IAEI George Washington Chapter

ABOUT US MEMBERSHIP PROFESSIONAL DEV. EVENTS MAGAZINE SHOP

Welcome to the May 20, 2020 meeting of our chapter.

After a couple of short pieces of chapter business, we'll turn this over to our presenters.

Forensic Electrical Engineering and Fire Investigation

A presentation for



Matt Benfer, P.E., IAAI-CFI®, CFEI, CVFI
Fire Protection Engineer/Fire Investigator

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Senior Electrical Engineer/Master Electrician
S-E-A, Baltimore, MD

May 20, 2020

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Storm / Catastrophe
Thermal / Combustion Sciences
Trucking & Transportation
Vehicle Dynamics

Disclaimer

All discussions, opinions, comments, photographs, images, etc., made during the presentation are meant for general training and educational purposes, and shall not be considered a professional opinion regarding any specific claim or legal matter.

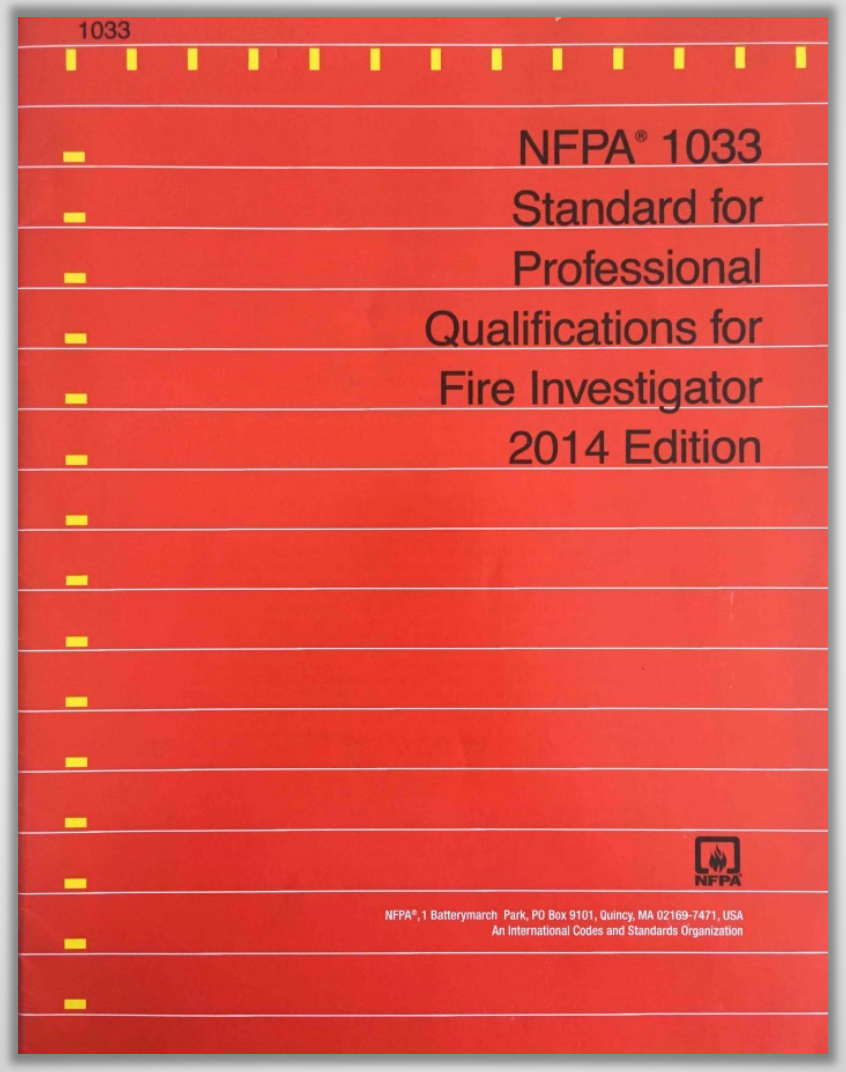
Presentation Objectives

- To be familiar with the scientific method
- To learn the basics of forensic fire and electrical investigation
- Why electrical inspections are important for preventing fires and electrical incidents
- Case Studies of Prior Investigations

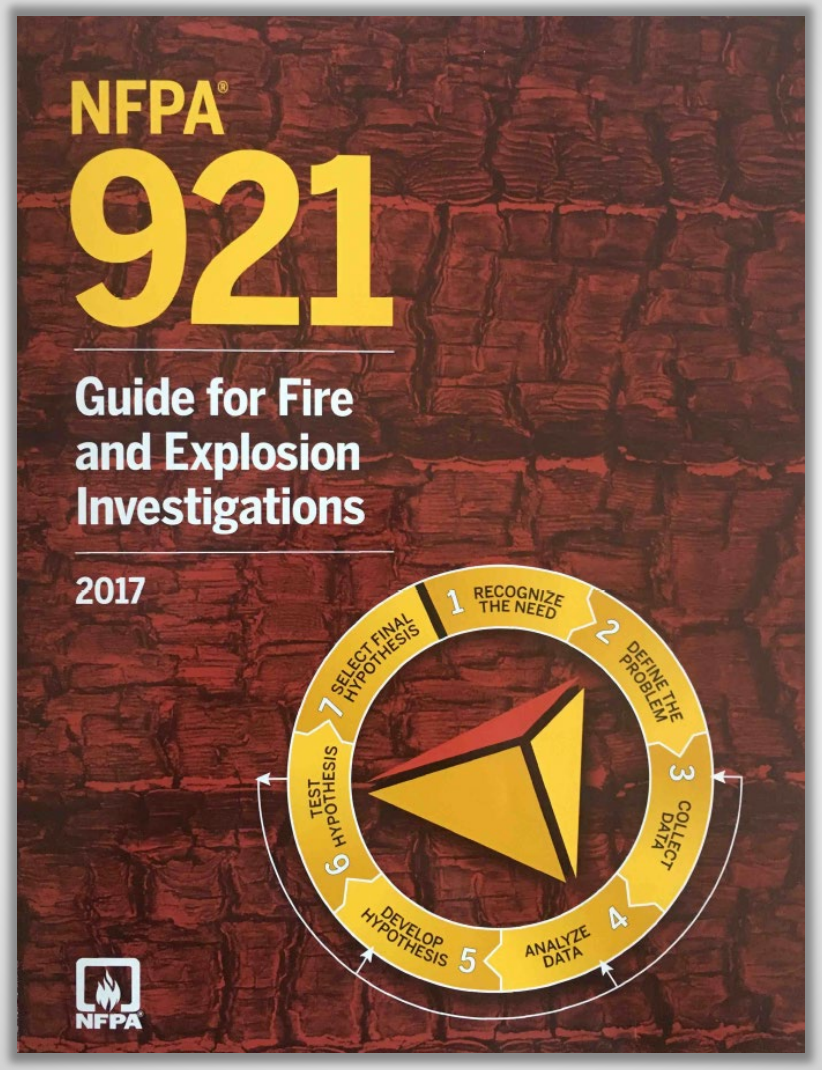
Fire Investigations

Matt Benfer, PE, IAAI-CFI, CFEI, CFEI
Fire Protection Engineer and Fire Investigator

Standards


1033
NFPA® 1033
Standard for
Professional
Qualifications for
Fire Investigator
2014 Edition
NFPA
NFPA®, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02169-7471, USA
An International Codes and Standards Organization

Standards


NFPA®
921
Guide for Fire and Explosion Investigations
2017
1 RECOGNIZE THE NEED
2 DEFINE THE PROBLEM
3 COLLECT DATA
4 ANALYZE DATA
5 DEVELOP HYPOTHESIS
6 TEST HYPOTHESIS
7 SELECT FINAL HYPOTHESIS
NFPA

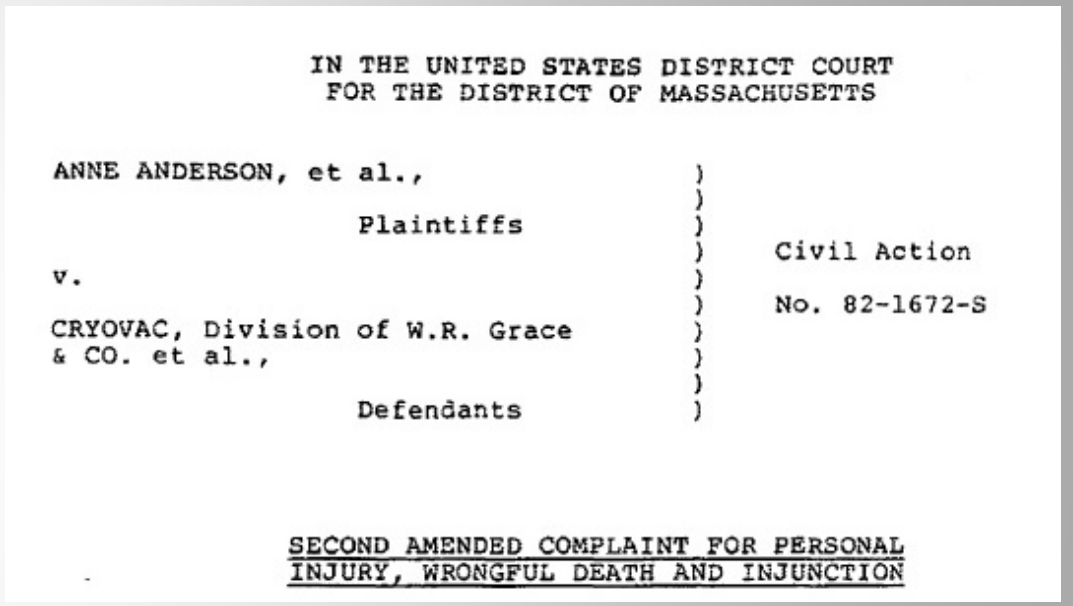
The Scientific Method



Recognize the Need/Define the Problem

- Pre-suit vs. In-suit

- **What** is the cause?
- **Why** did it happen?
- **Who** is responsible?



IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF MASSACHUSETTS

ANNE ANDERSON, et al.,
Plaintiffs

v.

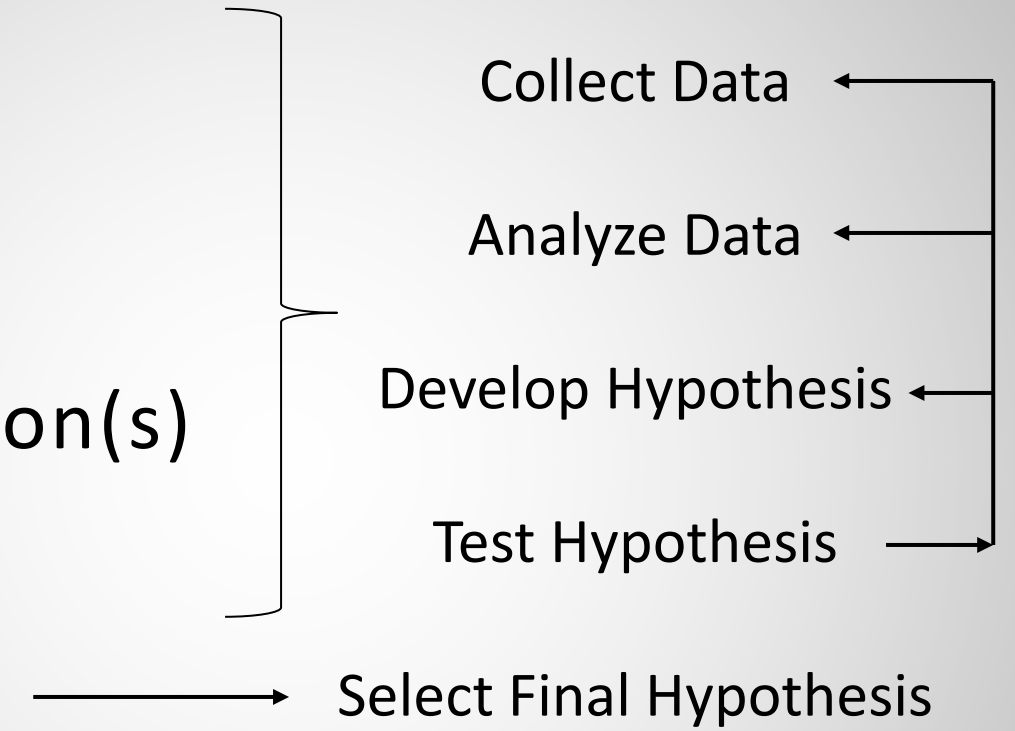
CRYOVAC, Division of W.R. Grace & CO. et al.,
Defendants

Civil Action
No. 82-1672-S

SECOND AMENDED COMPLAINT FOR PERSONAL INJURY, WRONGFUL DEATH AND INJUNCTION

The Investigation

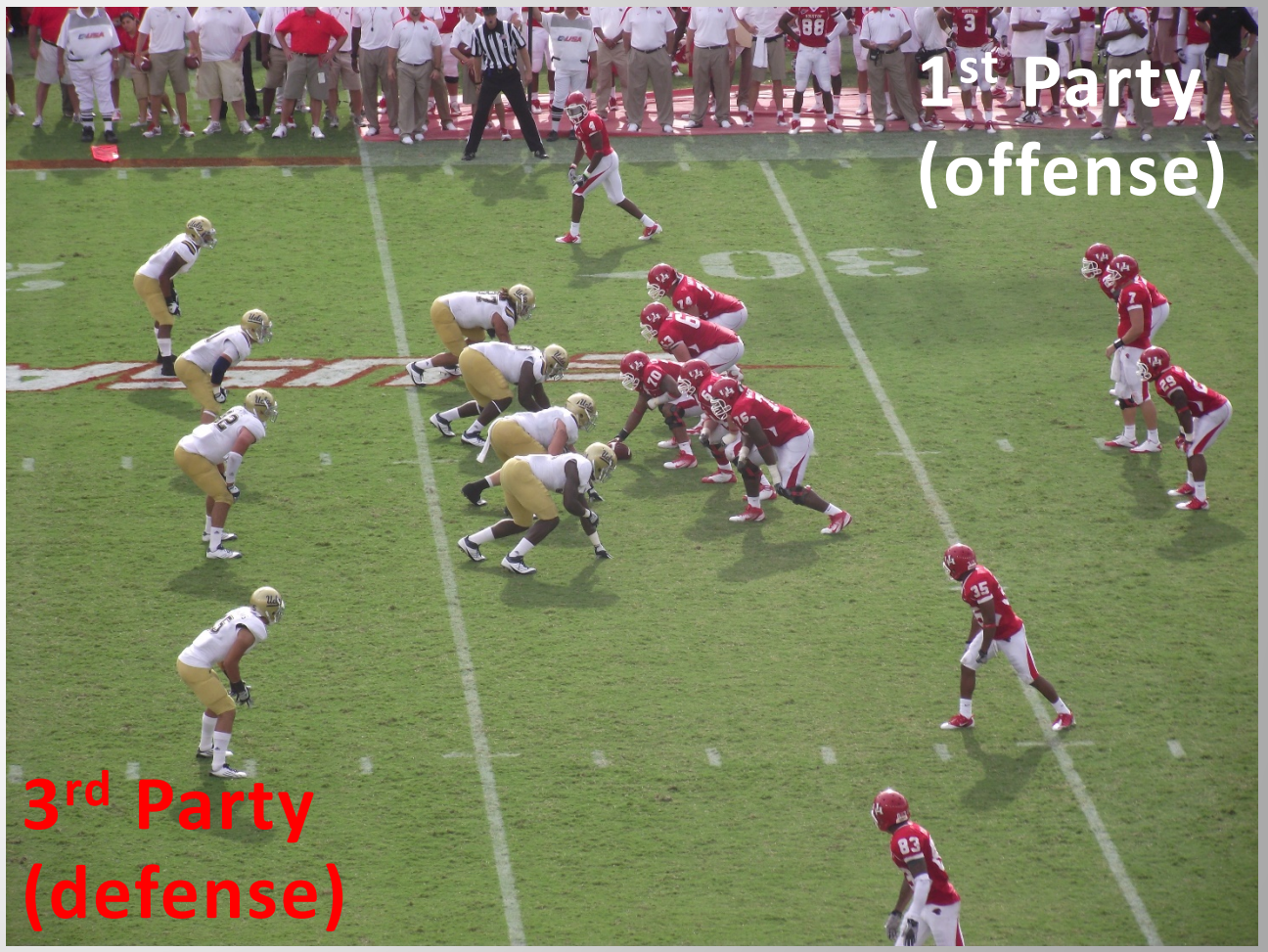
- Site Exam
- Research
- Interviews
- Laboratory Examination(s)
- Testing
- Reports/Testimony



Our Clients

- Insurance companies
- Attorneys
- Business entities
- Government entities

- 1st Party (casualty) or 3rd Party (liability) and sometimes both!



Site Exam - The Parties

- 1st Party (casualty)
  - Property owners
  - Tenants
  - Individuals
- 3rd Party (liability)
  - Could include 1st party entities
  - Product manufacturers
  - Component manufacturers
  - Service companies
  - Installation companies

Each party may have one or more investigators, an adjuster, or an attorney present for each site exam or lab exam.

Origin and Cause



Determining Area of Origin

- Witness information and/or electronic data
- Fire Patterns
- Fire Dynamics
- Arc Mapping***



Witness Information

- Interviews/Depositions
  - 1st hand witnesses of events
  - Owners/users
  - Installers/maintenance personnel
  - The earlier the better
- As a potential defendant/party in a fire loss
  - Provide as much information as possible to your investigator.
  - Never assume information you have is not important to the investigation.



Electronic Data

- Fire alarm records
- Fire incident reports
- Surveillance systems
- Security systems
- Access control
- Social media (facebook/twitter)
- “Smart” devices



Fire Patterns

- "The visual or measurable physical changes or identifiable shapes, formed by a fire effect or group of fire effects."
  - Mass loss of material
  - Deformation
  - Soot deposits
  - Melting, alloying
  - Charring
  - Calcination of gypsum wallboard
  - Oxidation/discoloration



Fire Dynamics

- The analysis of the physics and chemistry of the fire initiation and growth and the interaction between fire and the building's systems
  - Material properties and ignition
  - Flame spread
  - Activation of sprinklers
  - Activation of smoke detectors
  - Affects of windows/doors opening


1778

Arc Mapping

- The analysis of the locations where electrical arcing has caused damage and the documentation of the involved electrical circuits
  - In a building
  - In a room
  - In an appliance

Determining Fire Cause

- Fire Cause: “the circumstances, conditions, or agencies that brought about or resulted in the fire or explosion […]”
  - Competent ignition source
  - First fuel ignited
  - Circumstances that allowed the ignition source and first fuel to come together
- In most cases, you must first determine the area of origin **before** the fire cause

Determining Fire Cause

- Fire investigators work together with other disciplines to evaluate fire causes:
  - Materials scientists
  - Electrical engineers
  - Mechanical engineers
  - Fire protection engineers



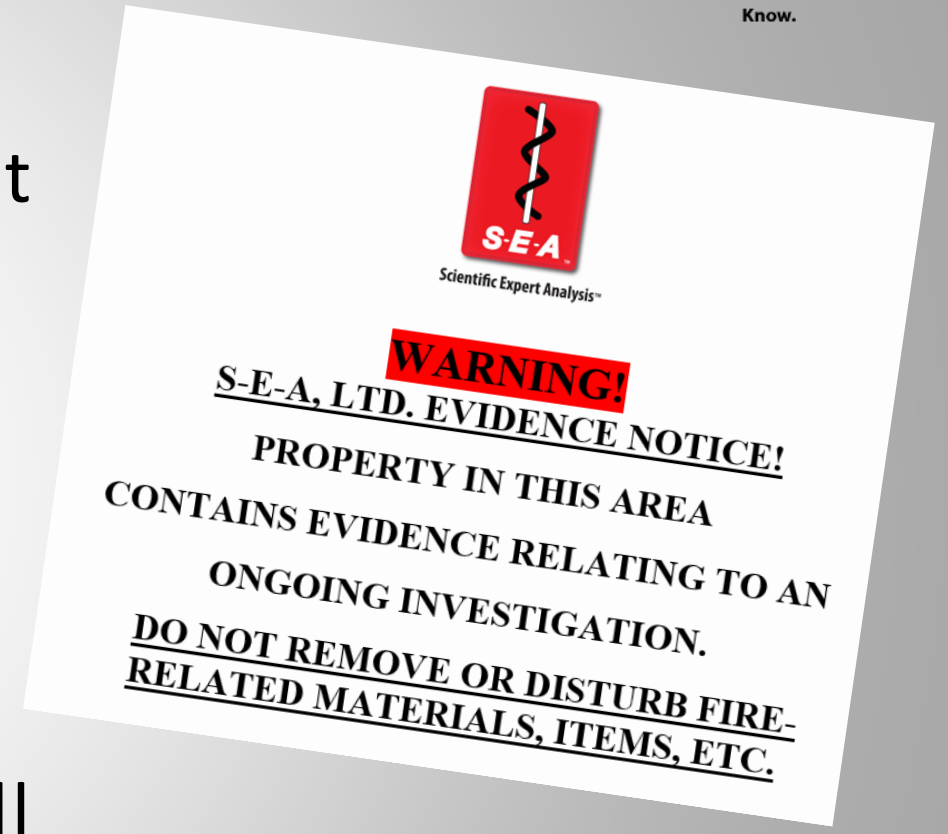


Determining Responsibility

- We are often asked to evaluate more than just the origin and cause of the incident.
- Did a human act contribute to the fire cause?
  - Improper installation
  - Improper design
  - Improper maintenance
  - Willful manipulation
- Did a human act contribute to bodily injury/death, increased damage/fire spread?

Spoliation

- "Loss, destruction, or material alteration of an object or document that is evidence or potential evidence in a legal proceeding by one who has the responsibility for its preservation."
- This could mean YOU!
- Most of our investigative activities are aimed at preventing spoliation unless all known parties agree.



QUESTIONS OR COMMENTS

CASE STUDY

Case Details

- Multi-Unit Hotel used as housing for seasonal employees
- Building hadn’t been used for 4 months
- No one in the building or balcony area in a few days, but maintenance did regular rounds
- Neighbor spotted smoke around 8AM and called 9-1-1
- First sign of fire seen outside and to the right of sliding glass door for Unit 408



General Area of Origin Determination

- Witness Statements
  - Smoke seen outside Unit 408
  - First flames to the right of the sliding glass door for Unit 408
  - Fire department photos upon arrival showing flames next to Unit 408 sliding glass door
- Fire Patterns
  - Minimal damage to the interior of Unit 408
  - Full involvement of exterior balcony on second floor
  - More charring outside to right of door
  - Thick wood siding/roofing materials



Area of Origin Determination

- At this point, a general area of origin was determined: **Unit 408 exterior wall and its balcony**
- Allows us to start looking at ignition sources/scenarios



Potential Ignition Sources

- Outside
  - Exterior sconce to the right of the sliding glass door
- Inside
  - PTAC unit and plug/outlet
  - Smoking Materials
- POLL



(Carelessly Discarded) Smoking Materials

Unlikely

- Potential first fuel(s) ignited
  - Interior: carpet, bedding materials
  - Exterior: decking, thick wood siding
- Hypothesis Testing
  - Witness Information:
    - Nobody in room at time of fire or in a few days before
    - Nobody in building at time of fire or in a few days before
  - Fire Patterns:
    - Minimal damage to interior and to potential first fuels ignited inside
  - First Fuel Ignited (outside):
    - Difficult to ignite wood decking and thick wood siding with cigarettes
    - No other visible fuel outside (e.g., trash, piles of leaves)



Exterior Sconce

- Potential first fuel(s) ignited
  - Wiring Insulation, decking, thick wood siding
- Hypothesis Testing
  - Witness Information:
    - Smoke first observed outside Unit 40
    - Fire first observed to the right of the sliding glass door
    - Unknown if sconce was present, but unlikely
  - Fire Patterns:
    - Minimal damage to interior
    - Most of the damage concentrated outside/above sconce
  - First Fuel Ignited:
    - Difficult, not impossible to ignite siding with sconce

Possible



PTAC Unit and Plug/Outlet

- Potential first fuel(s) ignited
  - — Wiring Insulation, wood wall stu[illegible]
- Hypothesis Testing
  - — Witness Information:
    - Smoke and fire first ob[illegible]
    - PTAC set to he[illegible] 40/50 °F
  - — Fi[illegible]
    - M[illegible]
    - Wo[illegible]
  - — First [illegible] Ignited:
    - Difficult to ignite wood studs/siding, but not impossible with PTAC or the outlet

Possible

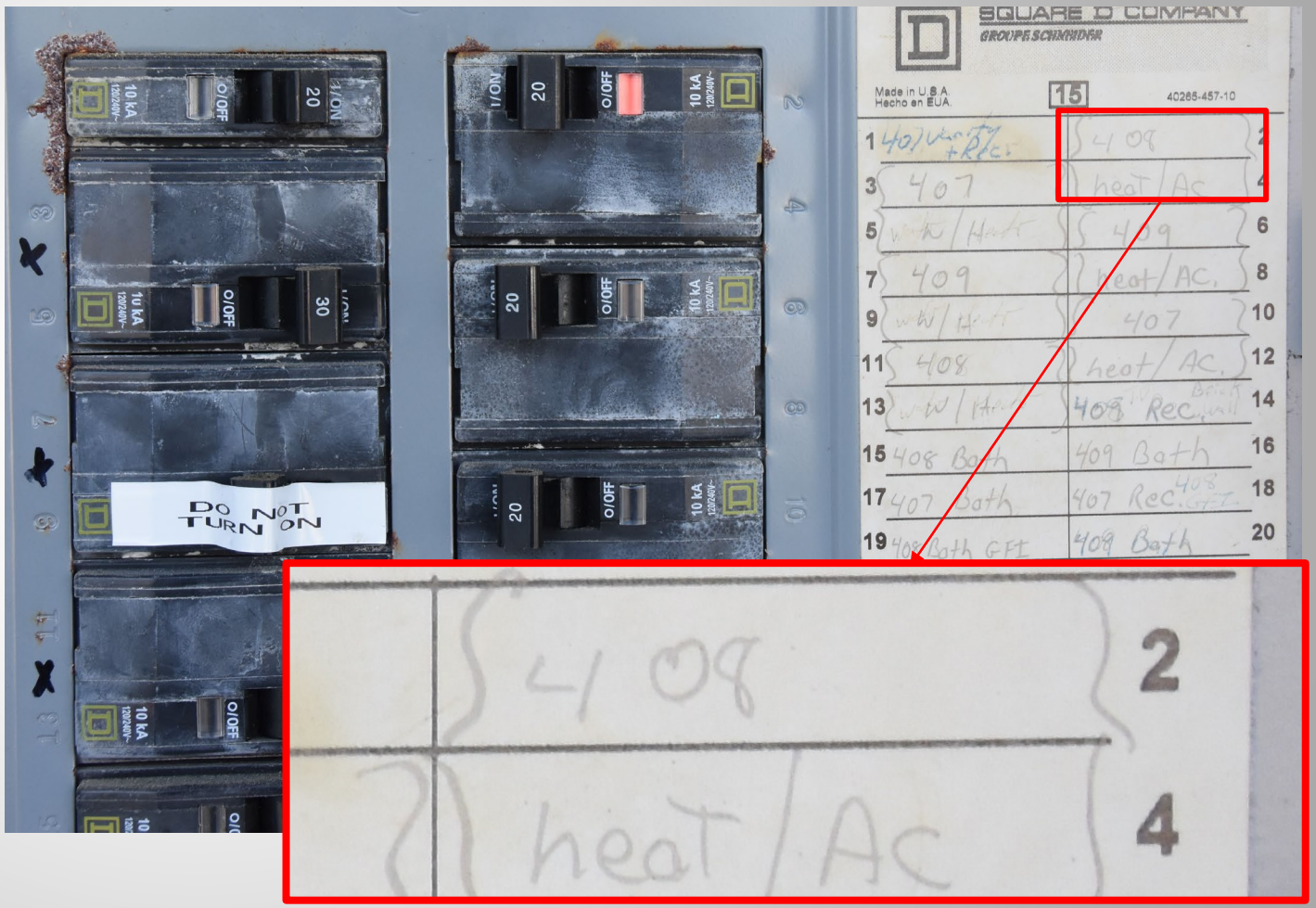


Next Steps



Main Panel – Unit 408

- The only circuit breaker that was tripped was the 2-pole, 20A breaker for Unit 408's PTAC
- No other circuits tripped



Exterior Sconce

- Damage to wiring and box minimal
- Damage to fiberboard insulation minimal
- Circuit breaker did not trip

Unlikely



PTAC Unit

- Damage to internal components minimal
  - Control panel damage minimal
  - Compressor damage minimal
  - Fan motor damage minimal
- Exterior damage to shroud concentrated near outlet
  - Not near any internal circuits/electrical sources
- Circuit breaker tripped





Unlikely

PTAC Plug/Outlet

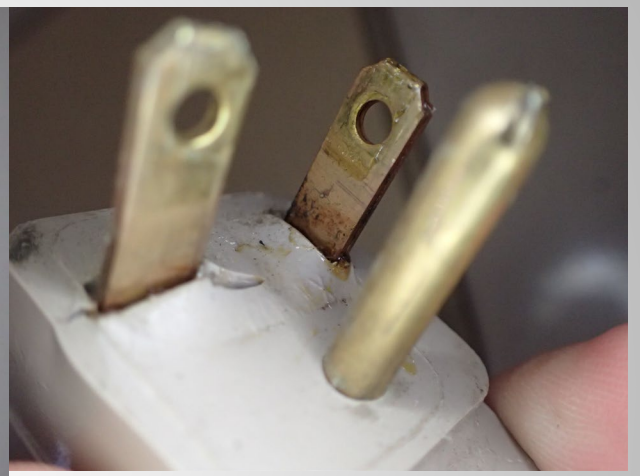
- Significant charring and loss of material for wood studs near outlet
- Plastic components of outlet completely consumed
- Circuit breaker tripped
- Oxidation of internal contacts of receptacle
- Damage to plug on side facing outlet



What about PTAC in other Units?









QUESTIONS OR COMMENTS

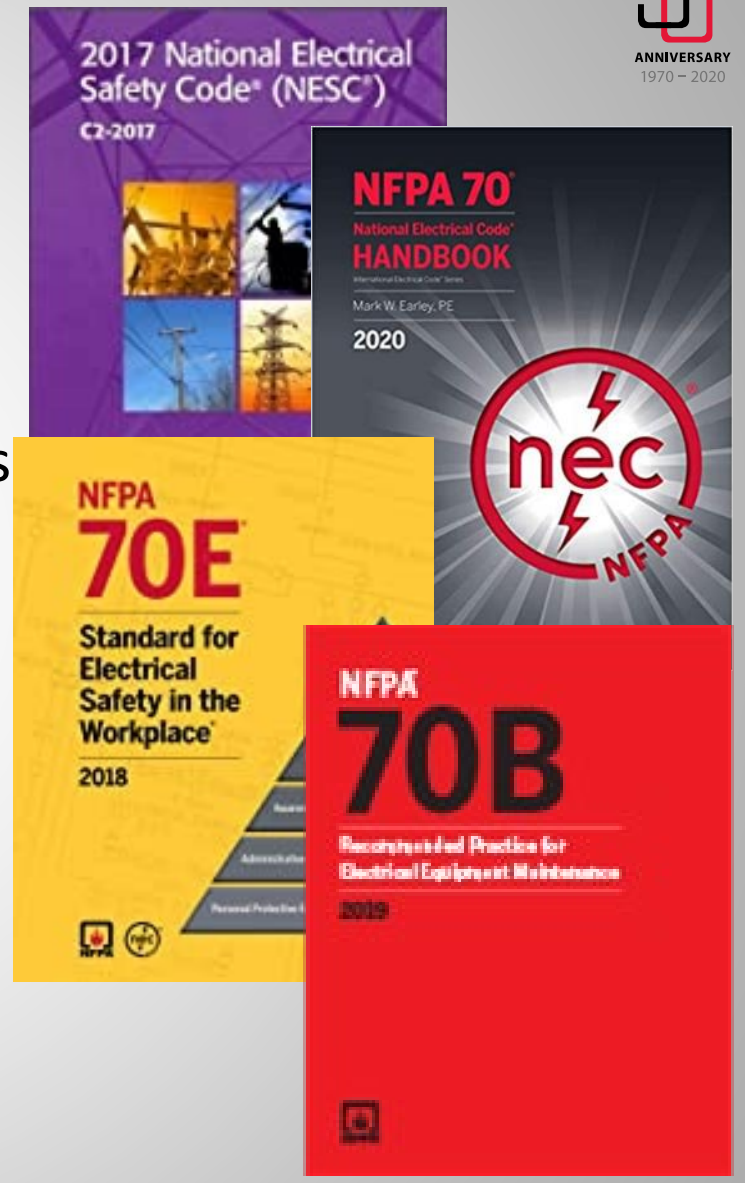
ELECTRICAL & CONTACT CASE INVESTIGATIONS

Robert A. Neary, PE, CFEI
Senior Electrical Engineer
Licensed Master Electrician (MD & VA)

Codes & Standards

Primary Reference Materials

- NFPA 921 – Guide for Fire & Explosion Investigations
- NFPA 1033 – Standard for Professional Qualifications for Fire Investigator
- NFPA 70 – National Electrical Code
- NFPA 70B – Recommended Practice for Electrical Equipment Maintenance
- NFPA 70E – Electrical Safety in the Workplace
- IEEE – C2 – National Electric Safety Code
- Public Service or Utility Commission Tariffs
- ASTM – E860 & E1199 Evidence Standards



Electrical Basics

Electrical Circuit Fundamentals

- DC – Direct Current Circuits
  - Current flow in one direction.
  - Batteries & Generators

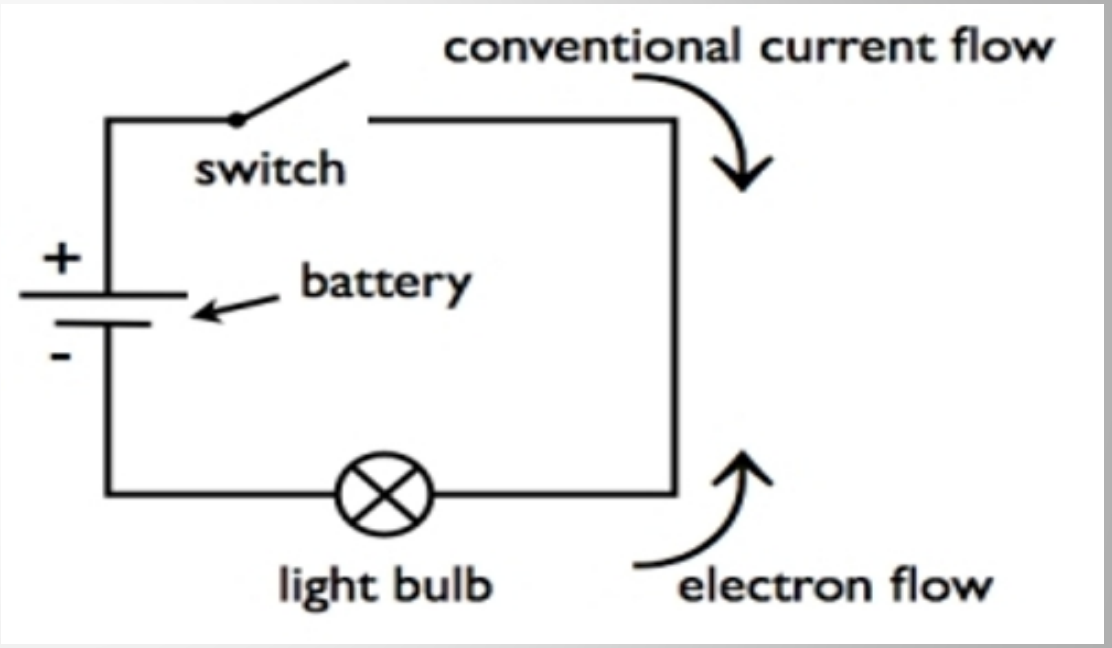
Ohm's Law E = IR, P = IE

E - Voltage (Volts)

I – Current (Amperes)

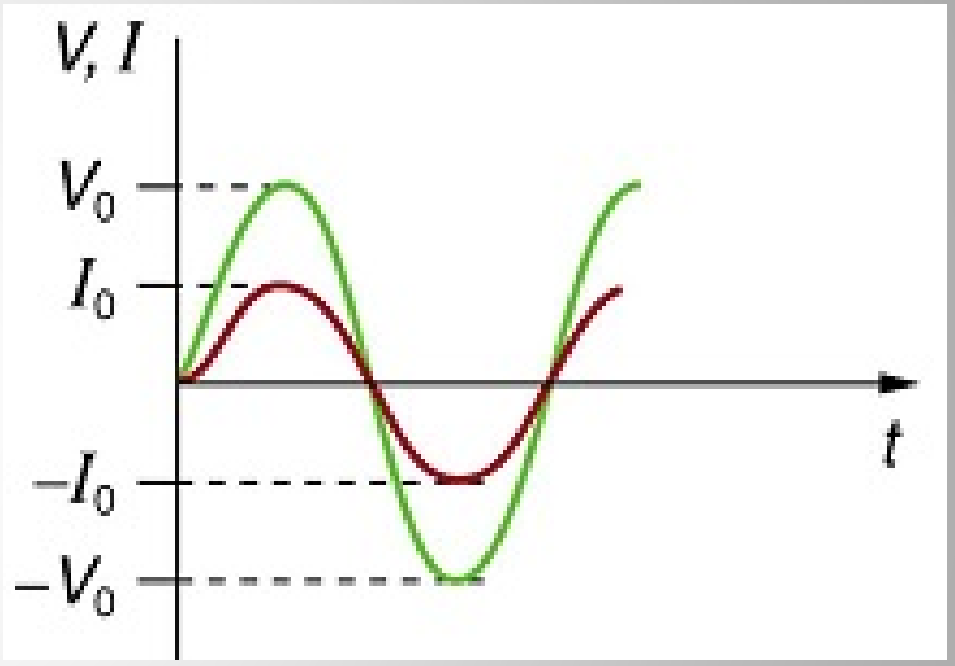
R - Resistance (Ohms)

P – Power (Watts)



Electrical Basics

- AC – Alternating Current Circuits
  - Current alternates in two directions.
  - Inverters & Alternators



Ohm's Law - E = IZ, P = EI(pf)

E = Voltage, I = Current,

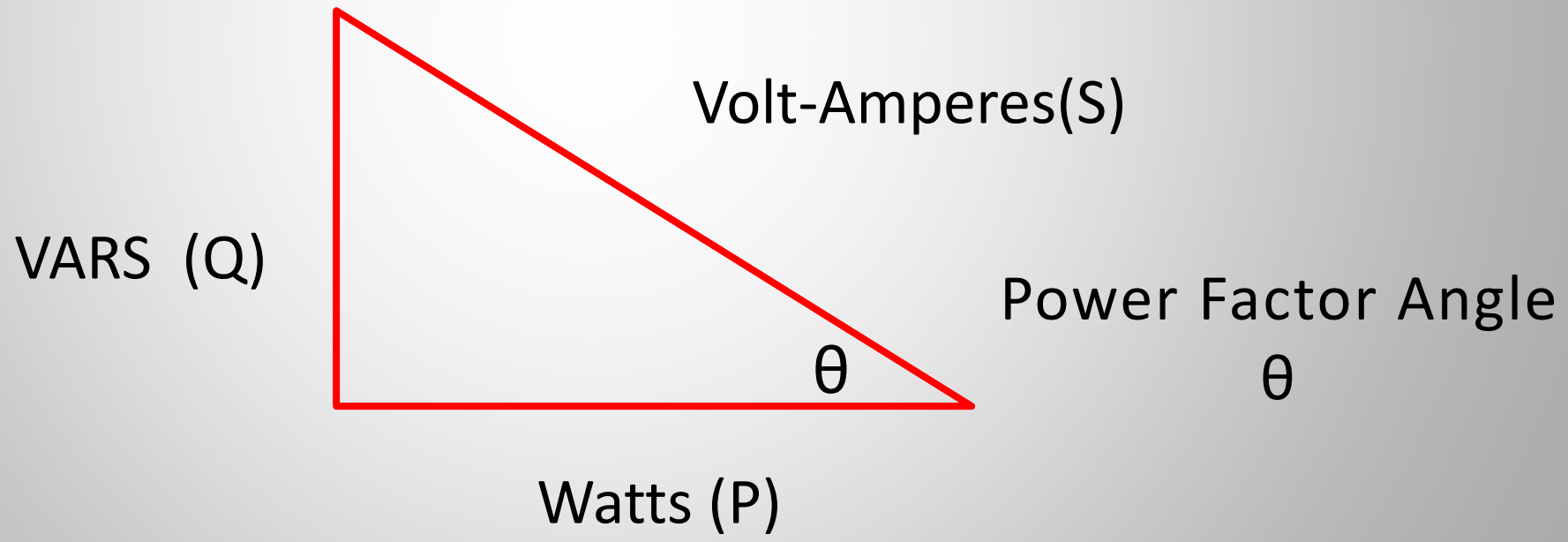
P = Volt-Amperes, Watts, VARs

Z = Impedance = Resistance + Reactance

R + j(X)

Electrical Power Fundamentals

- Pf = Power factor = Power(W)/Power(VA)
- Frequency = Hertz
- Reactance (Ohms) is Capacitive (Farads) and Inductive (Henrys).
- Reactance is frequency dependent



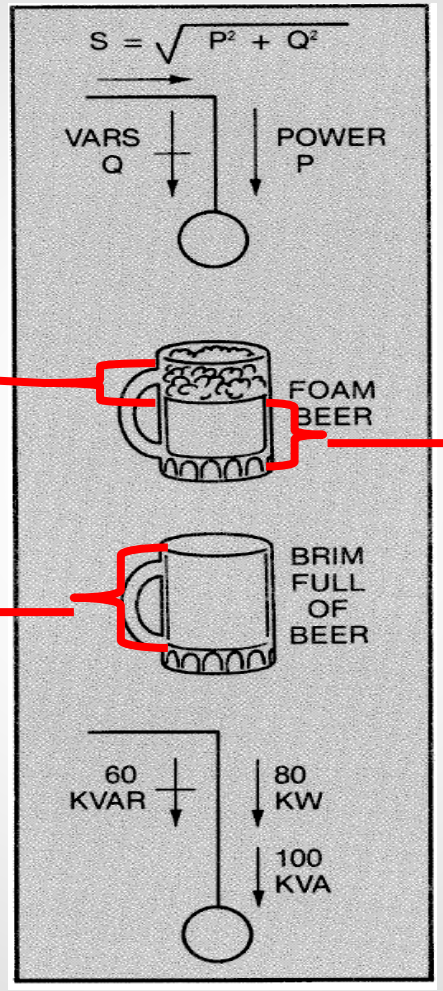
Electrical Power Fundamentals

Volt-Amperes Reactive

(Q) VARS

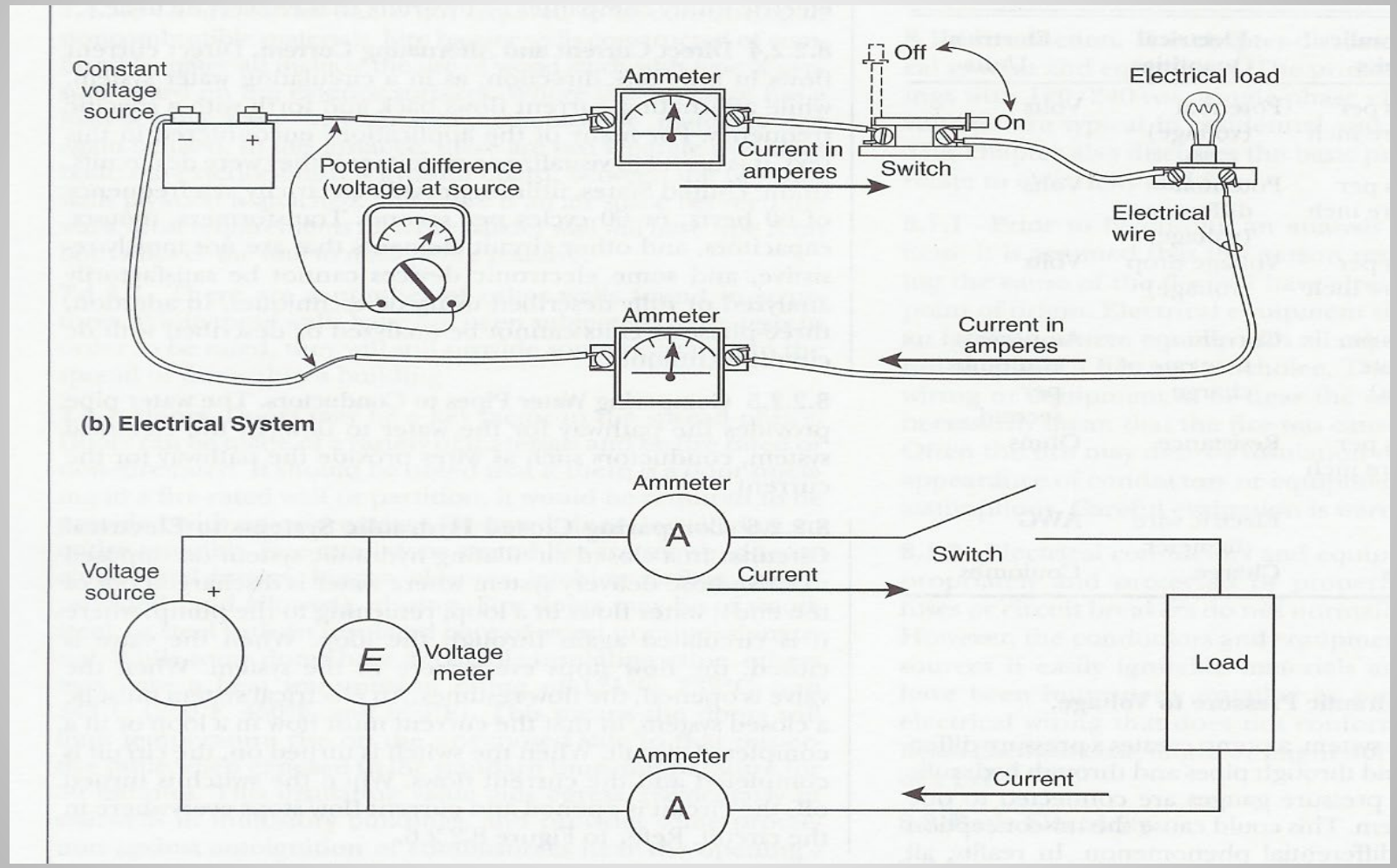
Kilovolt-Amperes kVA

(S)



Kilowatts – kW (P)

Electrical Power Fundamentals

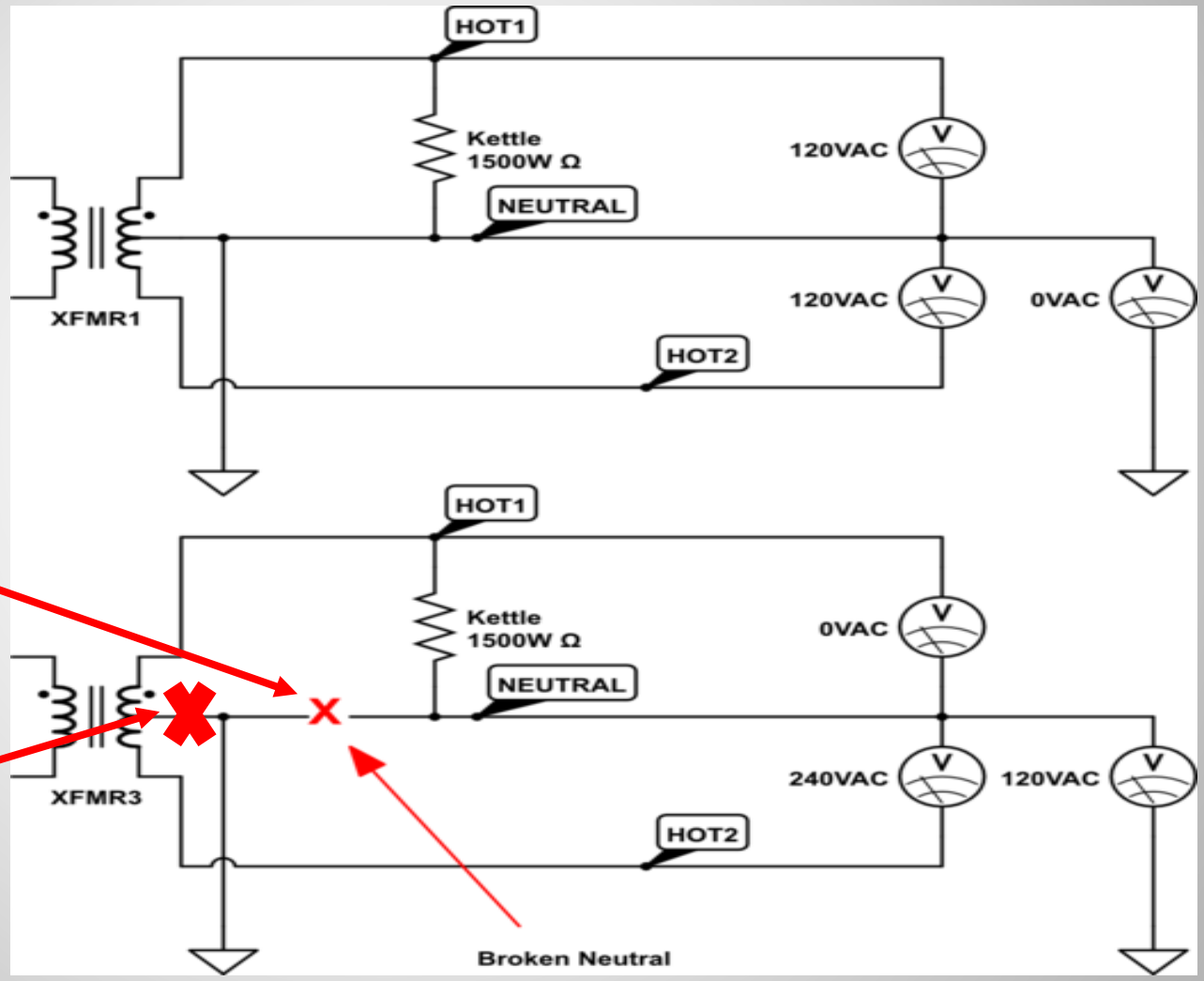


Electrical Power Fundamentals

Normal Operation

Open Neutral
Customer Side

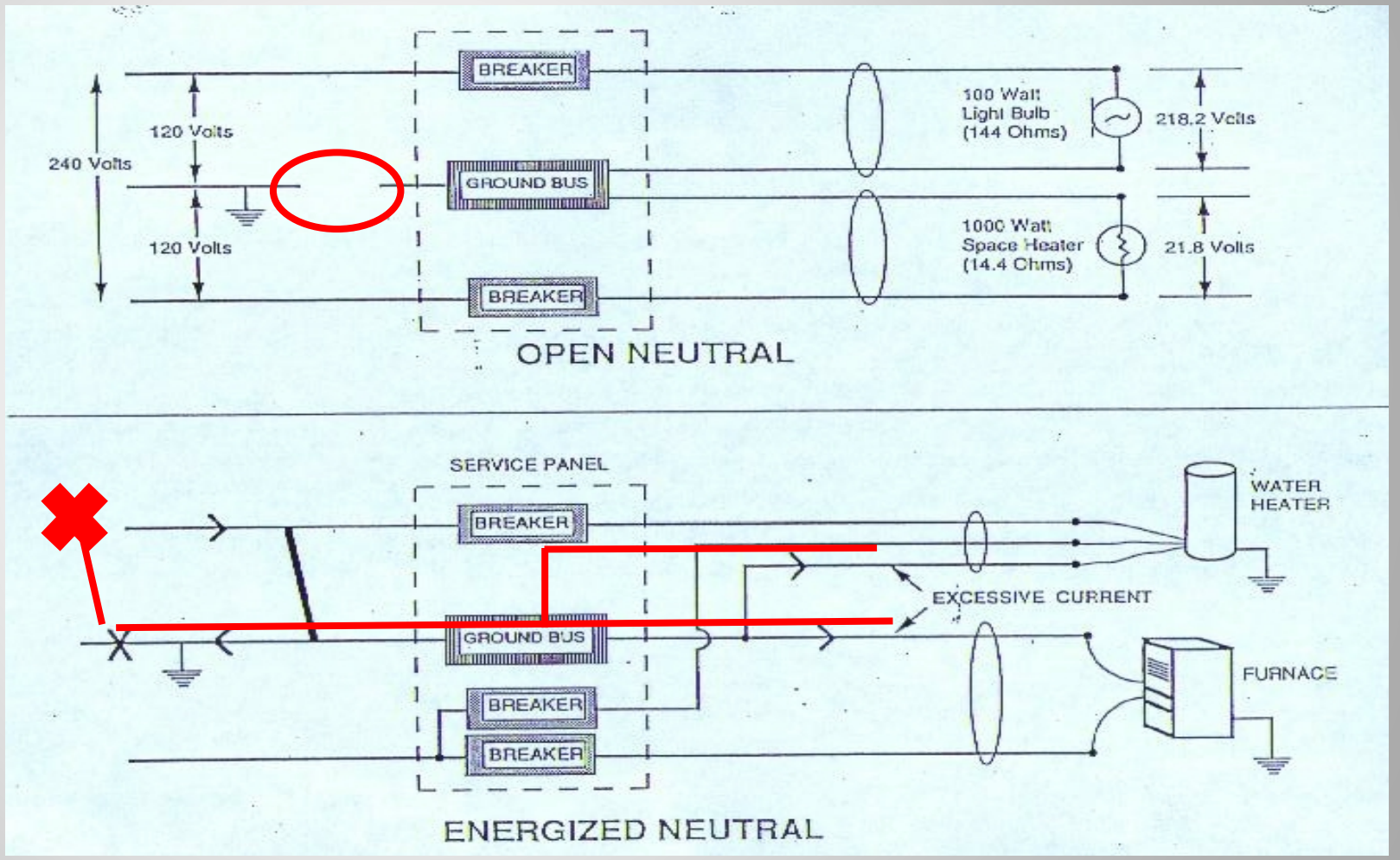
Open Neutral
Utility Side



Electrical Power Fundamentals – Neutral Failures

- No fixed voltage reference
- Voltage of each leg depends on the loads
- “Dim or bright lights”
- “Malfunctioning appliances”

- Neutrals & Grounds become energized.



Typical Overhead Utility Transformer Pole

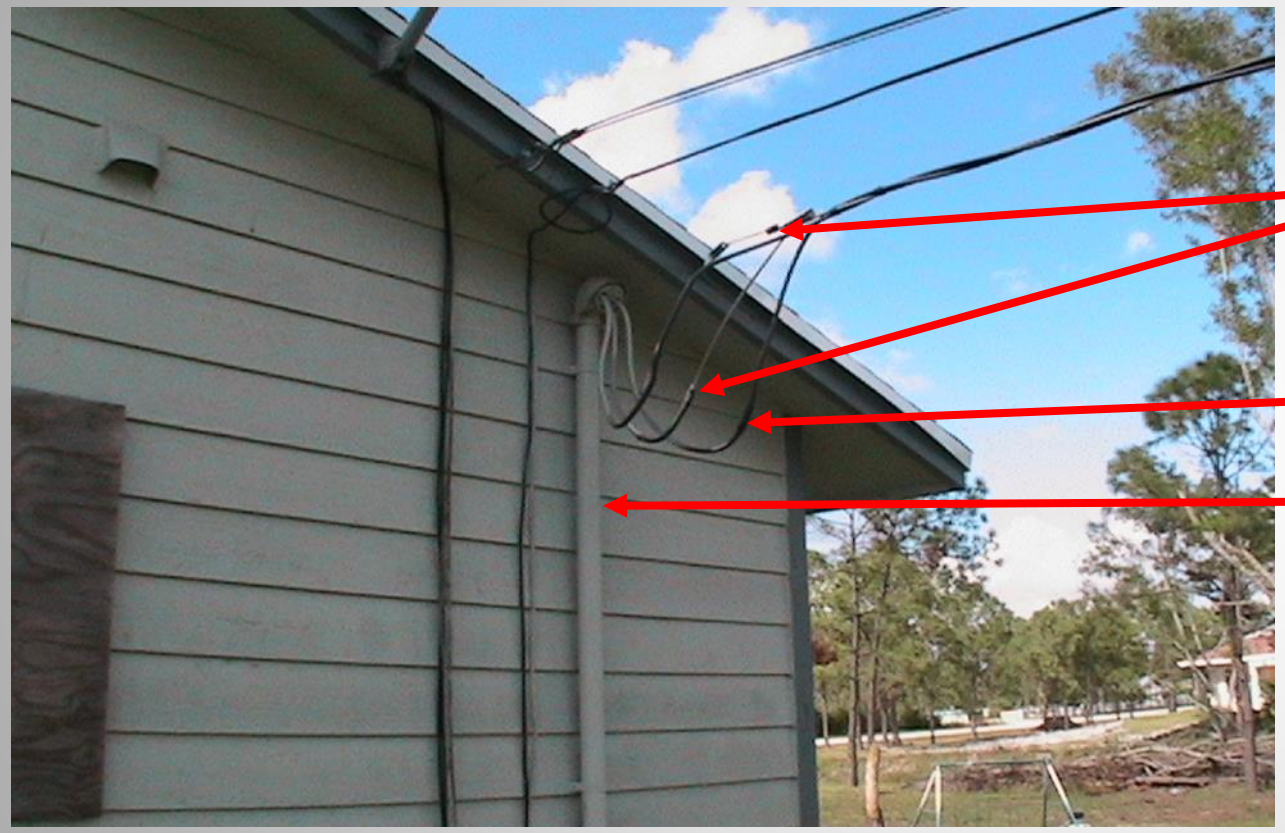


Typical Overhead Utility Transformer Pole





Typical Overhead Service Attachment



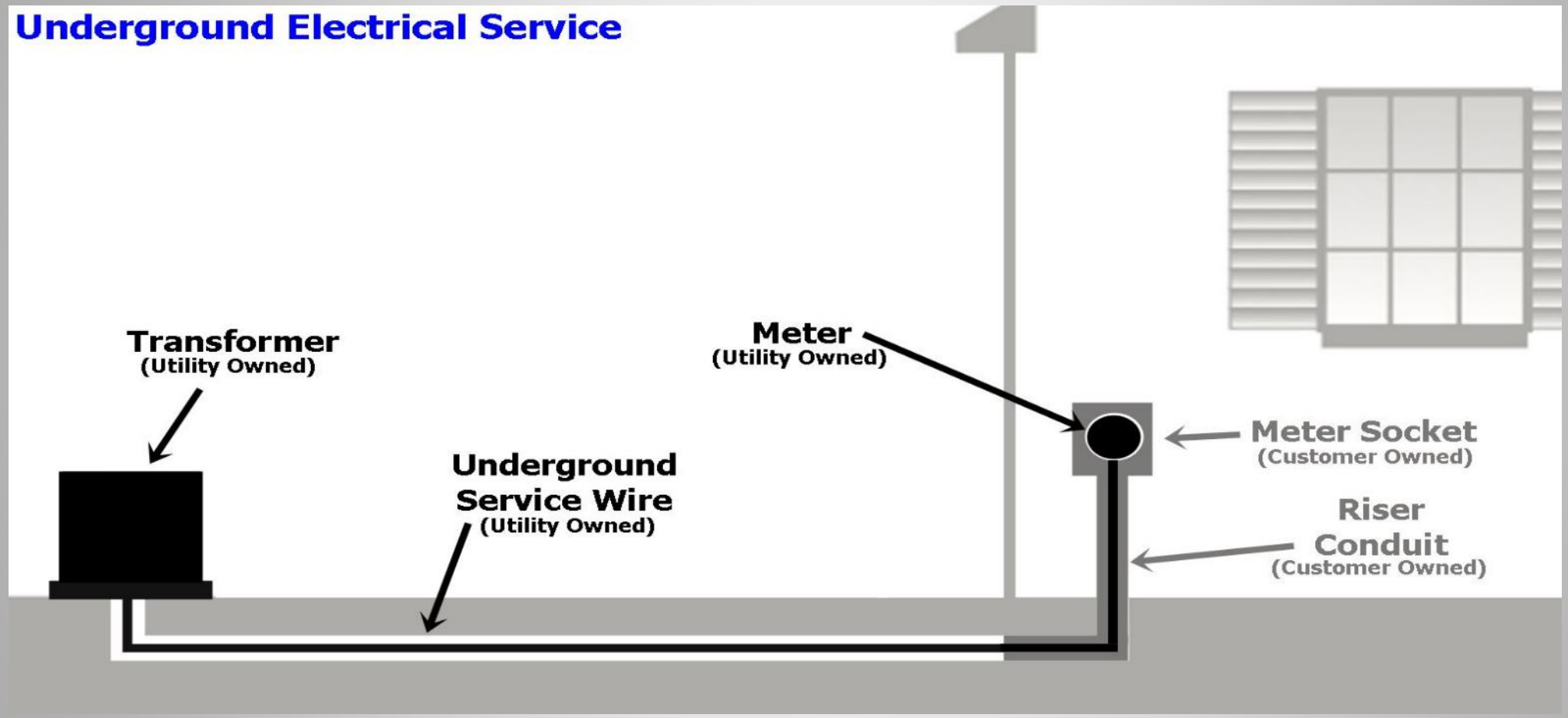
Point of Attachment

Drip Loop

Customer Service Entrance Conduit or Cable (SEC)

NOTE – Most (> 95%) overhead utility ownership stops at the point of attachment, except for meter itself

Typical Underground Service Entrance



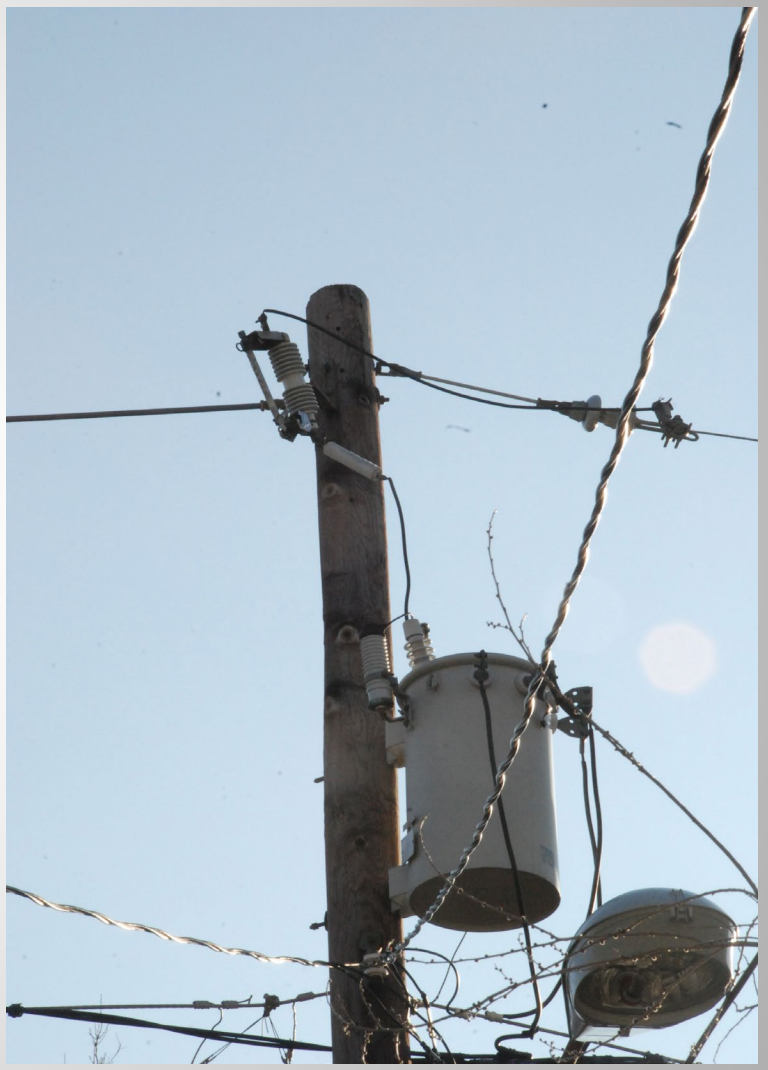
Electrical Failures

- Major Causes of Electrical Failures and Fires
  - Improper Installation
  - Overcurrent Protection Failure
  - Deterioration and/or Age
  - Lack of Maintenance
    - Equipment Failure
    - High Resistance (Loose) Connection



Electrical Failures

- Was It a Power Surge?
  - Term widely misused
  - Other services/locations impacted
  - Lightening
  - Utility equipment failure
  - Utility error



Electrical Failures

- Was it a Fault Condition?
  - Service
  - Feeder or Bus Duct
  - Branch Circuit
  - Improperly Rated Equipment (AIC Rating)
    - Ampere interrupting capacity
    - Main service equipment must be rated for electric utilities' available fault current



Electrical Failures

- Was It a Neutral Failure?
  - Service Entrance Conductors (SEC)
  - Utility System
  - Loose Connections
  - Neutral/Ground Bar



Electrical Failures

- Was it Overloaded?
  - Properly Sized Electric Service



Electrical Failures

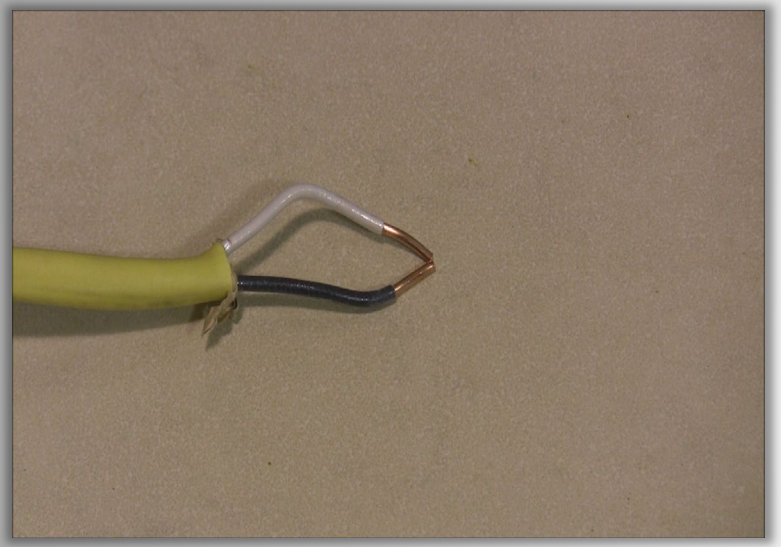
- Was it an Improper Installation?

1. Design Deficiency
2. Workmanship
3. Code Compliance





Electrical Failures – Short Circuits







CSST Failures

- Corrugated Stainless Steel Tubing
- Plumbers Love It – Great Product
- One BIG Problem – Lightening
- CSST Manufacturers – Required Bonding after 2006
- NFPA 54 – Required Bonding Manifold Direct to Ground Rod
- NFPA 70 – Code Making Panel No. 5 Did Not Require Bonding
- NFPA 54 – No One on Technical Committee had Electrical Experience when Decision was made

CSST Failures





CSST Failures





CSST Failures



Appliance Failures

- All structures contain various types of electrical appliances:
  - Ranges and Cooktops
  - Refrigerators
  - Coffee Makers
  - Exhaust Fans
  - HVAC Systems
  - Light Fixtures and Lamps
  - Electronic Equipment usually connected to a Plug Strip/Power Tap

Appliance Failures

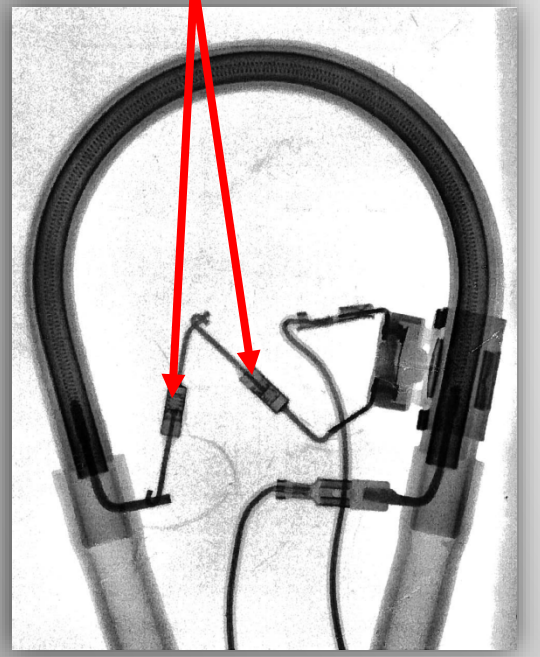
- Typical Components of Appliances
  - Switches – Toggle & Centrifugal
  - Thermostats
  - High Temperature Limit (HTL)
  - Thermal Cut-offs (TCO) or Thermal Fuses
    - One Time Operation – Usually Thermal Fuse
    - Resettable – Usually a TCO will reset when the Appliance cools down
  - Timers

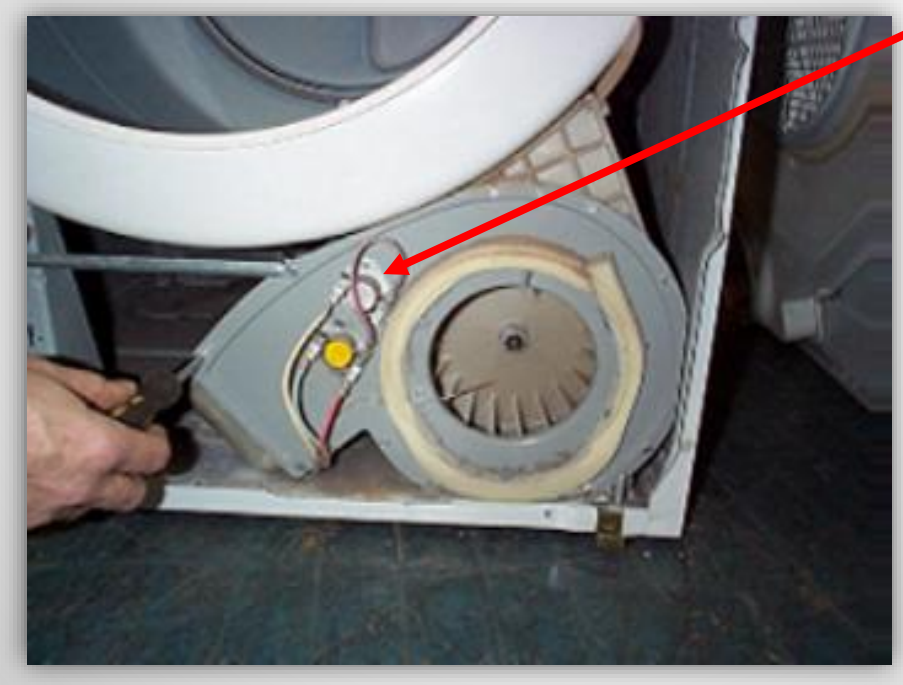
Appliance Failures

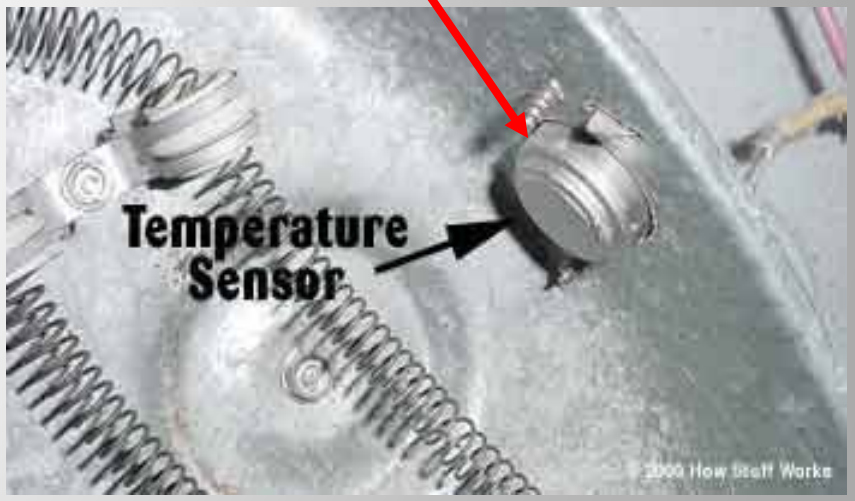
Thermal Cut-Offs (TCOs)

One Shot

Resettable







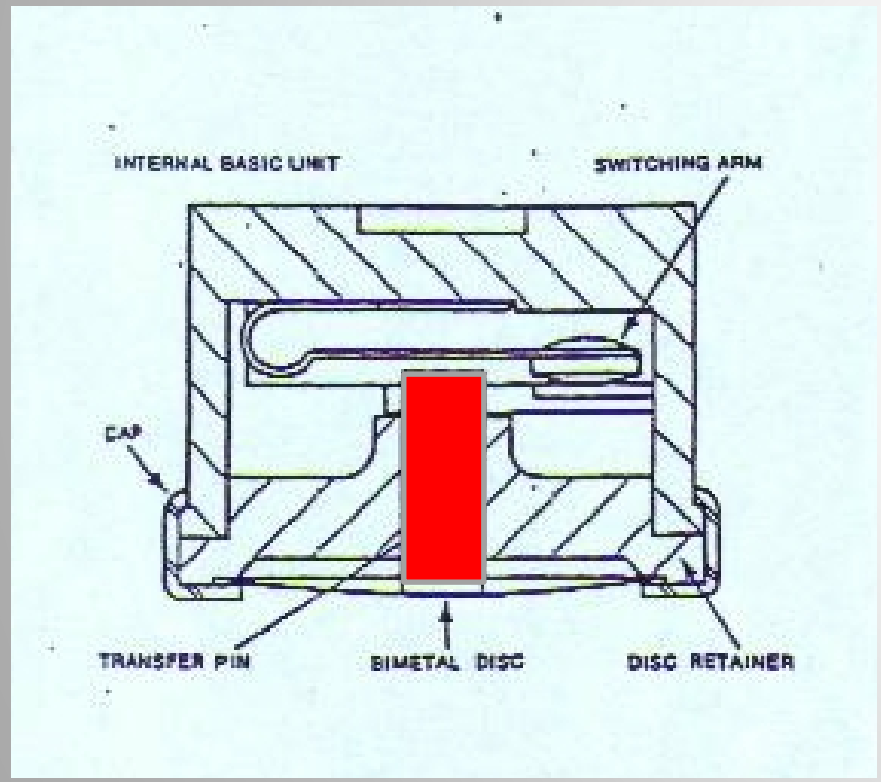
Coffee Maker

Dryer Blower Fan

Dryer Heating Element

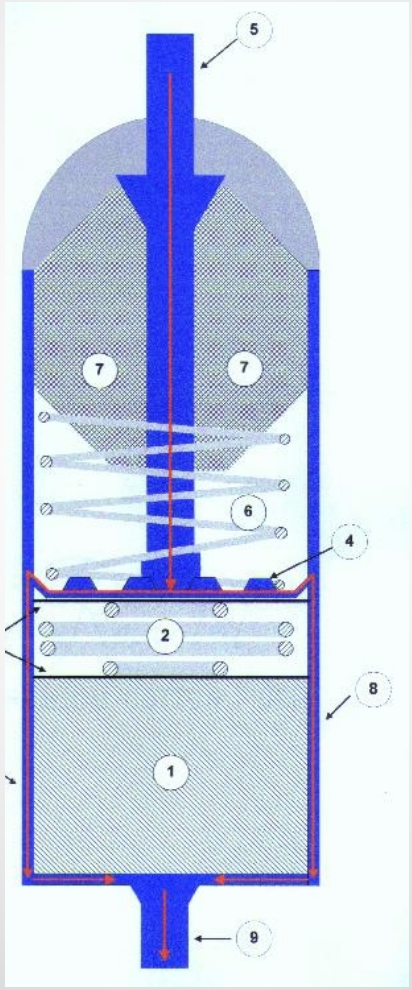
Appliance Failures

Self Resetting

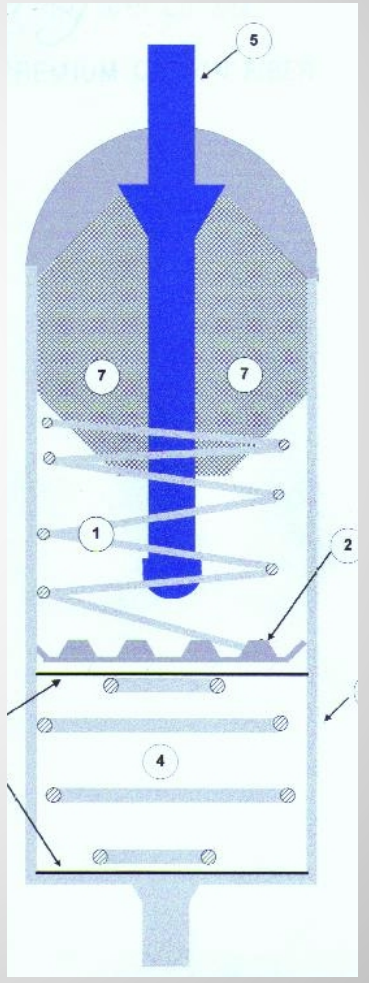


One Shot

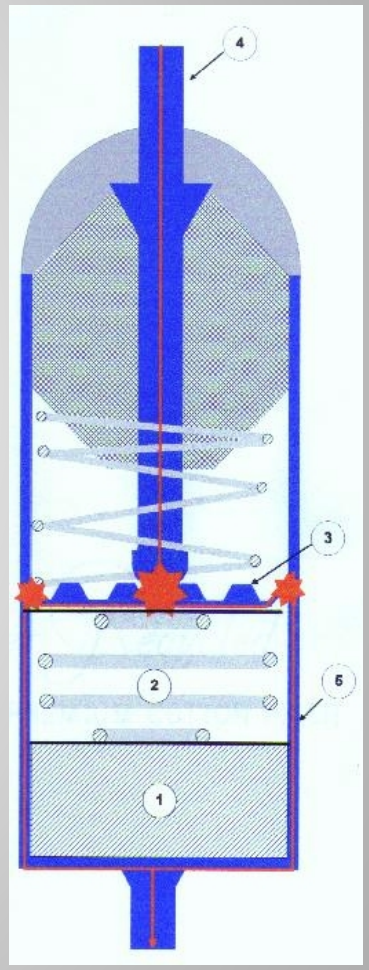
Normal



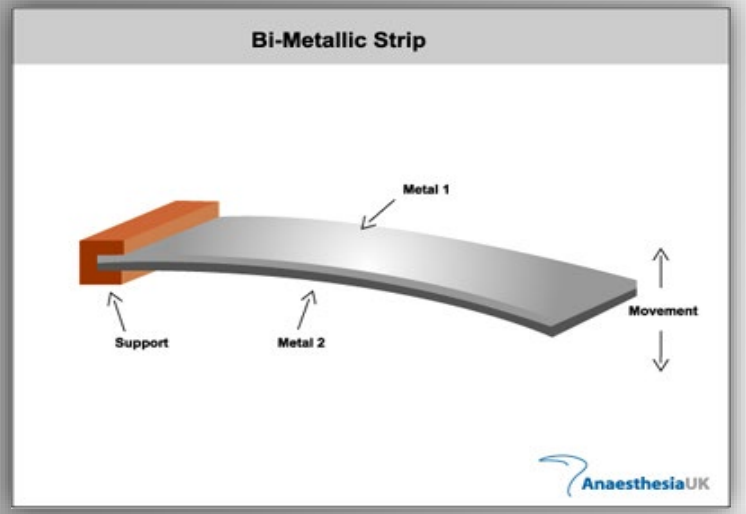
Activated

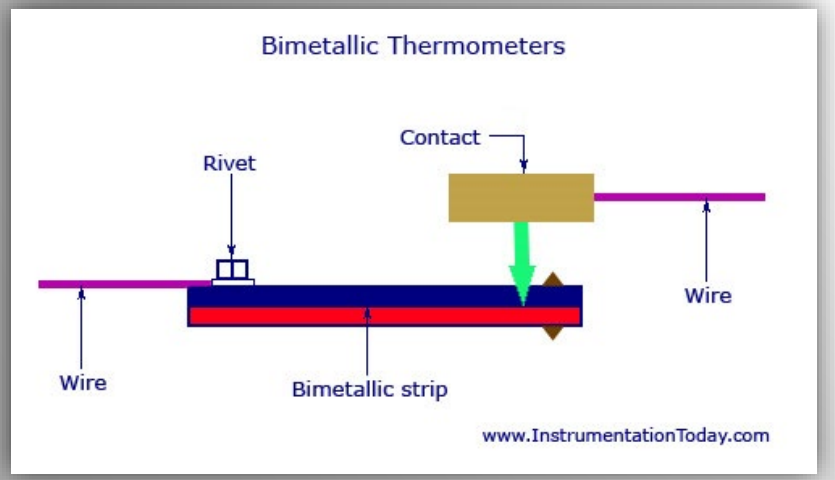


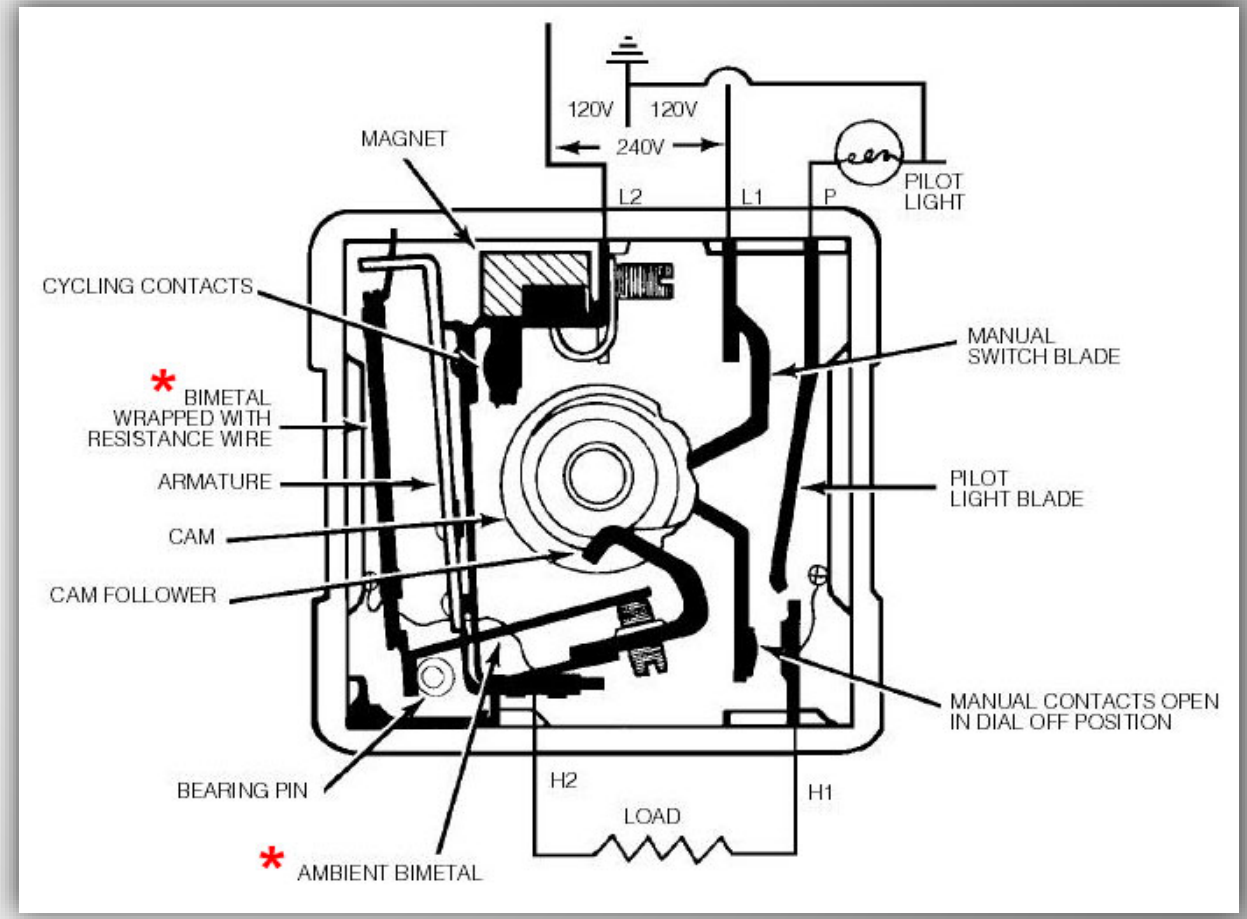
Abnormal



Appliance Failures



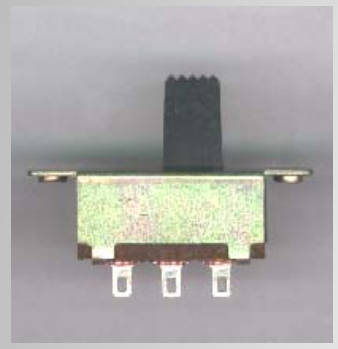


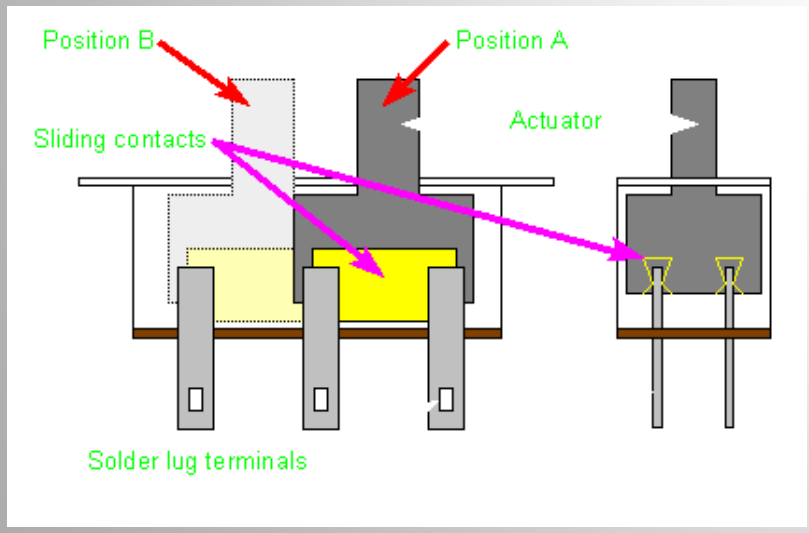


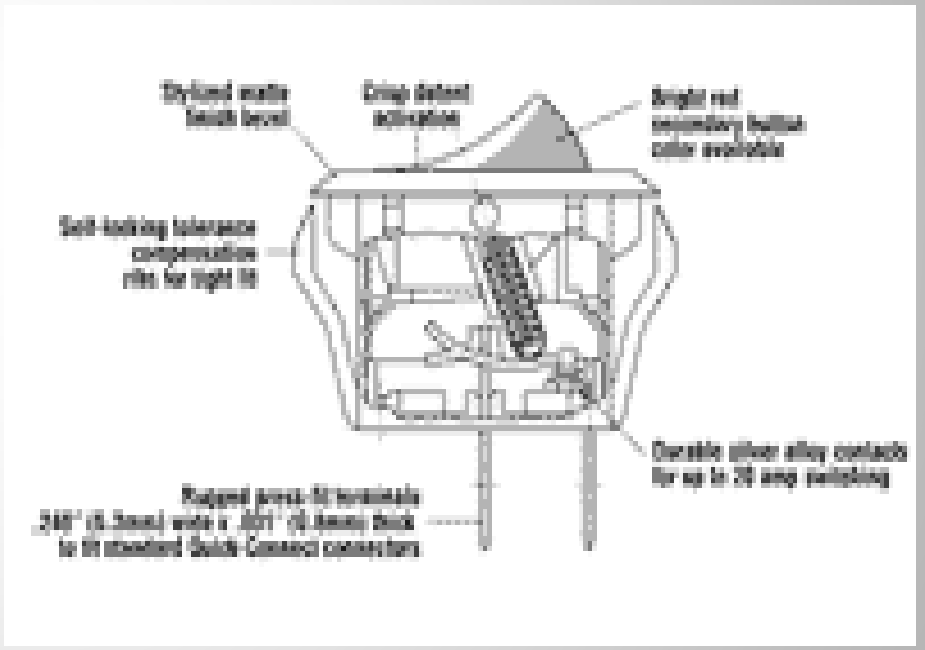
Infinite Control – Range Heating Element

Appliance Failures

- Switch Components







Electrocution, Shock, & Arc Flash Investigation

- Investigations
  - OSHA (DC, DE, NJ) or in MD & VA are conducted by the state
  - Workman's Compensation Insurance
  - Representatives of Injured or Deceased
  - Acquire public investigator files through FOIA requests
  - Preservation of evidence of utility facilities
  - Witness statements
  - Scene documentation –
    - Photographs, Notes, Scanning, Drones



Electrocution or Shock (Contact) Cases

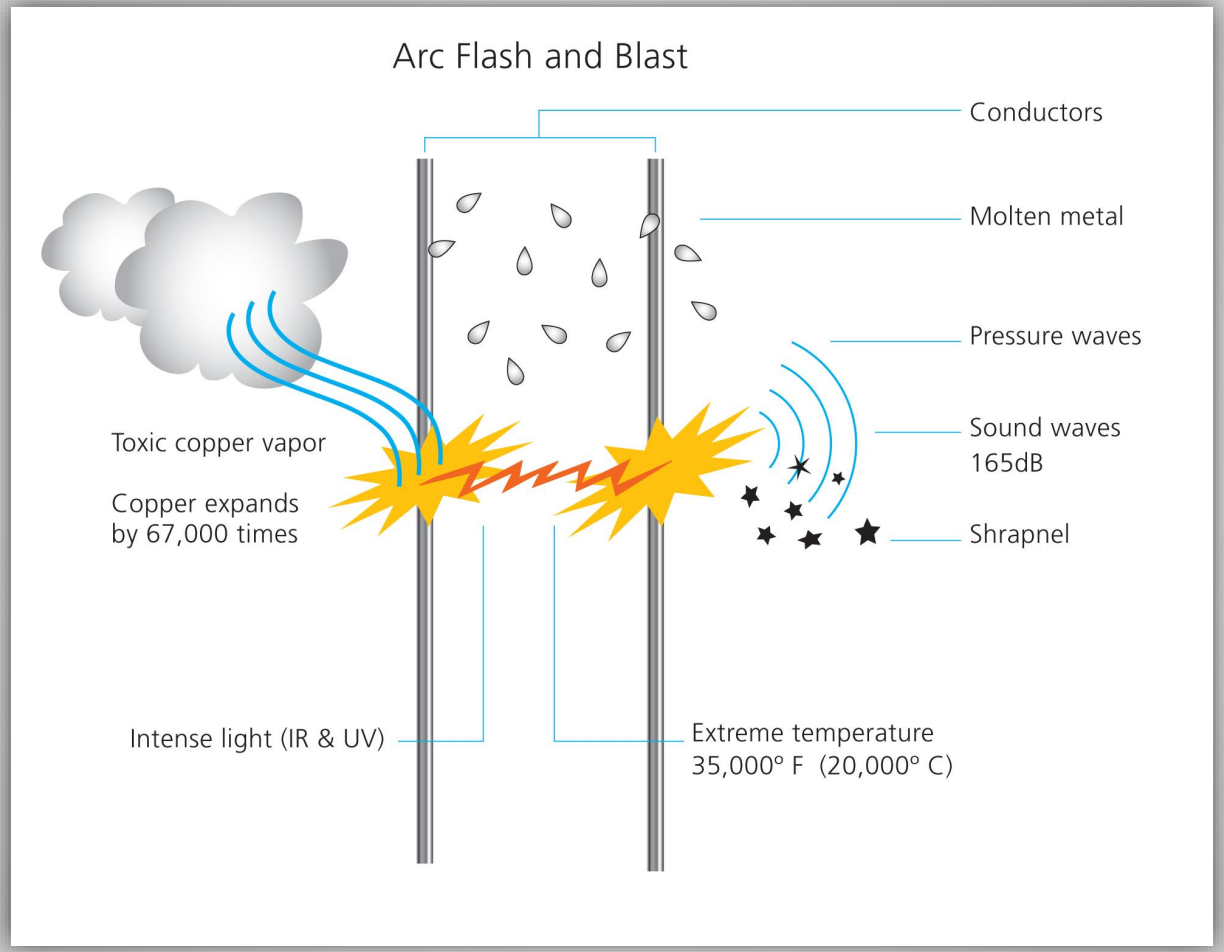
- Identify All Parties Involved
  - Victim – Adult or Minor
  - Employer or Self-Employed
  - Qualified Employee (NFPA 70E & OSHA)
  - Agency responsible for the investigation
  - Witnesses - Statements



Electrical Failures – Arc Flash/Arc Blast

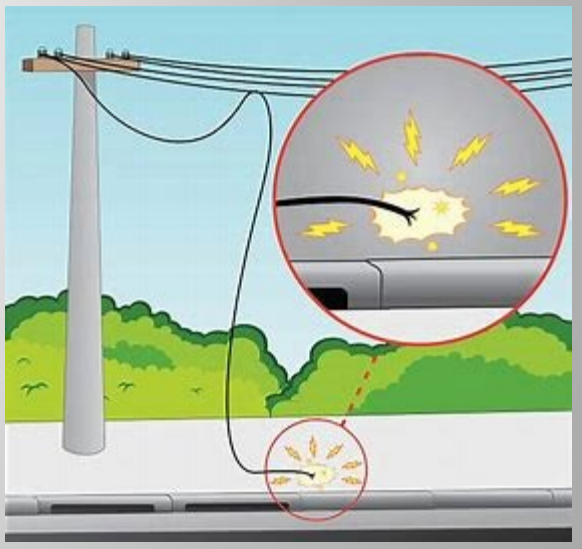


Electrical Failures – Arc Flash/Arc Blast



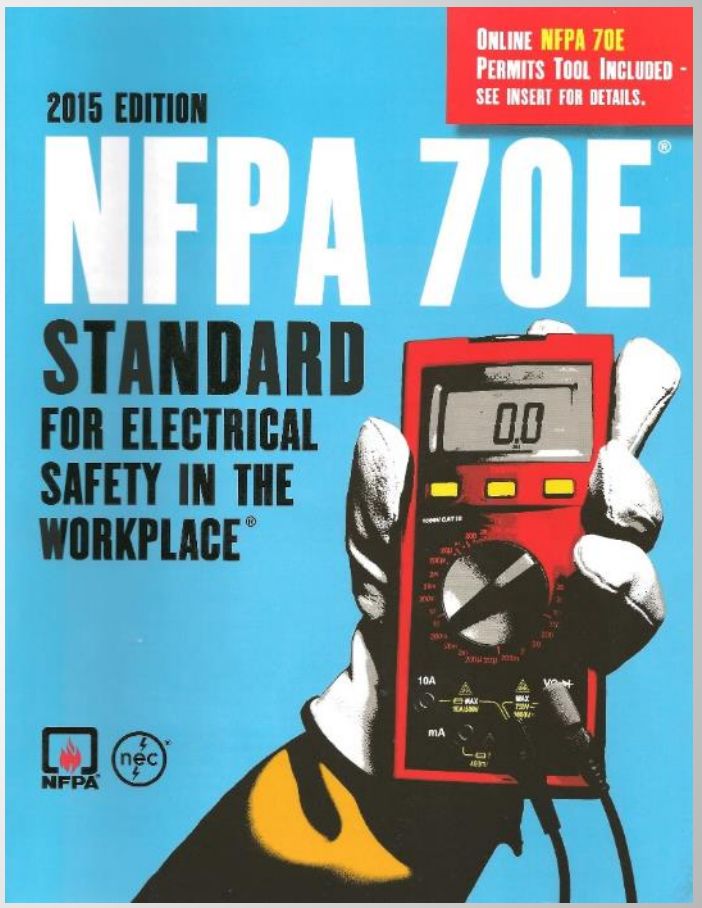
Electrocution or Shock (Contact) Cases

- Informational Items
  - Locate Clothing, Tools, and Any PPE
  - Scope of Work or Activity of Victim
    - Hot Work Permit (NFPA 70E & OSHA)
  - Source of Electrical Energy and Voltage Classification
  - Restricted Approach Zone (NFPA 70E & OSHA)
  - Warnings and Signage
  - Preserve and Protect and Evidence



Electrocution or Shock (Contact) Cases

- NFPA 70E – Electrical Workplace Safety Standard
  - First published 1979
  - Assisted OSHA to establish workplace safety rules
  - NEC applies to installation only
  - Not part of OSHA regulations
  - OSHA – Reference Document
  - Compliance with 70E is accepted OSHA



Electrocution or Shock (Contact) Cases

- Host and Contract Employer Responsibilities
- Qualified & Unqualified Persons
- Lockout Tagout (LOTO)
- Approach Boundaries (See Chart)
- Energized Work Permit
- Arc Flash Hazard & Boundary

Table 130.4(D)(a) Approach Boundaries to Energized Electrical Conductors or Circuit Parts for Shock Protection for Alternating-Current Systems (All dimensions are distance from energized electrical conductor or circuit part to employee.)

(1)	(2)	(3)	(4)
	Limited Approach Boundary[b]		Restricted Approach Boundary[b]; Includes Inadvertent Movement Adder
Nominal System Voltage Range, Phase to Phase[a]	Exposed Movable Conductor[c]	Exposed Fixed Circuit Part	
<50 V	Not specified	Not specified	Not specified
50 V–150 V[d]	3.0 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	Avoid contact
151 V–750 V	3.0 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.3 m (1 ft 0 in.)
751 V–15 kV	3.0 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.7 m (2 ft 2 in.)
15.1 kV–36 kV	3.0 m (10 ft 0 in.)	1.8 m (6 ft 0 in.)	0.8 m (2 ft 7 in.)
36.1 kV–46 kV	3.0 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	0.8 m (2 ft 9 in.)
46.1 kV–72.5 kV	3.0 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	1.0 m (3 ft 3 in.)
72.6 kV–121 kV	3.3 m (10 ft 8 in.)	2.5 m (8 ft 0 in.)	1.0 m (3 ft 4 in.)
138 kV–145 kV	3.4 m (11 ft 0 in.)	3.0 m (10 ft 0 in.)	1.2 m (3 ft 10 in.)
161 kV–169 kV	3.6 m (11 ft 8 in.)	3.6 m (11 ft 8 in.)	1.3 m (4 ft 3 in.)
230 kV–242 kV	4.0 m (13 ft 0 in.)	4.0 m (13 ft 0 in.)	1.7 m (5 ft 8 in.)
345 kV–362 kV	4.7 m (15 ft 4 in.)	4.7 m (15 ft 4 in.)	2.8 m (9 ft 2 in.)
500 kV–550 kV	5.8 m (19 ft 0 in.)	5.8 m (19 ft 0 in.)	3.6 m (11 ft 10 in.)
765 kV–800 kV	7.2 m (23 ft 9 in.)	7.2 m (23 ft 9 in.)	4.9 m (15 ft 11 in.)

Note (1): For arc flash boundary, see 130.5(A).
Note (2): All dimensions are distance from exposed energized electrical conductors or circuit part to employee.
[a] For single-phase systems above 250V, select the range that is equal to the system's maximum phase-to-ground voltage multiplied by 1.732.
[b] See definition in Article 100 and text in 130.4(D)(2) and Informative Annex C for elaboration.
[c] *Exposed movable conductors* describes a condition in which the distance between the conductor and a person is not under the control of the person. The term is normally applied to overhead line conductors supported by poles.
[d] This includes circuits where the exposure does not exceed 120V.

QUESTIONS OR COMMENTS

CASE STUDIES

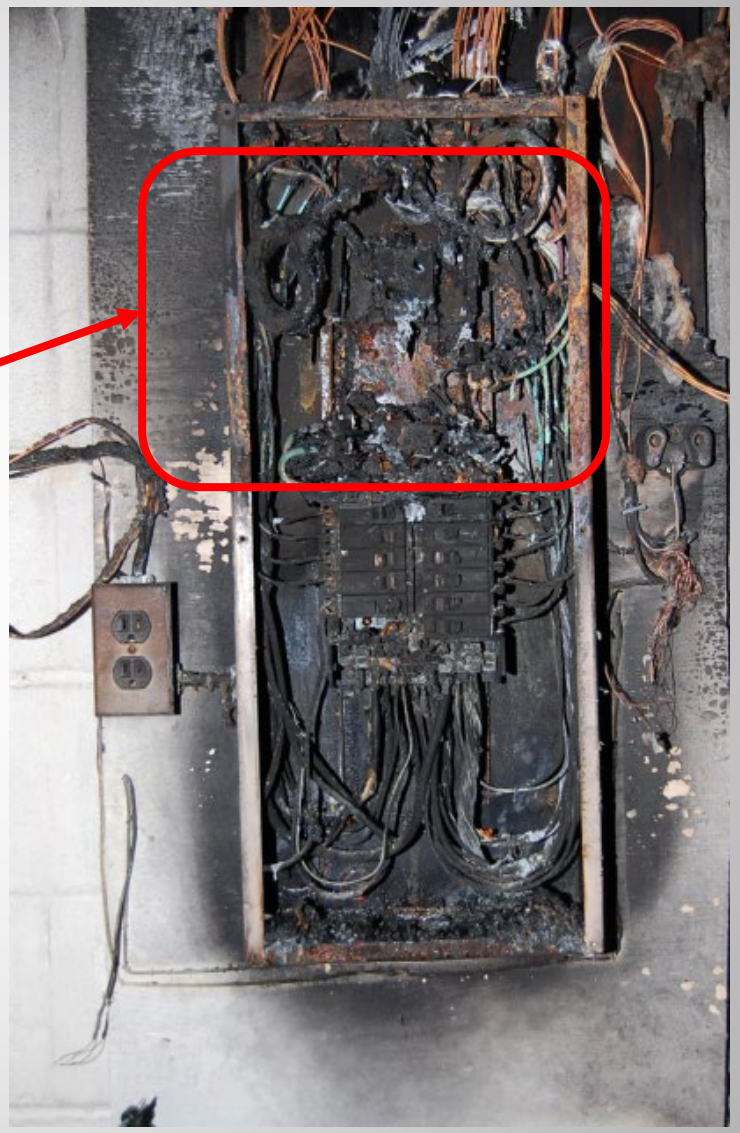
• Case Study No. 1- Residential Service

- Panel in Garage
- Installed 1970's
- Possible claim?



Case Study No. 1

- Main Service Panel Failure
  - Utility likely put on notice
  - Usually labeled a “Surge”
  - Top of panel heavily damaged
  - Investigation revealed split bus panel
    - No main circuit breaker
    - 1981 NEC no longer approved
    - Top Section – Feeder Breakers Only
    - Bottom Section – Lighting and Branch Circuits



• Case Study No. 2 -Neutral/Grounding System Case

- Utility working on OH transformer
- Allowed a loss of neutral
- Damage to houses on transformer





Case Study No. 2 -Neutral/Grounding System Case

Main Service Ground





Main Electric Panel

Split Bus Panel

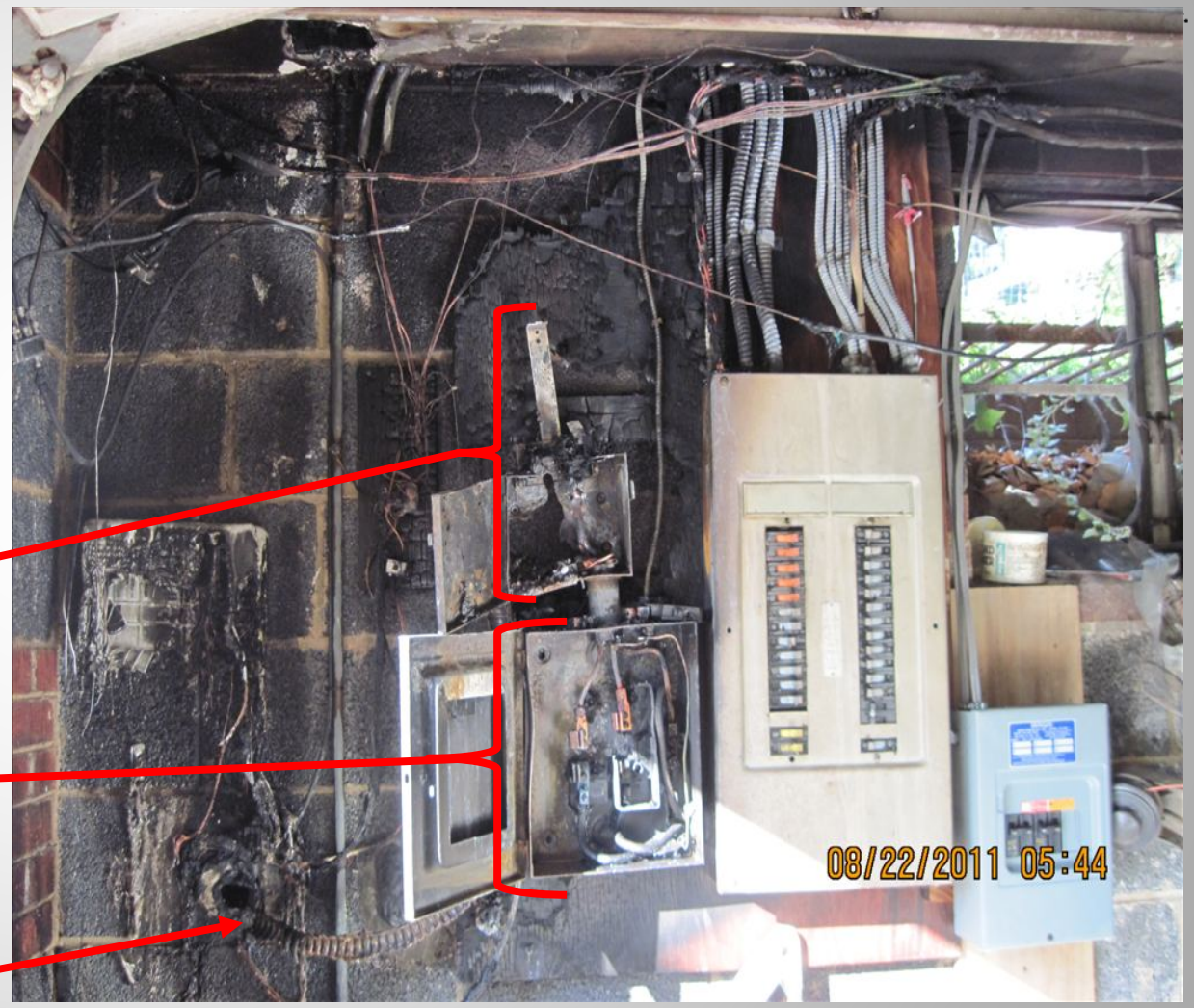
Case Study No. 3 - Meter Failure Claim?

- Reportedly AMI Meter failed and caused a fire
- Homeowners reported sparks and flames from AMI Meter
- AMI Meter was installed in recent past.



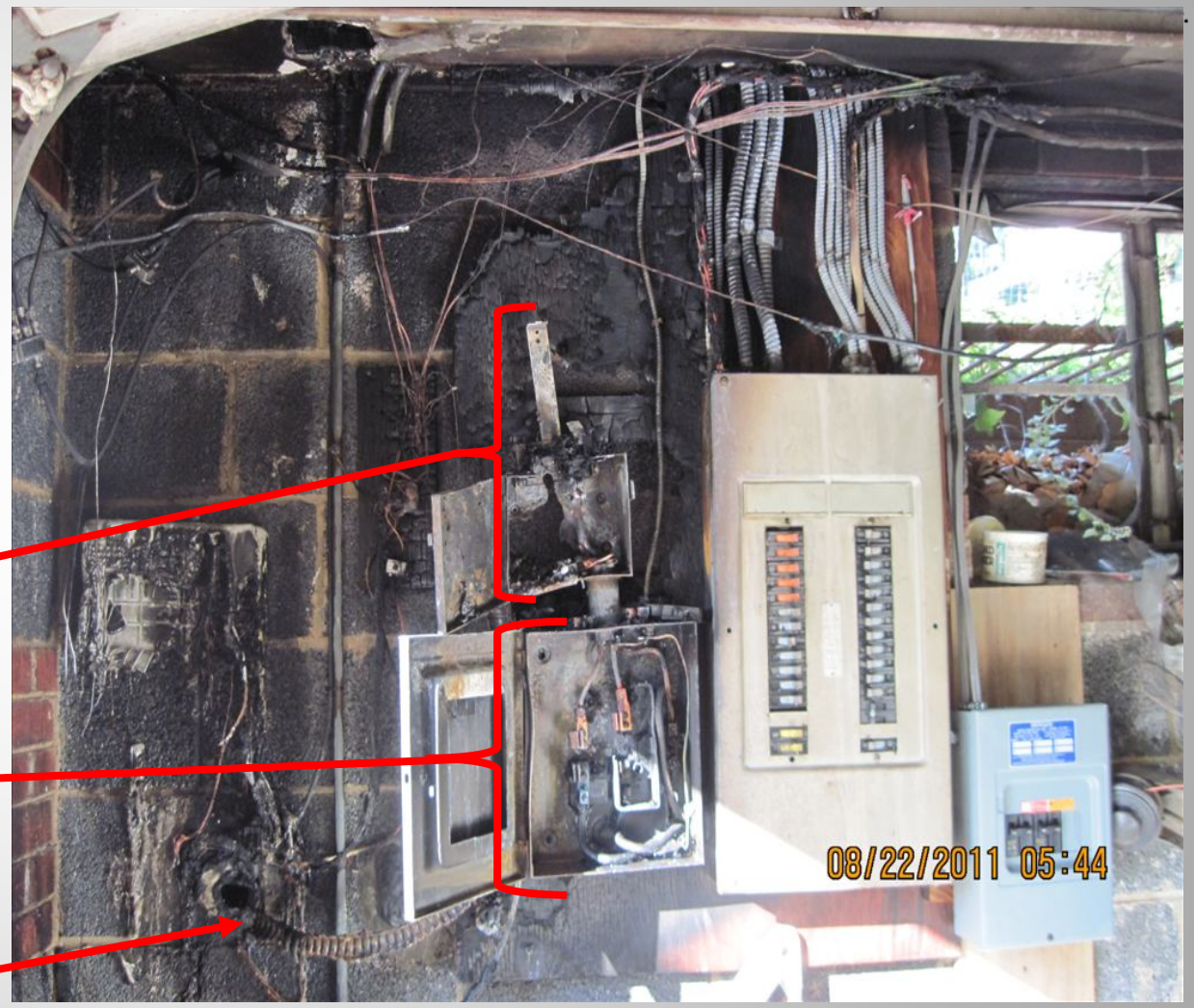
Case Study No. 3 - Meter Failure Claim?

Main Electric Service in
Customer's Garage
1940's Main Disc
1960's Panel



Case Study No. 3 - Meter Failure Claim?

Main Electric Service in
Customer's Garage
1940's Main Disc
1960's Panel

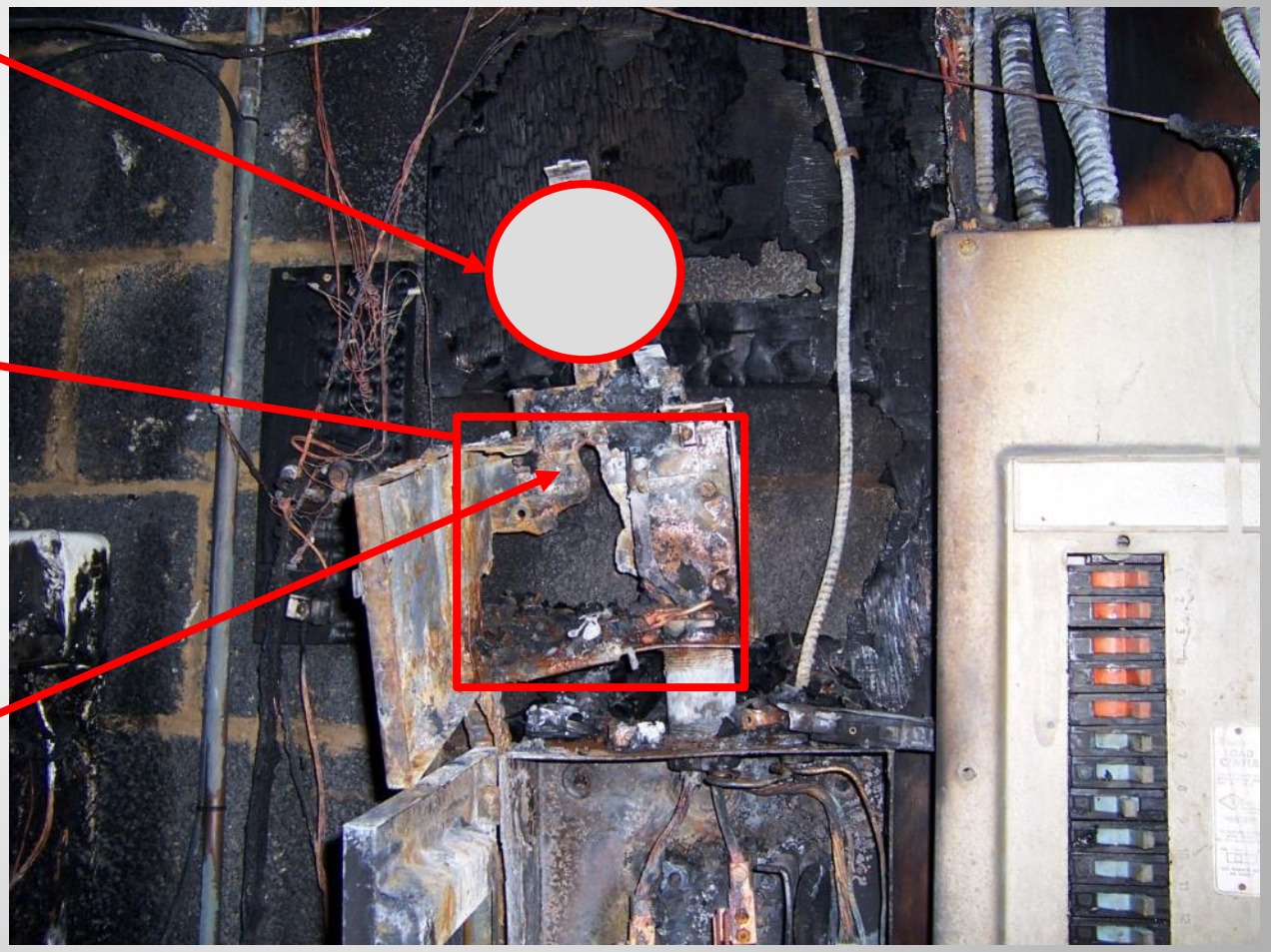


Case Study No. 4 - Meter Failure Claim?

Location of Meter

Customer Service Entrance Box

Starting point of Electrical Failure



Case Study No. 4 – Overloaded Service

Old house converted to a Coffeehouse/Nightclub

Fire started at the A-Base Meter Socket



Case Study No. 4 – Overloaded Service

Two 60 Ampere Services

SEC Cable To Panel

Origin Area of the Fire



Case Study No. 4 – Overloaded Service

New SEC's from Meters

New 200 Amp Disconnect

New 200 Amp Panel

NO PERMITS!

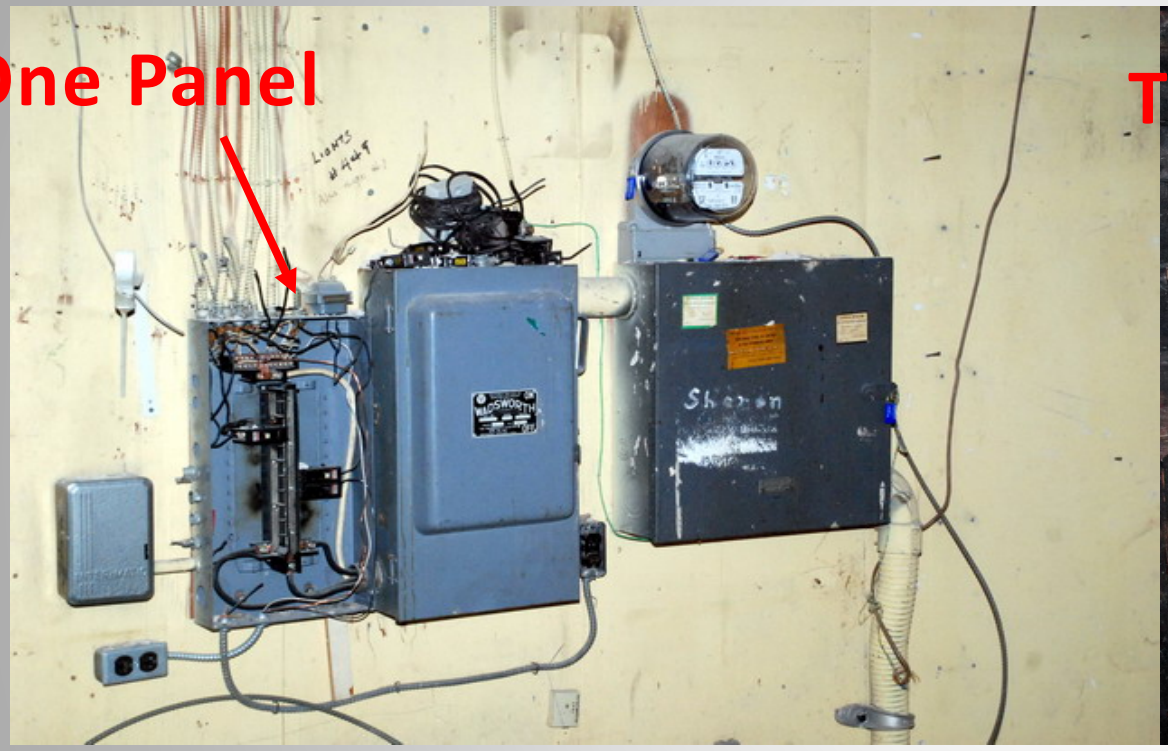


Case Study No. 5 - Overloaded Service

- Strip Mall Built Circa 1959
- Each Space 150 or 200 ampere Three Phase 120/208 Volt Service
- After Remodel Complete Liquor Store is Sold to New Owner
- 200 Ampere Meter Fails
- Utility Tests Meter and Determined it was Overloaded.
- Was Store Owner Notified?



Case Study No. 5 - Overloaded Service





Store Service Before Remodel

Store Service After Remodel

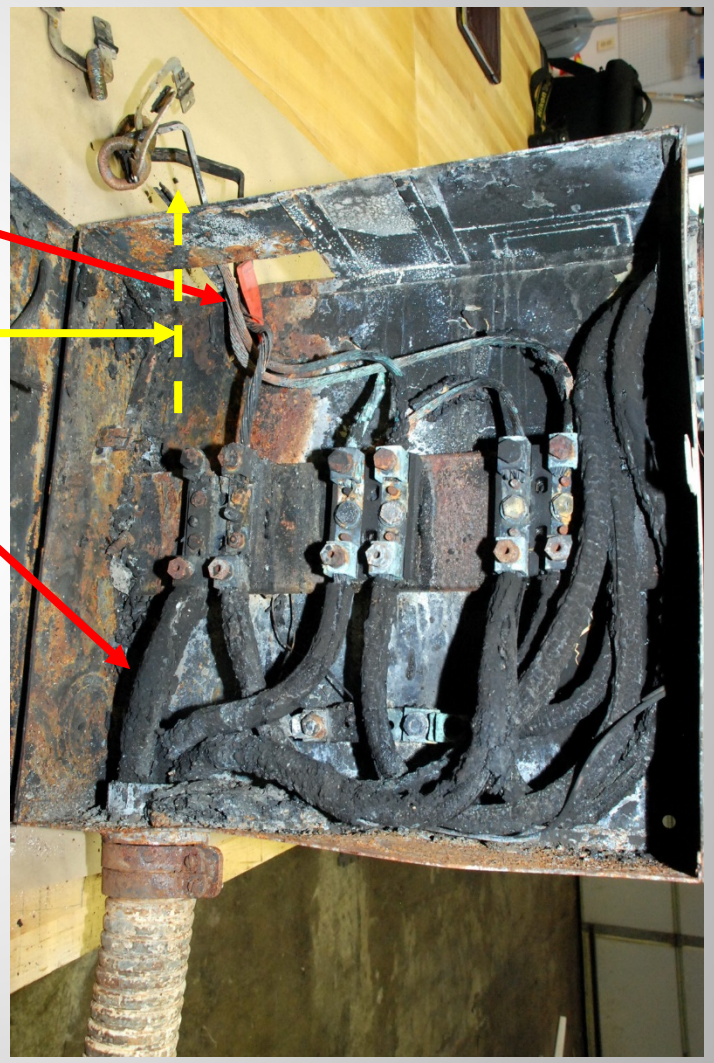
Case Study No. 5 - Overloaded Service

1/0 Wire to Missing Meter

‘A’ Phase 1/0 Wire Completely Melted

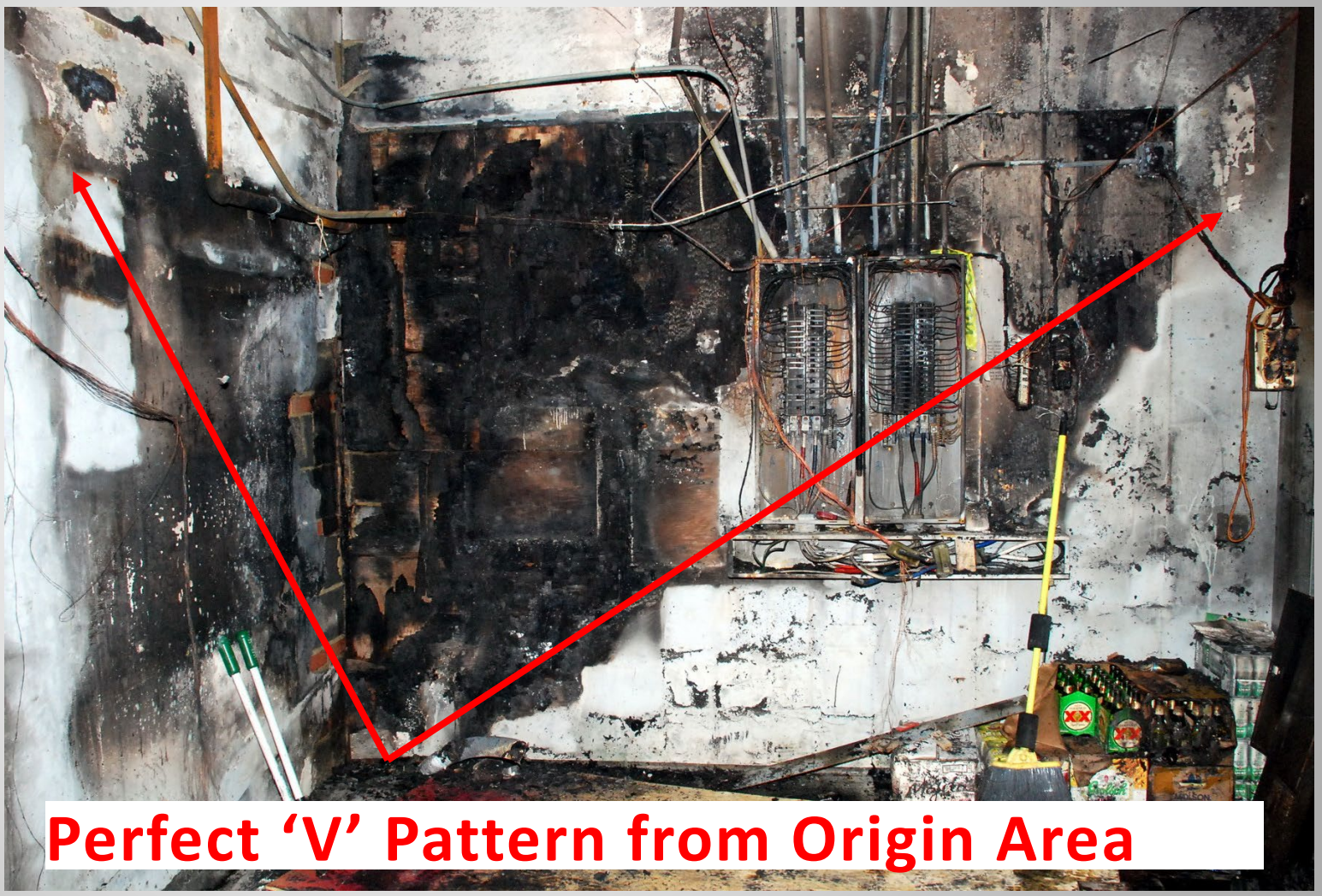
3/0 Wire From Utility Vault

3/0 CU Wire Rated 200 Amperes
1/0 CU Wire Rated 130 Amperes



Case Study No. 5 - Overloaded Service

- Unlicensed Electrical Contractor Hired by the Previous Owner Performed Work
- No Documented Evidence Utility Notified the Customer After Meter was Tested to be Overloaded
- NO PERMITS



Case Study No. 6 – Undersized Service

Electrical Event Occurs at Customer's Point of Attachment.

Why was there a Failure at the Point of Attachment?



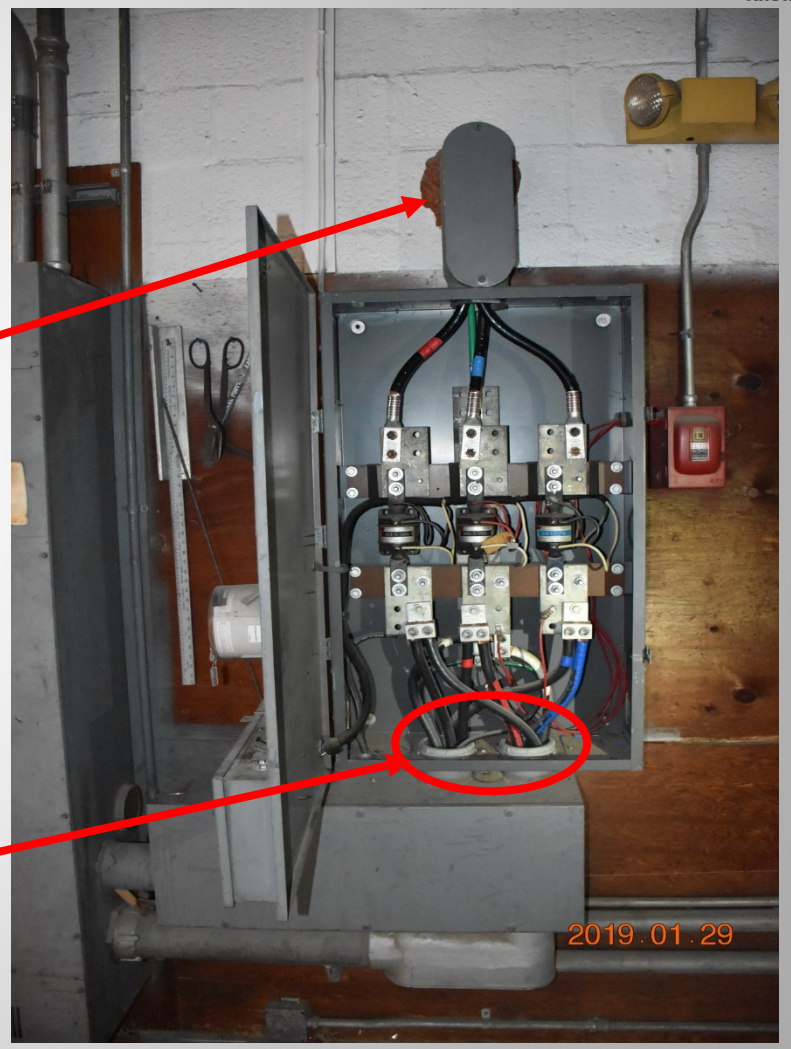
Case Study No. 6 – Undersized Service



Evidence of Electrical Event at the Service Head.

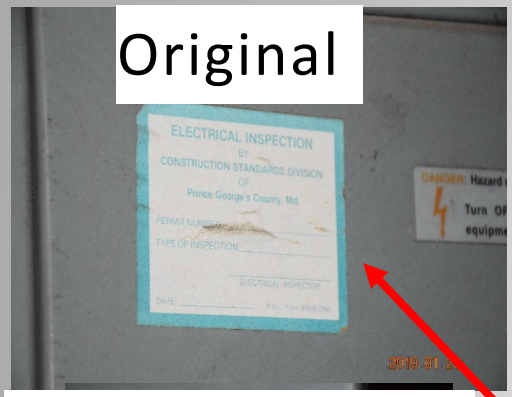
Service Has One 4” Conduit on the Outside.

CT Cabinet Has One 4 Inch Conduit for Incoming SEC and Two 4 Inch Outgoing Conduits.

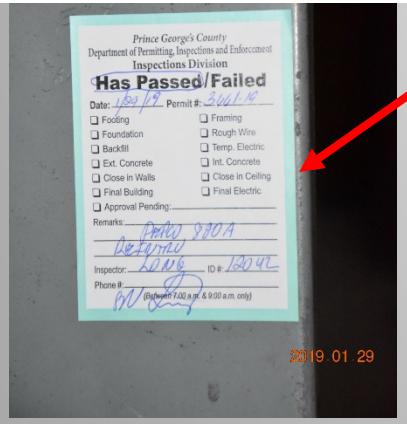


Case Study No. 6 – Undersized Service

Original

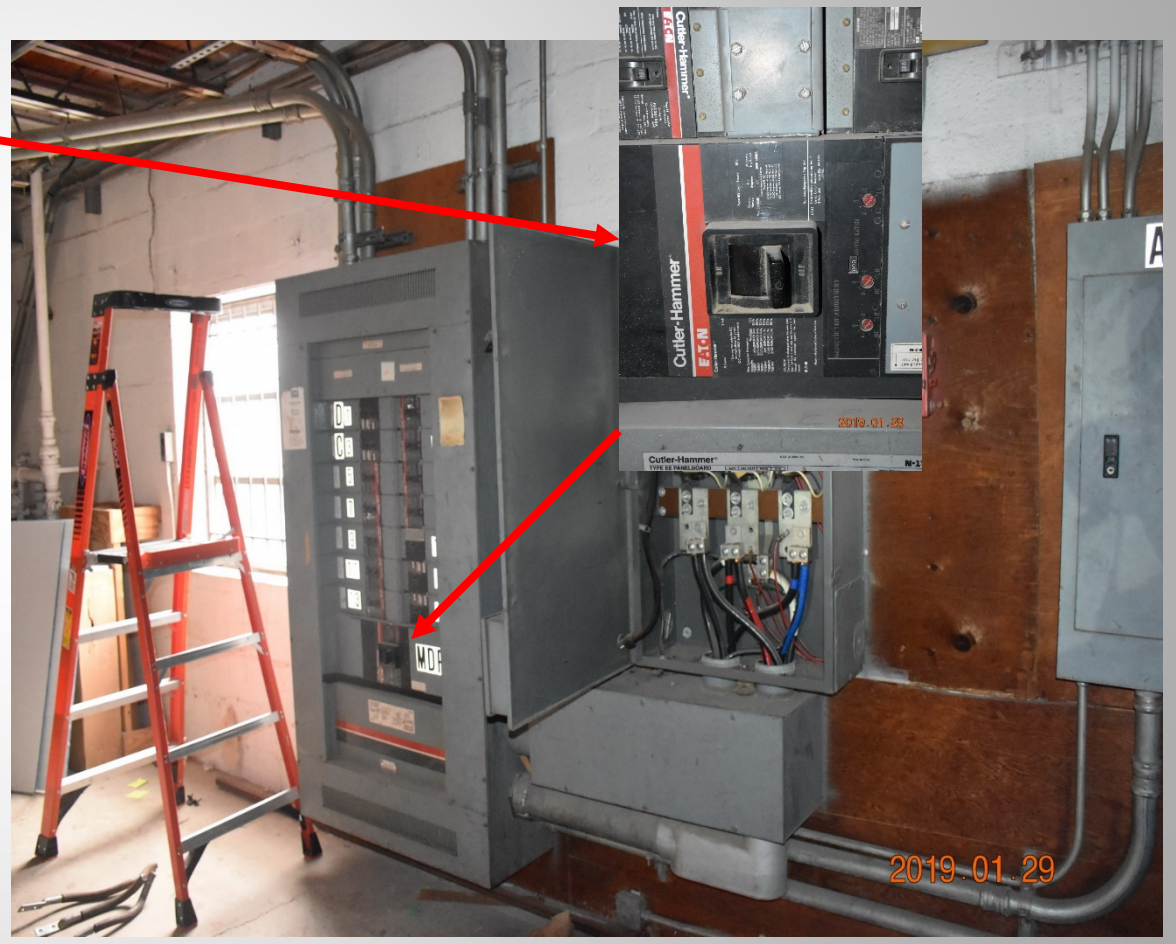


For Repairs and Reconnection



800 Ampere Main Circuit Breaker

Two County Passed Inspection Stickers.



Case Study No. 7 – Underground Utilites



Electrical Investigations



Case Study No. 8 – Contact Case

House built in 1870's with a Formal Dining Room addition in 1900's

Painter was painting the chimney.



Case Study No. 8 – Contact Case

A large Skylight is over the Dining Room Table that is Supplemented with Incandescent Lighting.



Case Study No. 8 – Contact Case





Case Study No. 8 – Contact Case





Case Study No. 8 – Contact Case



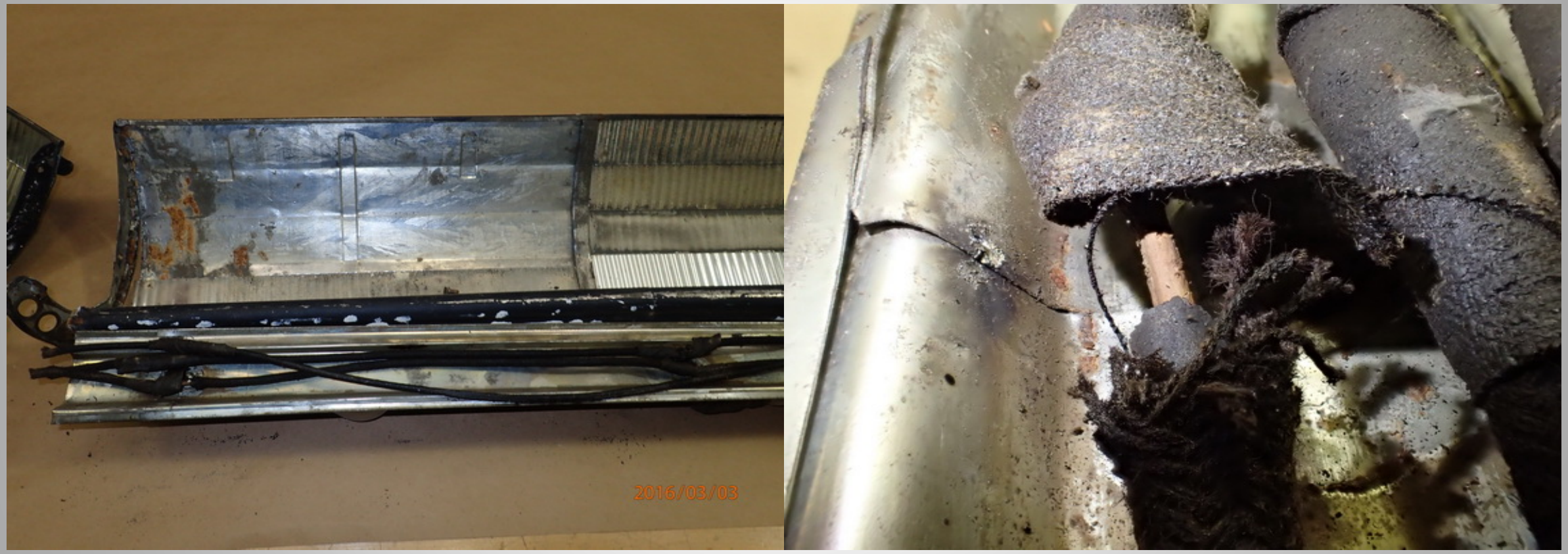


Case Study No. 8 – Contact Case





Case Study No. 8 – Contact Case



QUESTIONS OR COMMENTS

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