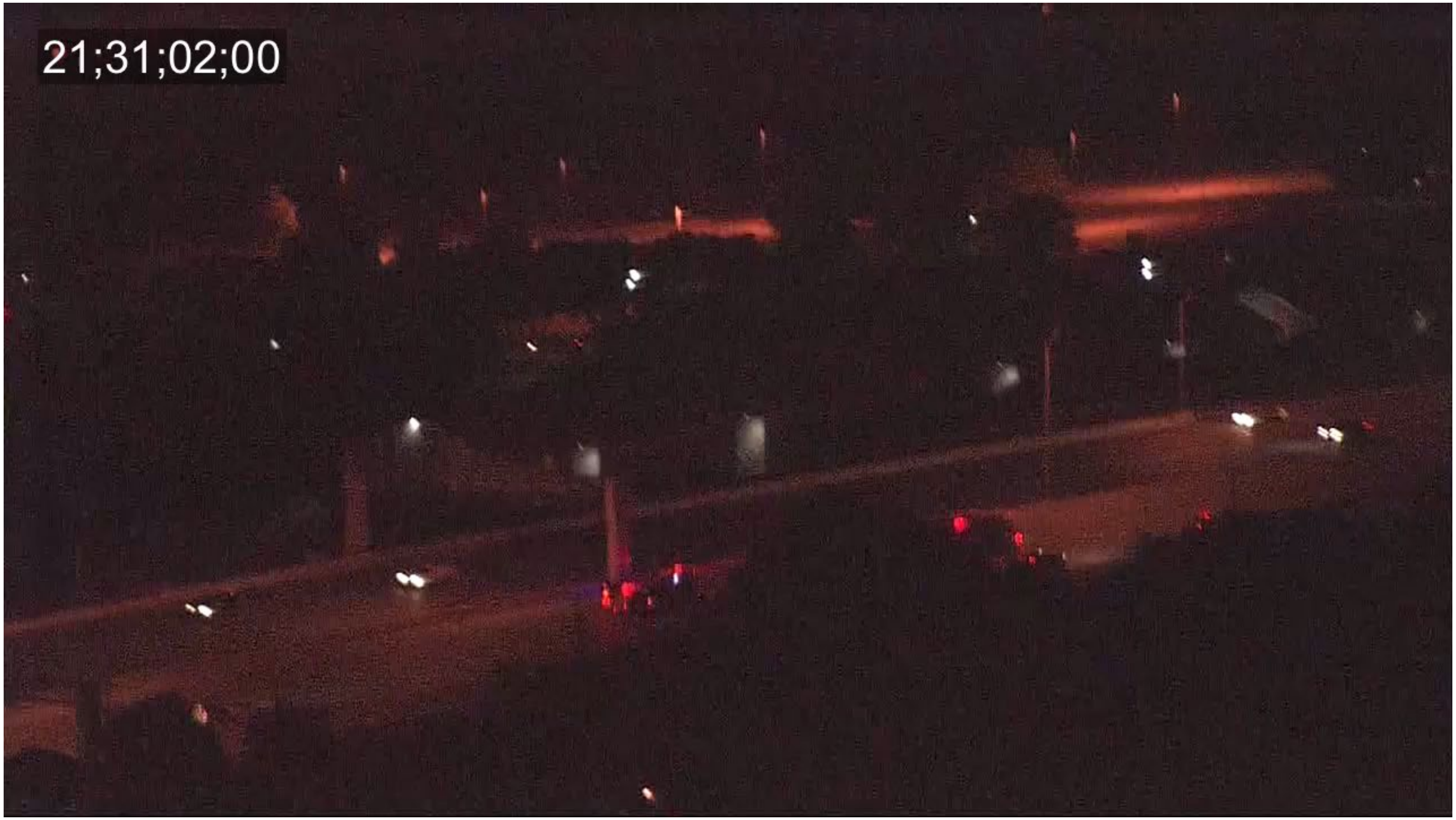
Technology and Smart Data

Consider the interconnection of everyday objects, connected via the internet to send and receive data.




20
30
10
40
45
MSA
PSI x 100
USE NO OIL
NO
MOTION
1:30 AM
Power Off
SCBA

San Antonio, TX


21;31;02;00

BUREAU OF ALCOHOL, TOBACCO, FIREARMS AND EXPLOSIVES 1972

FIRE RESEARCH LABORATORY ATF

BUREAU OF ALCOHOL, TOBACCO, FIREARMS AND EXPLOSIVES 1972

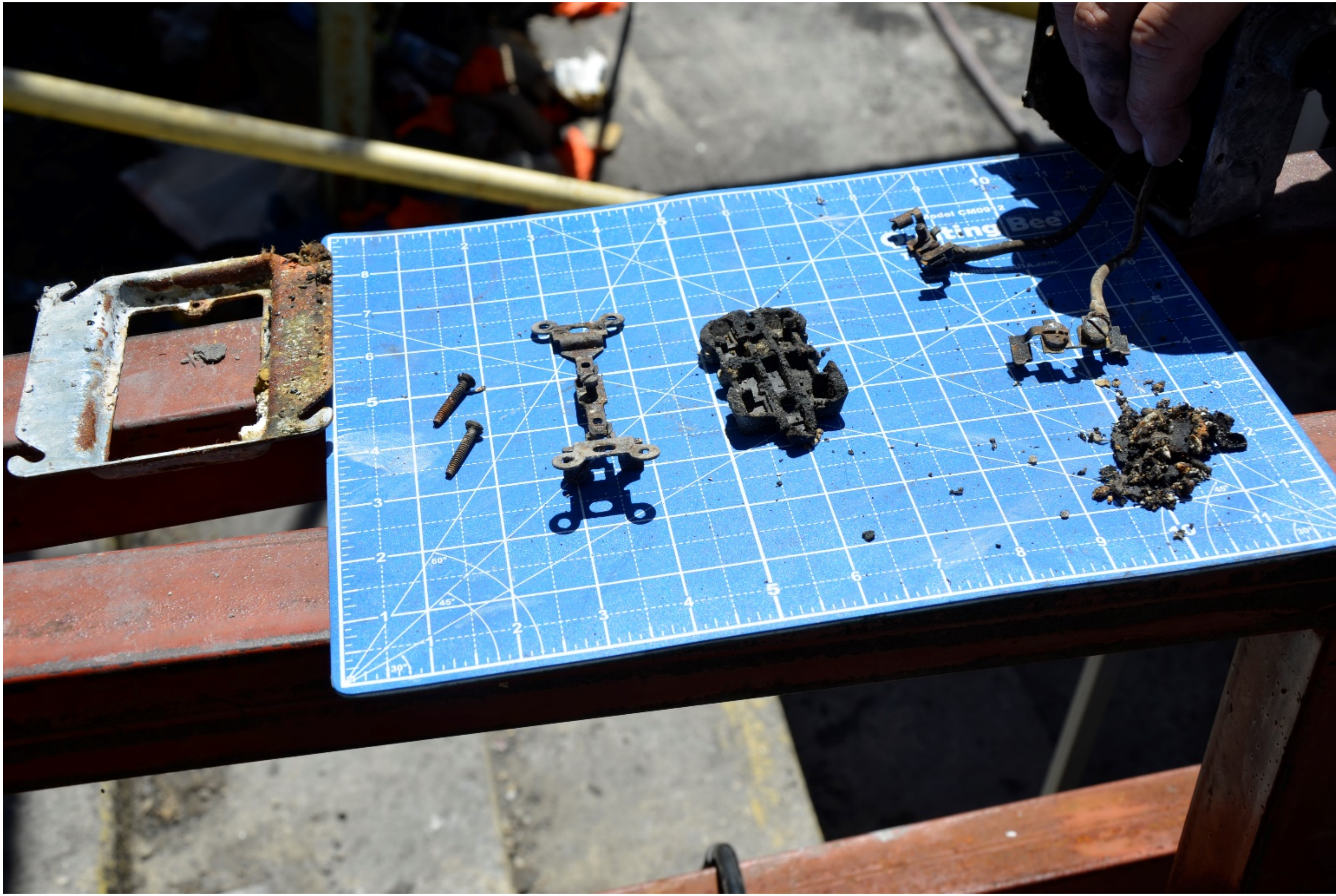
FIRE RESEARCH LABORATORY ATF


E2314

FIRE RESEARCH LABORATORY
ATF

BUREAU OF ALCOHOL, TOBACCO, FIREARMS AND EXPLOSIVES 1972

FIRE RESEARCH LABORATORY ATF



BUREAU OF ALCOHOL, TOBACCO, FIREARMS AND EXPLOSIVES 1972

FIRE RESEARCH LABORATORY ATF

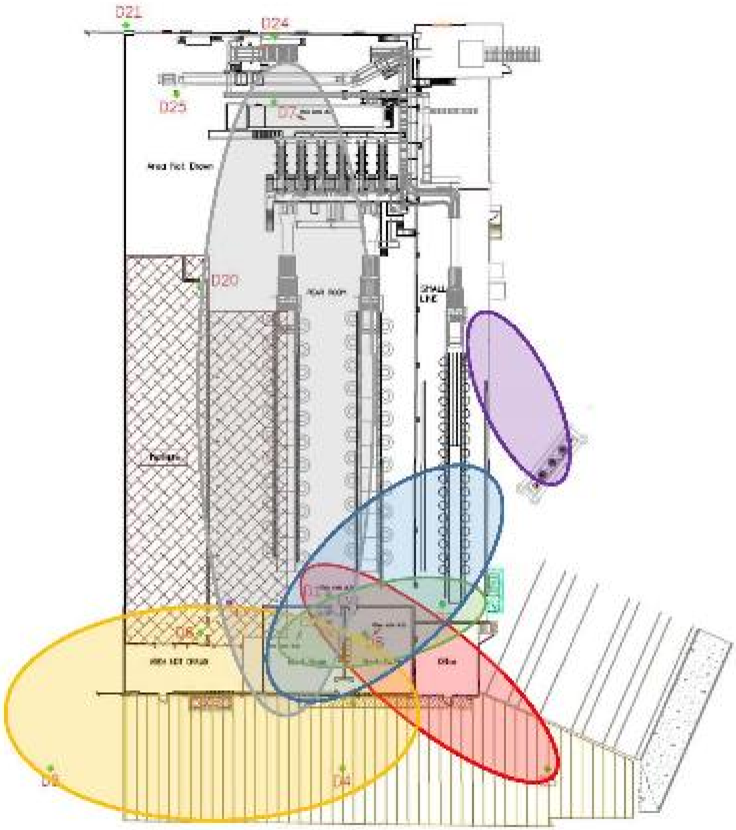
FIRE RESEARCH LABORATORY
ATF

Pacific Northwest

BUREAU OF ALCOHOL, TOBACCO, FIREARMS AND EXPLOSIVES 1972

FIRE RESEARCH LABORATORY ATF

Surveillance System Failure Mapping



Beaufort County Black Chamber of Commerce

FIRE RESEARCH LABORATORY
ATF

FIRE RESEARCH LABORATORY
ATF


POLICE LINE DO NOT CROSS

FIRE RESEARCH LABORATORY
ATF

Aguirre AEE Fire and Explosion
Salinas, Puerto Rico

Background

- On September 21, 2016, at approximately 2:30 pm, a fire and an explosion occurred at the Electric Power Company (Autoridad de Energia Electrica, AEE) Aguirre Thermoelectric Plant located in Aguirre, Salinas, Puerto Rico resulting in a power outage on the island that left more than 3 million inhabitants on the island without power for days that followed.

BUREAU OF ALCOHOL, TOBACCO, FIREARMS AND EXPLOSIVES 1972

FIRE RESEARCH LABORATORY ATF


4x4

FIRE RESEARCH LABORATORY
ATF

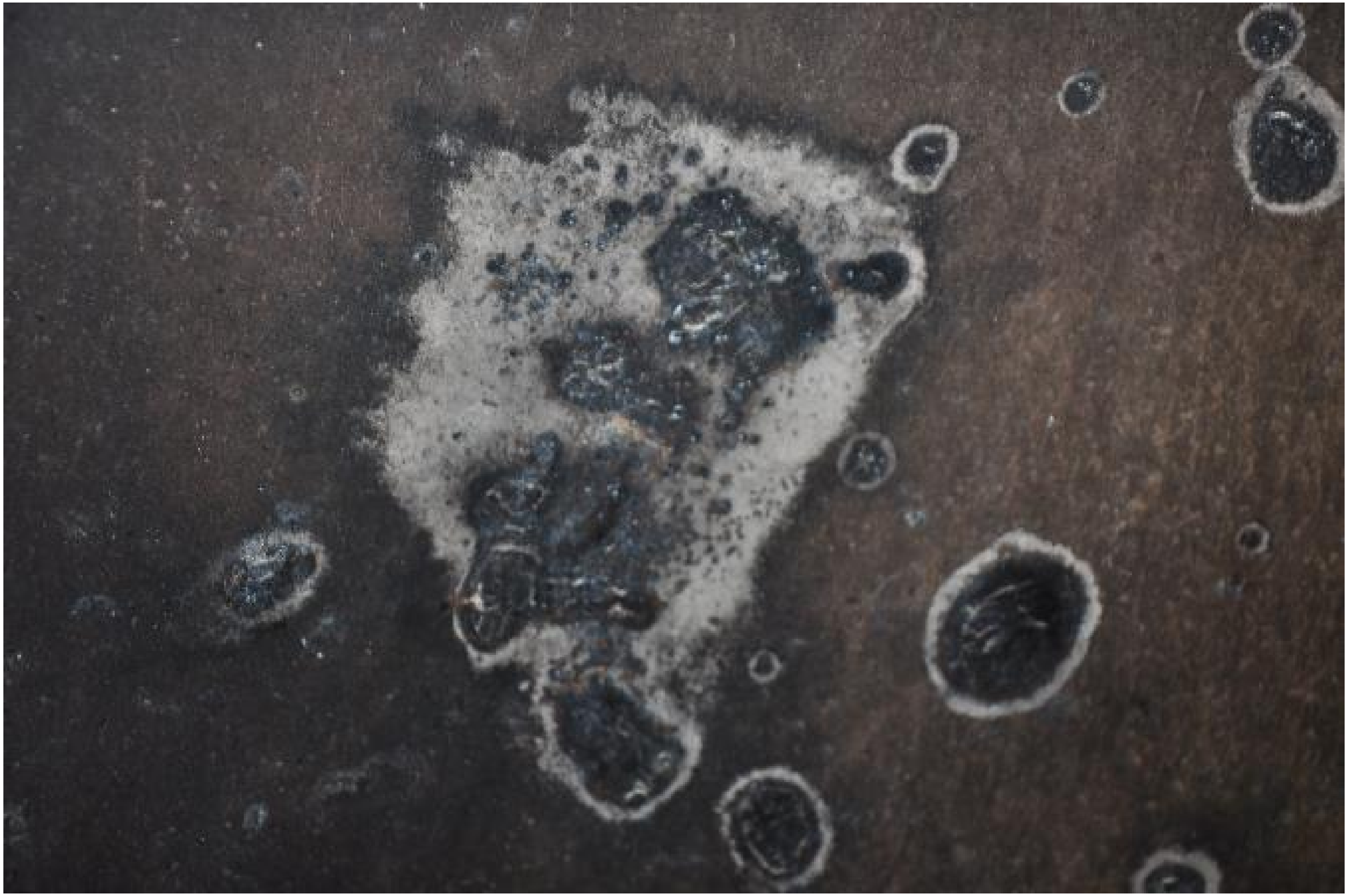
FIRE RESEARCH LABORATORY
ATF

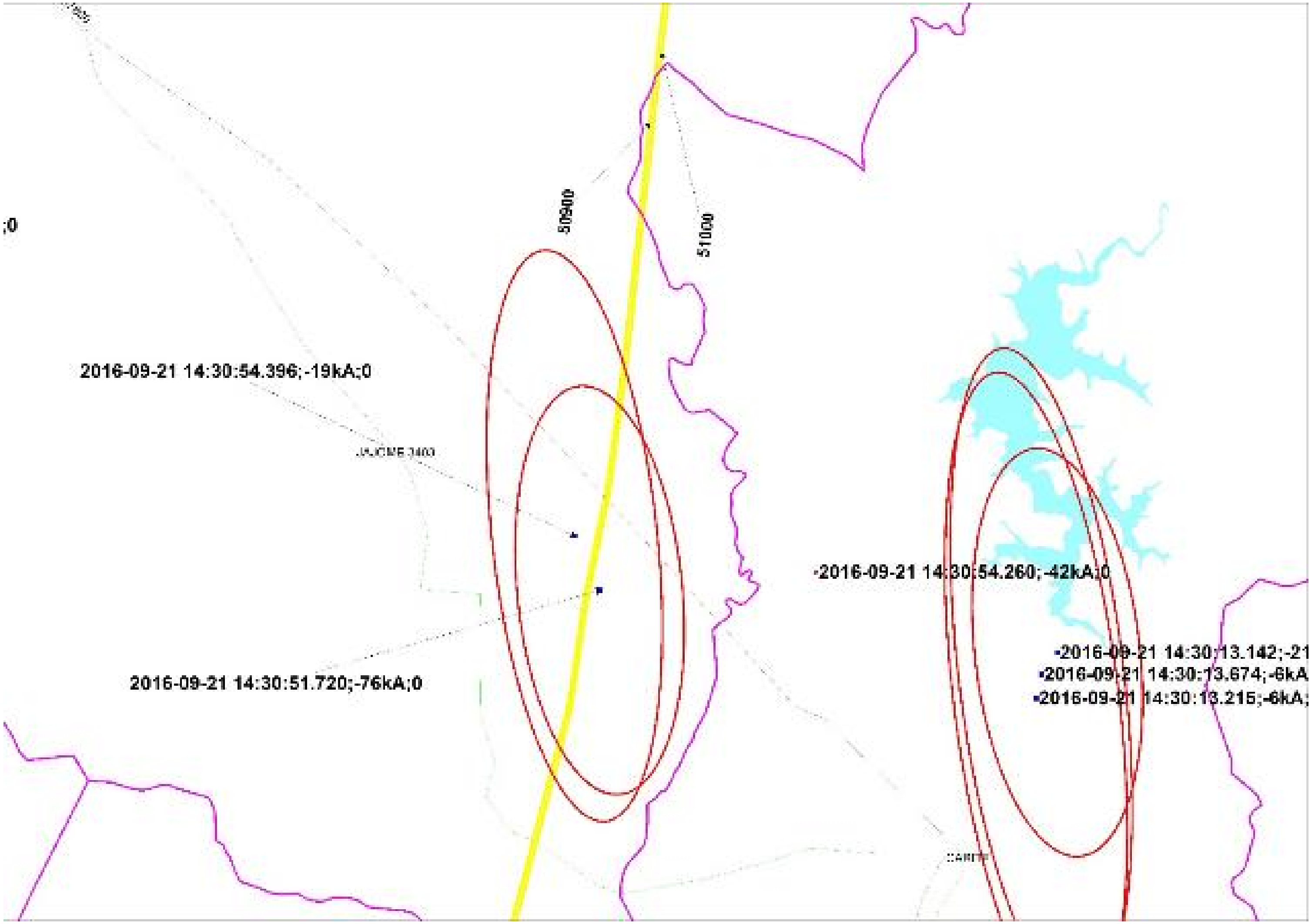
FIRE RESEARCH LABORATORY
ATF

BUREAU OF ALCOHOL, TOBACCO, FIREARMS AND EXPLOSIVES
1972

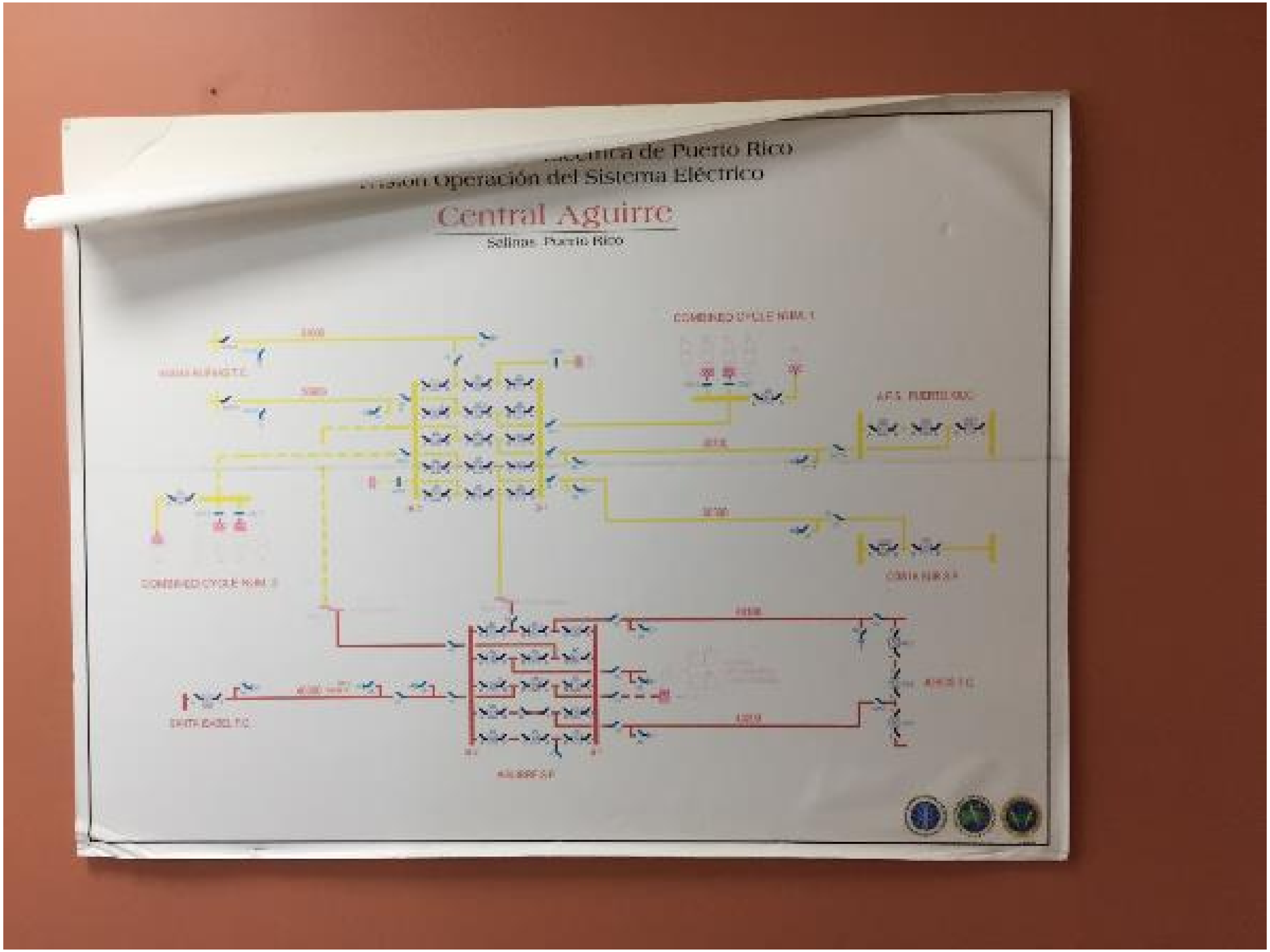
FIRE RESEARCH LABORATORY
ATF

FIRE RESEARCH LABORATORY
ATF





FIRE RESEARCH LABORATORY
ATF



Central Aguirre
Salinas, Puerto Rico

APP 013.4-47
9/69

PUERTO RICO WATER RESOURCES AUTHORITY
CIRCUIT BREAKER HISTORY CARD

Location: Aguirre Subst.	Equipment No. 091-00-00-10	Permanent Property No. 091-00-00-10
Equipment Name: OCB 50930	Manufacturer: ITE Imperial Corporation	Serial No. 41-30125-5011
Pur. Order No.	Supplier Order No. / Shop Order No.	Installed in Aguirre Subst. Date
Date Purchased: 1970	Date Manufactured: 1969 / Equipment Cost:	

Type 230 KM 20000-20B Int. MVA 20000 Cycles 60
Rated Volts 230 KV Max. Design Volts 242 KV Imp. w/stand BIL 900 KV
Rated Amps at Rated Voltage 2000 Max. Int. Amps 43000 Momentary Amps

Transferred To / Date
Transferred To / Date
Transferred To / Date

Opening Time 3 cycles Closing Time Trip Free Time Reclosing Time
Trip Time Opr. Range Close Volts Opr. Range

OPERATING PRESSURE		GOVERNOR		ALARM		LOW PRESS. CUT OUT	
Normal 275	Min. 190	In 255	Out 275	In 225	Out 240	In 205	Out 190

Operating Mech. Type P-45A Motor HP Century 1.5 Frame 184 Motor Volts 104/208 VAC Phase Comp. Type Worthington SN LM 1549 Size 2 7/8 X 1 11/16 X 1 1/4 2 type

BUSHINGS

Type Class or Dwg. Cat. No. Inst. Book ASA Std.
C.B. Inst. Book O5X020-08 C.B. Parts Bull. Ope Mech. Inst. Book
C.B. Conn. Diag. Outline Dwg. CT Conn. Diag. Mech. P/Bull.
CT's Type BR Rating 2000/5 Location 2/Bushing CT Type Rating Location
C.B. Weight 40260# Gals. Oil 196 Oil Weight Total Weight 84 060 # Height

MISCELLANEOUS INFORMATION

Inst. Manual 051L011-35
Wiring Dwg. 99B221
~~Wt. w/Oil 82840 lbs.~~
Oil Tank 1975 Gals.

CTS Accuracy Class type 2.5 L 800
Ratio:

60/1	160/1	300/1
80/1	220/1	320/1
100/1	240/1	400/1

Control Voltage Range
Closing 90-130VDC-56
Tripping 70-14VDC-9
Main Valve - 208 VAC
Heaten Voltage 115 VAC

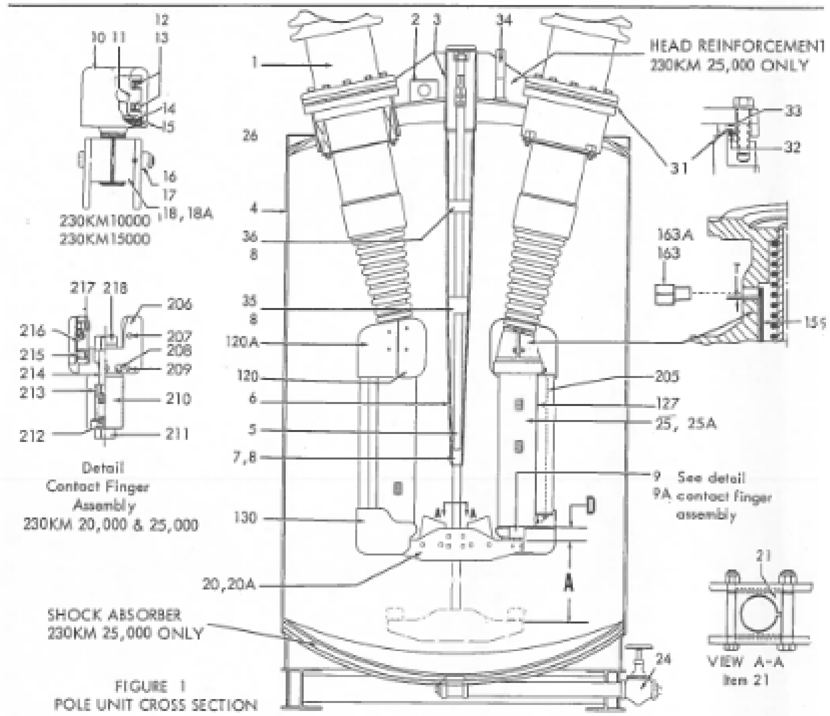
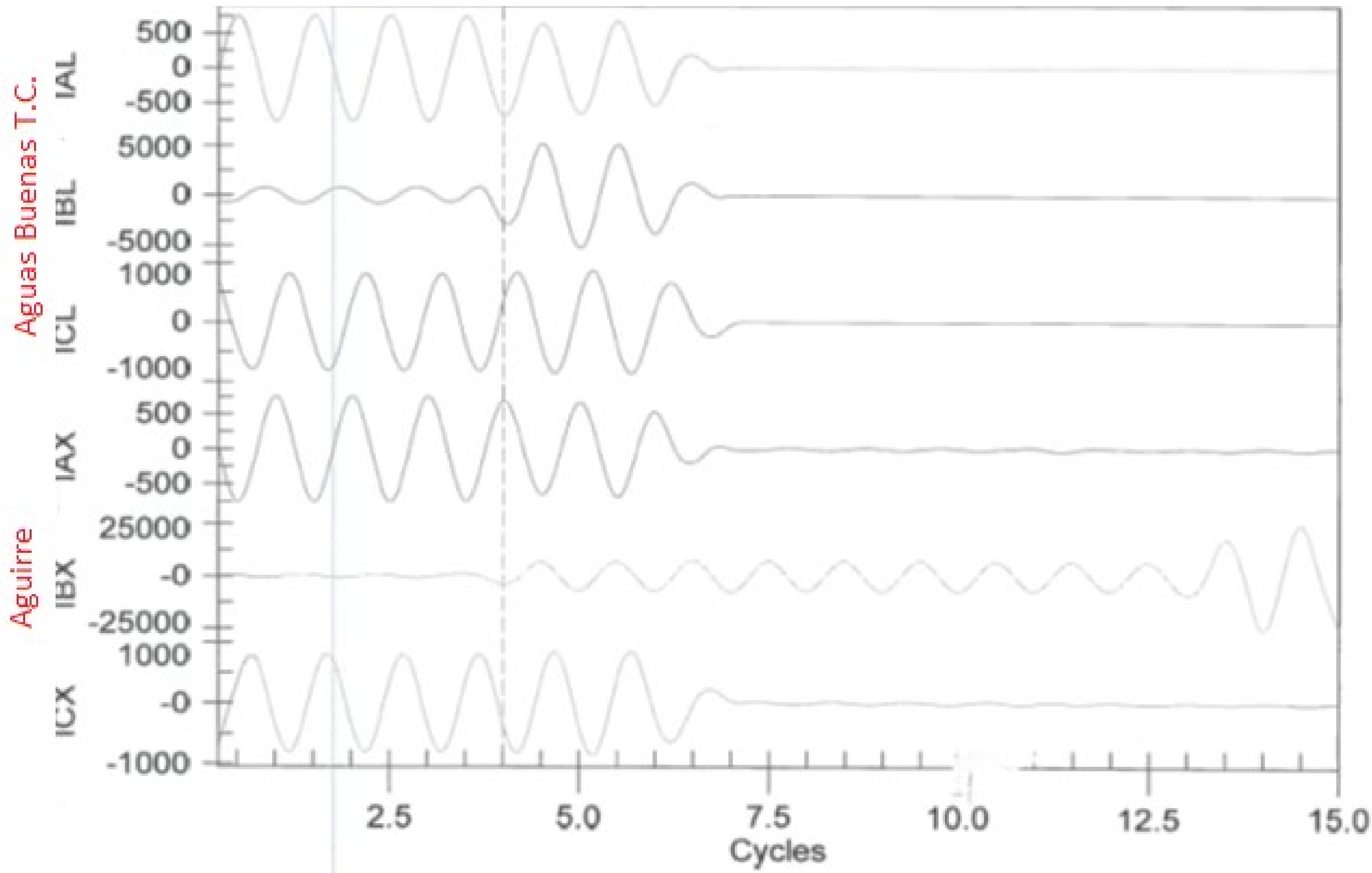
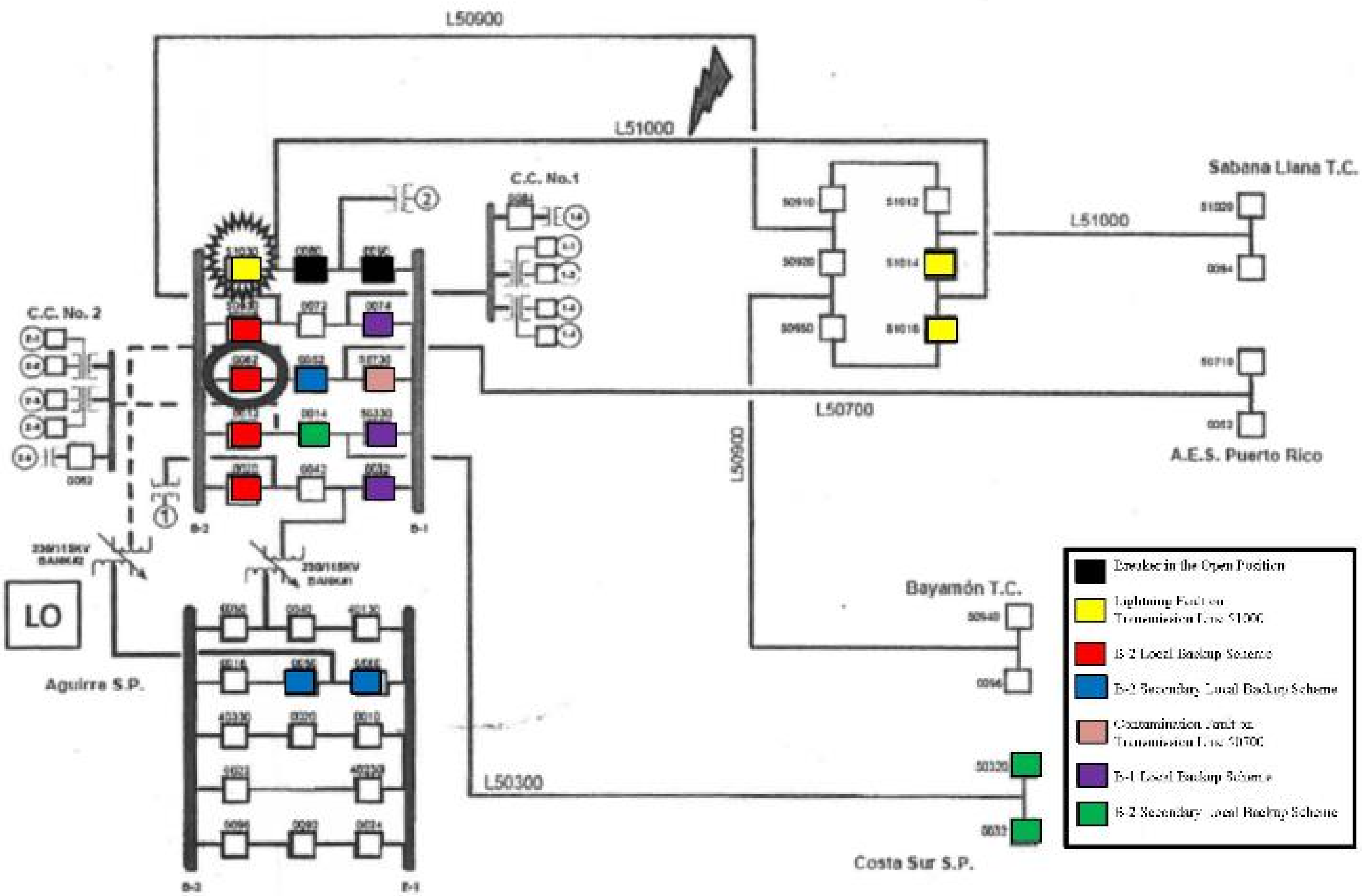


FIGURE 1
POLE UNIT CROSS SECTION

ITEM	DESCRIPTION	ITEM	DESCRIPTION	ITEM	DESCRIPTION
1	Bushing, include all data from Bushing Nameplate	18	Contact Adapter 10 & 15,000	120A	Upper Shield
2	Pull Box, Bushing C.T. Leads	18A	Contact Adapter 20 & 25,000	127	Resistor 1875 Ohm
3	Pole Unit Mechanism Frame	20	Crossbar Ass'y 10 & 15,000	130	Lower Shield
4	Tank	20A	Crossbar Ass'y 20 & 25,000	159	Piston
5	Lift Rod	21	Lift Rod Support	163	Valve Ass'y 10 & 15,000
6	Lift Rod Guide Supports	24	Globe Valve	163A	Valve Ass'y 20 & 25,000
7	Lift Rod Guide	25	Interrupter Upper Stationary Contact & Adapter 10 & 15,000	205	Capacitor
8	Screw	25A	Interrupter Upper Stationary Contact & Adapter 20 & 25,000	206	Shield
9	Crossbar Contact Ass'y 10 & 15,000	26	Bushing Current Transformer include all data from Bushing C.T. Nameplate	207	Spring Pin
9A	Crossbar Contact Ass'y 20 & 25,000	31	Bushing Adapter Ring	208	Cap Screw
10	Shield	32	Seal Ring	209	Spring Pin
11	Contact	33	Gasket, Bushing	210	Body
12	Spring	35	Lift Rod Guide	211	Plug
13	Insulation Button	36	Lift Rod Guide	212	Spring, Die
14	Contact Plate	120	Upper Shield	213	Disc
15	Nylok Set Screw			214	Rod
16	Cap Screw			215	Button, Insulation
17	Hex Nut			216	Contact
				217	Spring, Die
				218	Contact



Aguas Buenas T.C.
Aguirre
IAL
IBL
ICL
IAX
IBX
ICX
500
0
-500
5000
0
-5000
1000
0
-1000
500
0
-500
25000
-0
-25000
1000
-0
-1000
2.5
5.0
7.5
10.0
12.5
15.0
Cycles



Note: Original diagram provided by S.V. Blasini, Jefa de Subdivisión, Protección del Sistema Eléctrico, AEE

BUREAU OF ALCOHOL, TOBACCO, FIREARMS AND EXPLOSIVES 1972

FIRE RESEARCH LABORATORY ATF

Methodology Summary

- Start Outside
  - Document the primary distribution transformer.
  - Get information about the service from the utility provider.
  - Determine when the scene was de-energized.
  - Examine and document the service entrance.

- Conduct Interviews
  - Obtain information about facility status, wiring, maintenance, etc from interviews.
  - Obtain information about what was / should have been energized.

- Move inside
  - Trace the system throughout the facility starting at the service entrance.
  - Emphasis is placed on feeders and branch circuits that are tripped or open.
  - Identify all instances of arc melting.
  - Obtain information from the alarm system

- Conclusions are only drawn when they are overlaid on the other information obtained from the scene.

Ignition factors to Consider:

- Distribution of energy
- Heat loss factors
- Duration of heating
- Type of fuel
- Geometry of fuel

Definition of Cause

- Competent ignition source
- First fuel ignited
- Circumstances that allowed them to come together

Conclusion

MICHAEL G. ABRAHAM, PE

ATF FIRE RESEARCH LABORATORY
6000 AMMENDALE ROAD
BELTSVILLE, MD 20705

PHONE: 202-648-6210
CELL: 302-758-6601
EMAIL: MICHAEL.ABRAHAM@ATF.GOV