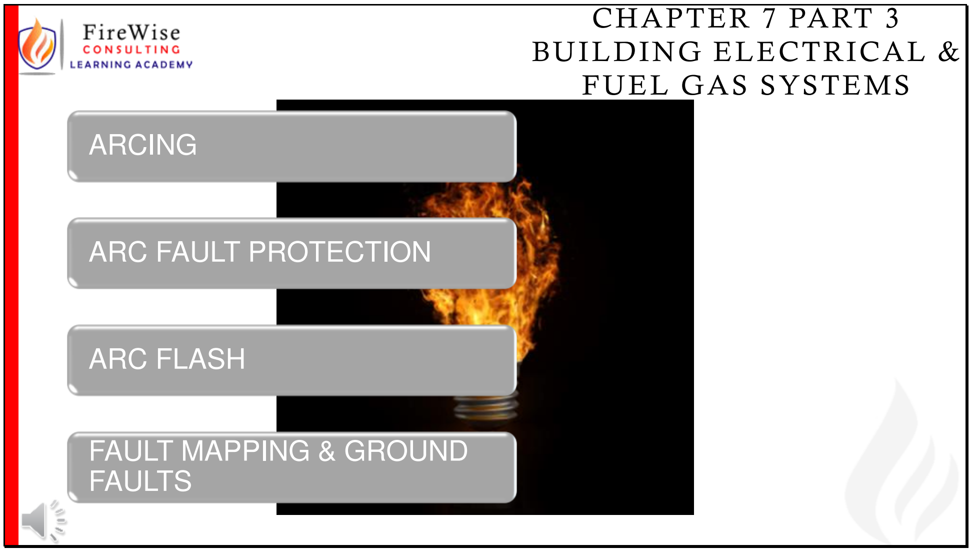
Slide 1



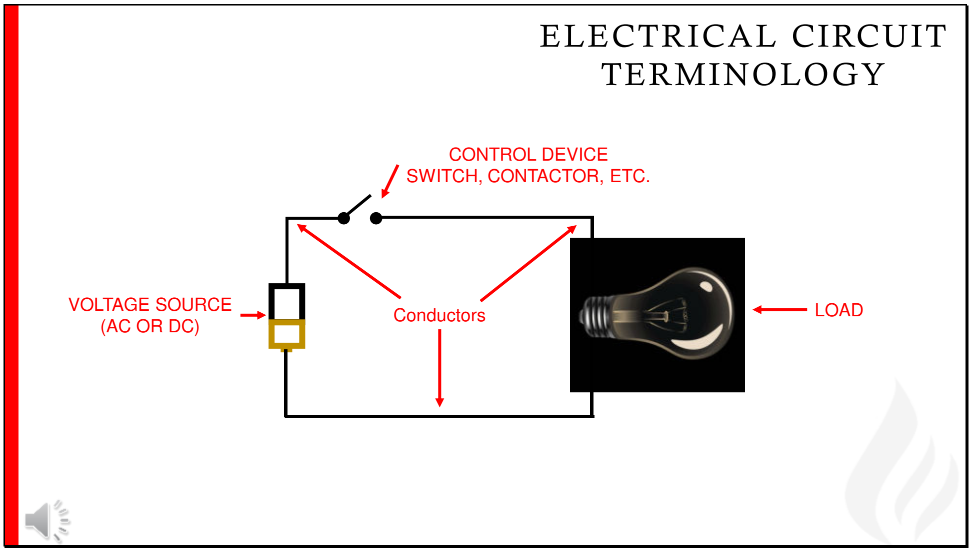
"Welcome to Part 3. In this part we will discuss electrical circuits terminology and problems, short circuits, circuit overload, terminations and splices, arcing, arc fault protection, arc flash, arc fault mapping and ground faults."

Slide 2

ELECTRICAL CIRCUIT
TERMINOLOGY & PROBLEMS

Electrical circuit terminology and problems.

Slide 3



A basic electrical circuit consists of a voltage source which could be AC or DC shown here as a DC source, conductors or wires to enable current flow, a load to do work such as a light bulb, and a means of control such as a switch.

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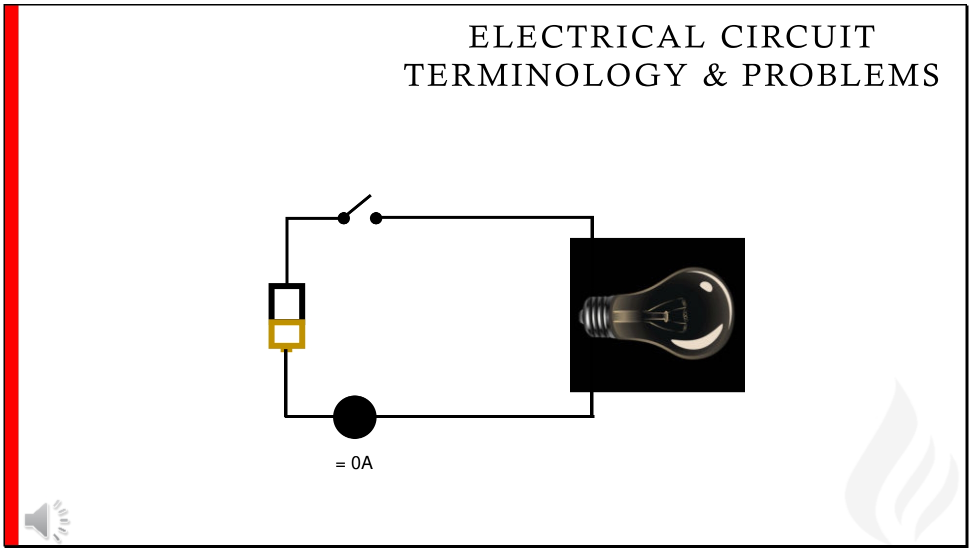
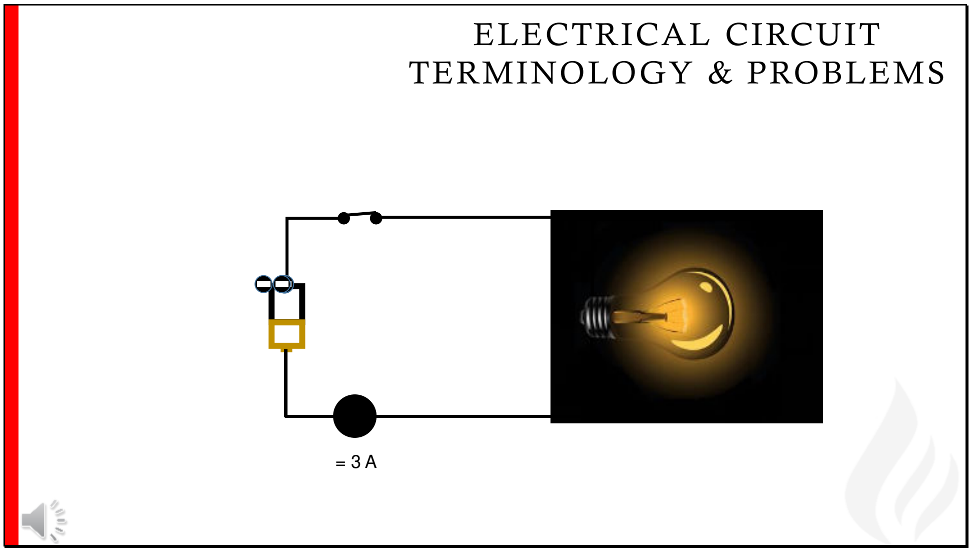


When the switch is open no current flow is present in the circuit as indicated by the ammeter as 0 amps, so the bulb is off.

Slide 5



If the switch is closed current will flow through the circuit. The value of which is limited only by the resistance of the bulb and is indicated on the ammeter as 3 amps.

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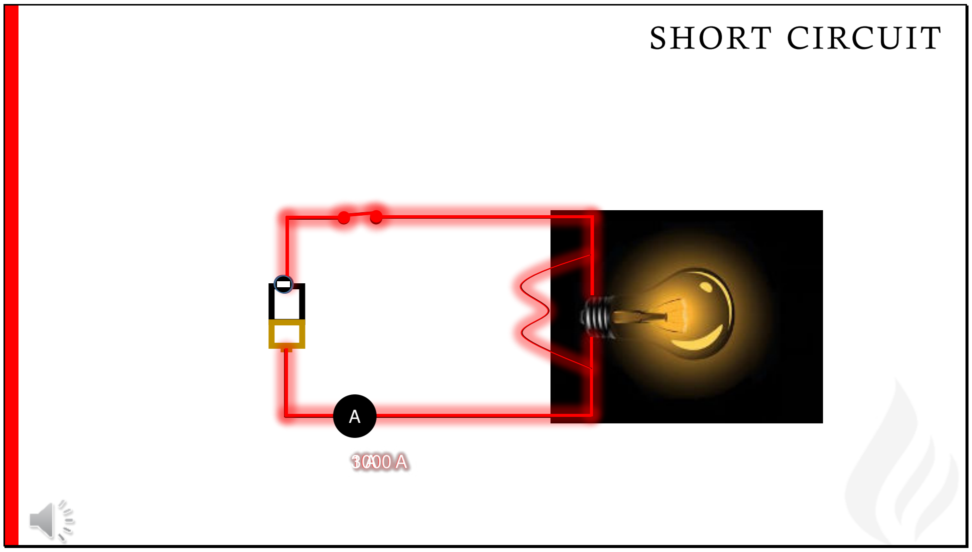
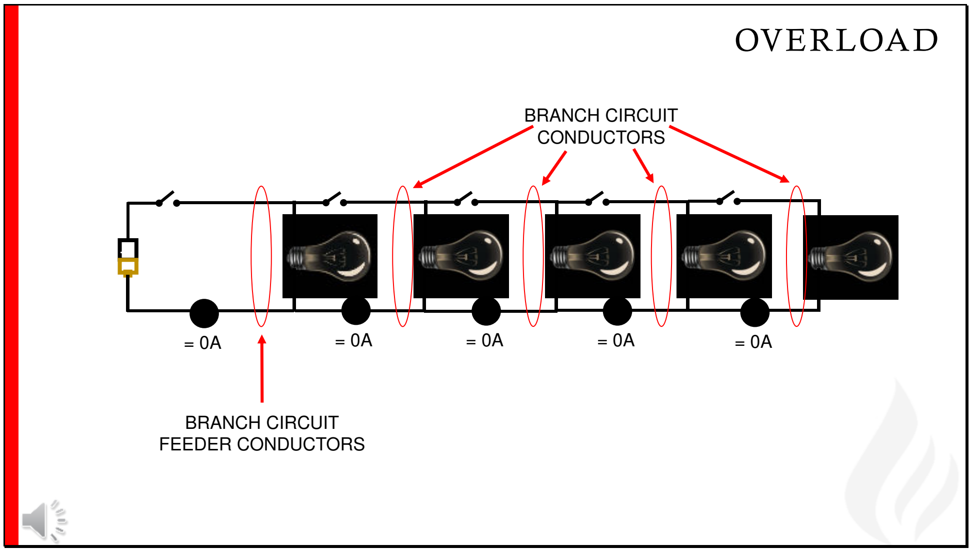


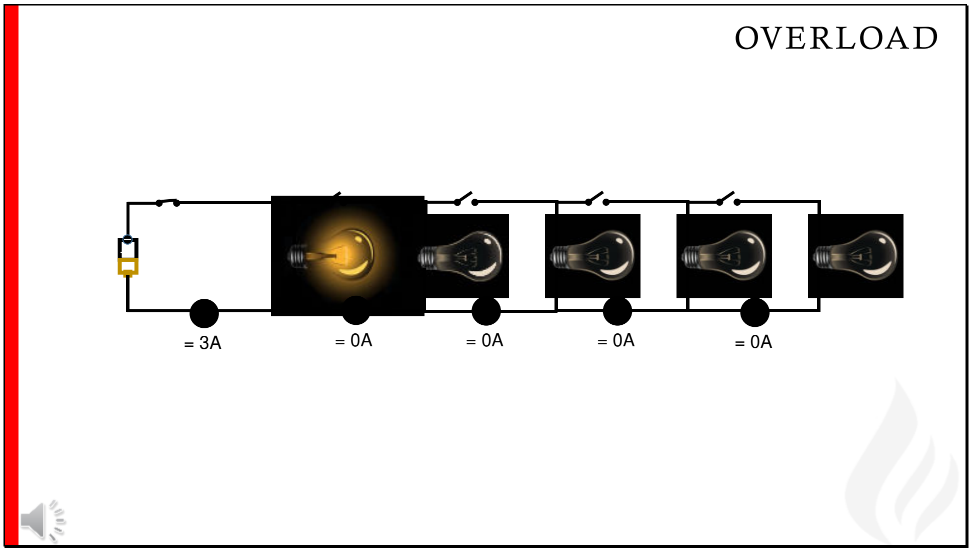
Current will follow the path of least resistance If a path of low resistance was introduced around the resistance of this light bulb, current would spike. Current flow would only be limited by the small amount of resistance offered by the conductors and the source itself, let’s say it limited to 1000A. If over current devices weren't present or failed to operate the conductors could get so hot that they melt. This condition is known as a short circuit.

Slide 7



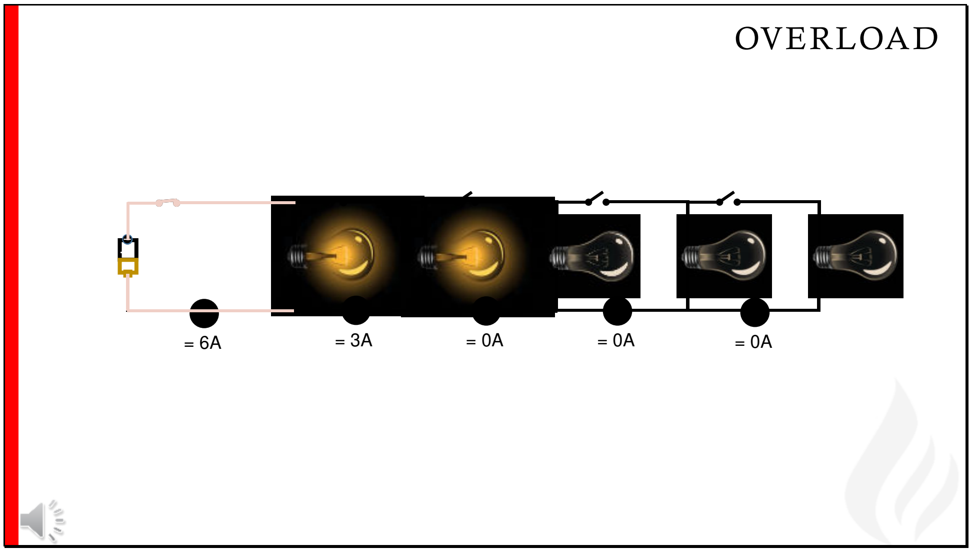
Another cause of a conductor carrying to much current is an overload situation. This occurs when too many loads or a load that draws too much ampacity is connected to a circuit. When higher than rated current flows through a circuit, heating of the branch circuit feeder conductors or the branch circuit conductors occurs.

Slide 8



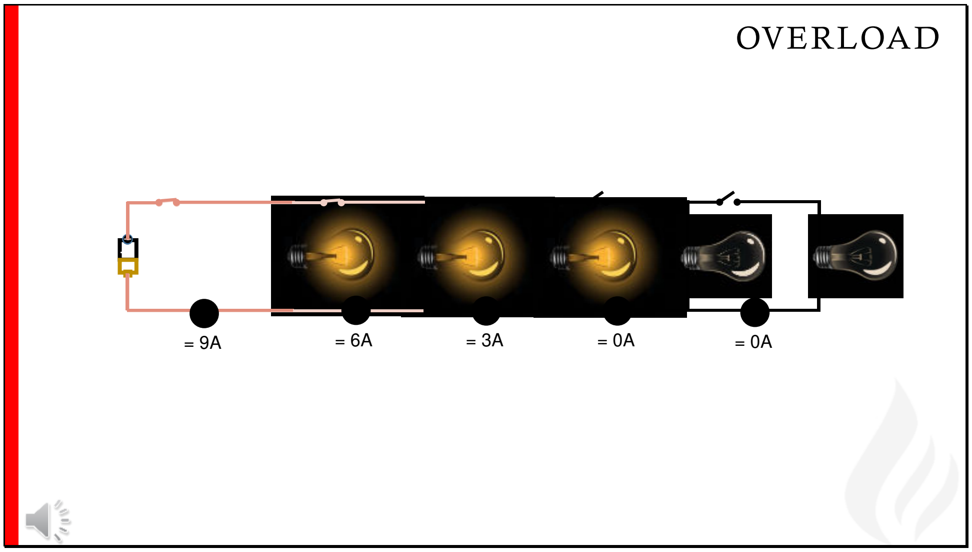
Assuming each load draws 3 amps observe the change in ampacity on each conductor as load is added to the circuit.

Slide 9



With each additional load the ampacity carried by the conductors increases, this causes the conductors to heat up.

Slide 10

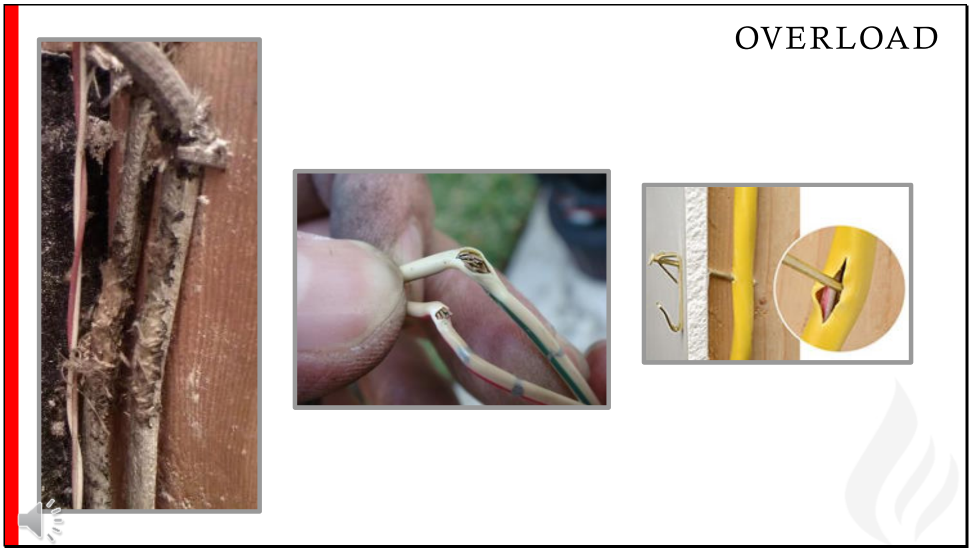


As the load on the branch circuit continues to increase so does the heat generated by the conductors.

Slide 11

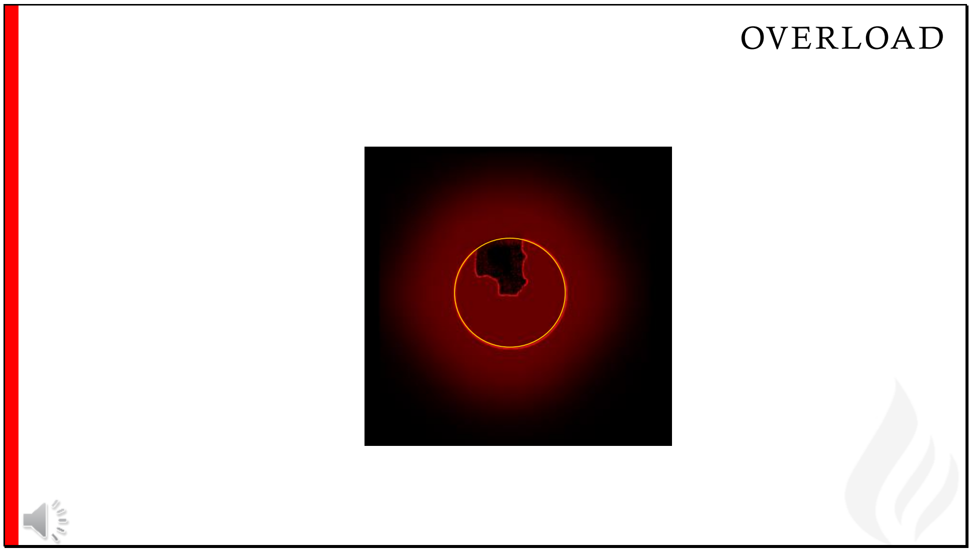
Another typical overload scenario is when too many loads are plugged in at one outlet, this can prove to be significantly dangerous. This is a common problem during the holidays when outlets and extension cords can be over exerted to supply decorations and lighting displays.

Slide 12



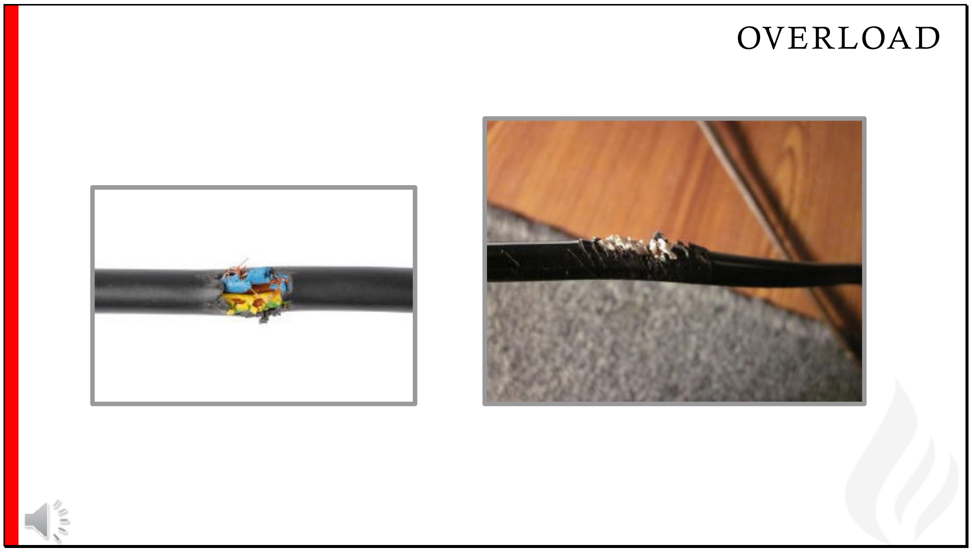
Over loading of a conductor can also result from conductor damage. Conductors can be damaged before, during or after installation.

Slide 13



One of the factors in a conductor’s ability to carry current is its cross-sectional area. When damage reduces the cross-sectional area the conductor, its ability to carry current is compromised at the point of damage, resulting in a localized hot spot.

Slide 14



Damaged equipment cables such as lamp cords are of particular concern as they are often in contact with combustible material.

Slide 15

Another source of unwanted heat in an electrical system is heat developed at terminations and splices. When a conductors are attached to a buss bars or device terminal it is referred to as a termination. A splice is the joining of two conductors.

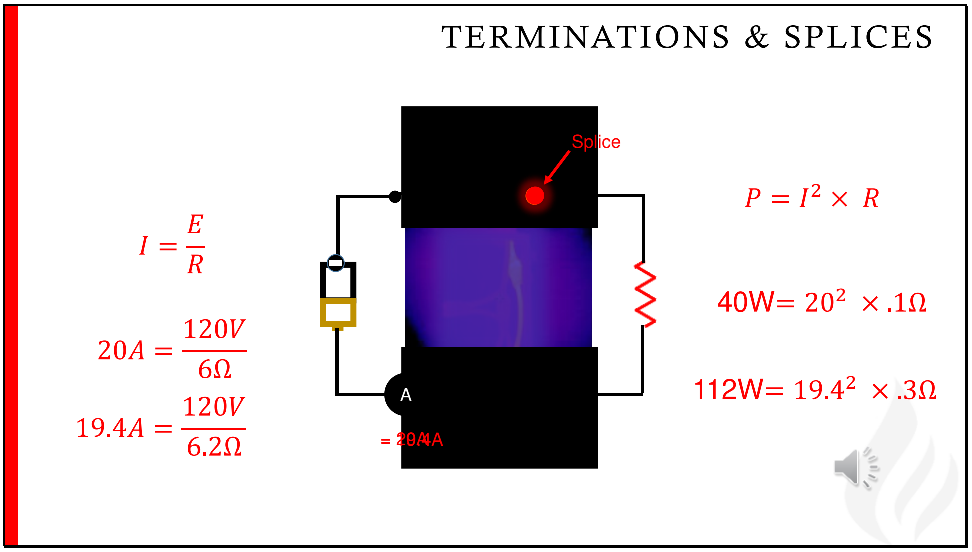
Slide 16

When two conductors are joined the connection offers more resistance than if they were one piece. This is due to the contact area between the two conductors and a form of resistance called contact resistance. Other factors such as oxidation of the conductors also play a role.

Slide 17

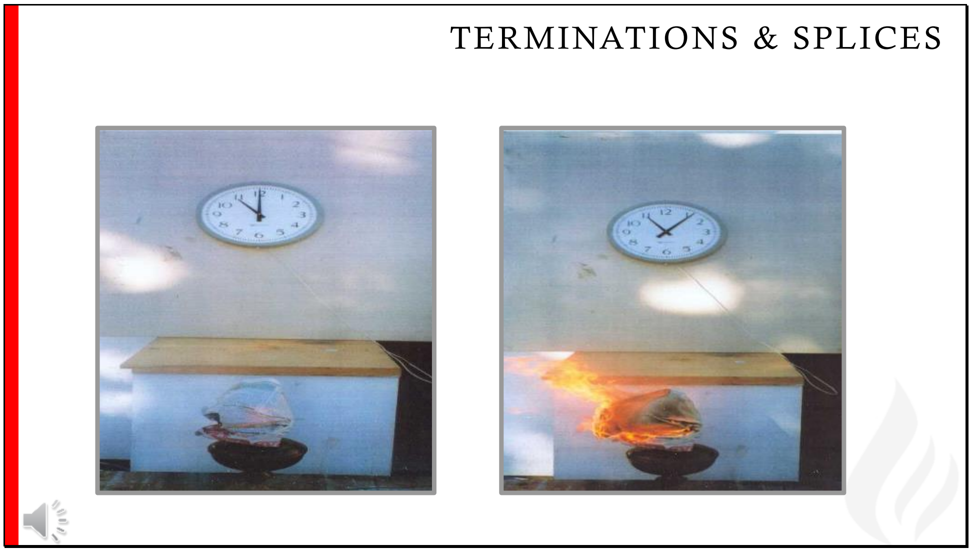
The contact resistance is inversely proportional to the tightness of the termination. The looser the connection the greater the resistance. The increase in resistance generally has little effect on over all circuit current. However it can have a large effect on the power produced at the splice or termination.

Slide 18



For instance if a 6 Ω circuit was being fed by a 120 volts the circuit ampacity would be 20 amps. Let's assume that a splice in the circuit represented 0.1 Ω's of the total resistance the power developed at the splice would equal 40 watts. However if the splice resistance was to increase to .3 of an Ω the total circuit resistance would rise to 6.2 Ω's and the ampacity would drop to 19.4 amps. The power produced by the splice would increase to 112.3W.

Slide 19



With that in mind consider what a 100W bulb wrapped in news paper can do in 5 minutes. Now let’s do the math for a loose connection at a service conductor where maximum load is anticipated to be 100A….

Slide 20

TERMINATIONS & SPLICES

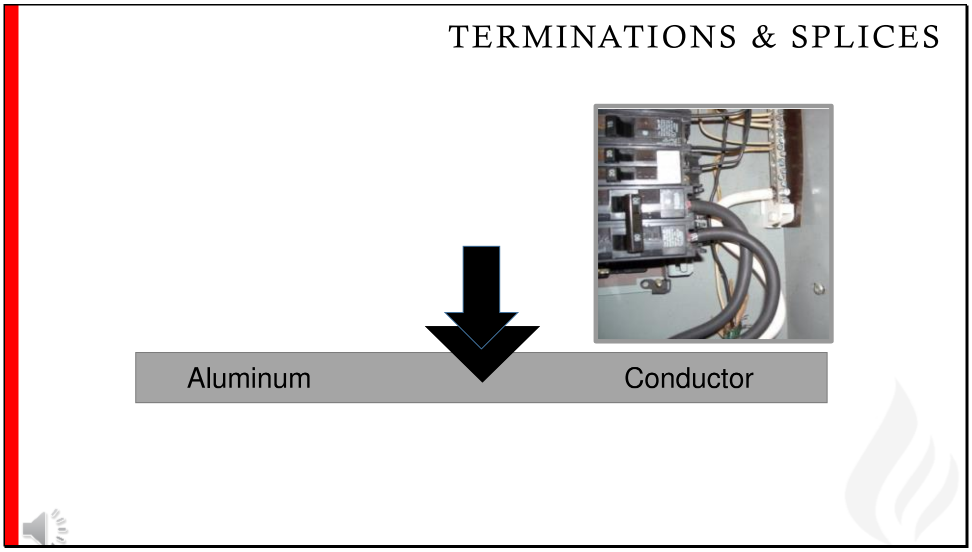
$$P = I^2 \times R$$

$$10W = 100A^2 \times .001\Omega$$

$$1010W = 100A^2 \times .101\Omega$$

If the termination resistance is 0.001 of an Ω the power developed would be 10W, but with an increase of only 0.1 of an ohm the power production jumps to 1010W, and because the ampacity of the circuit has not changed or possibly slightly decreased the overcurrent devices will not protect against this type of problem.

Slide 21



Tightness of connections becomes of greater concern when aluminum conductors are used. Aluminum possesses the property of cold flow, that is to say that aluminum will flow away from pressure. For instance if pressure is applied in one spot on an aluminum conductor the aluminum atoms will move away from the pressure resulting in a thinning of the conductor at the point of pressure and the contact pressure will be reduced. When aluminum is terminated to a lug it needs to retightened after a couple of days to compensate for colt flow. The natural heating and cooling of the conductor as current flow through it varies leads to expansion and contraction of the conductor which exasperates the situation.

Slide 22

TERMINATIONS & SPLICES

ALUMINUM IS COMMONLY FOUND TO BE USED FOR SERVICE CONDUCTORS ONLY

Aluminum also oxidizes at a faster rate than copper. Aluminum oxide which is resistive, forms on the surface of aluminum conductors. This increases the resistance of joints and splices. A compound called an antioxidant should be applied to aluminum when making connections. In modern electrical systems aluminum is commonly found to be used for service conductors only.

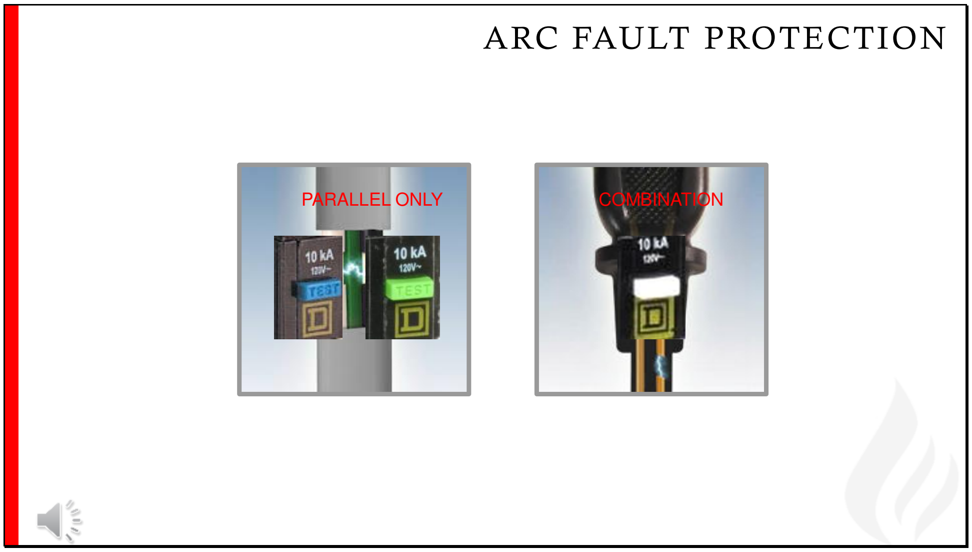
Slide 23

An electrical arc is produced when a potential difference overcomes the resistance between two conductors. The resistance could be conductor insulation or the air between them. Electrical arching can produce significant heat in fact electrical arcs produce some of the highest temperatures that occur on earth.

Slide 24

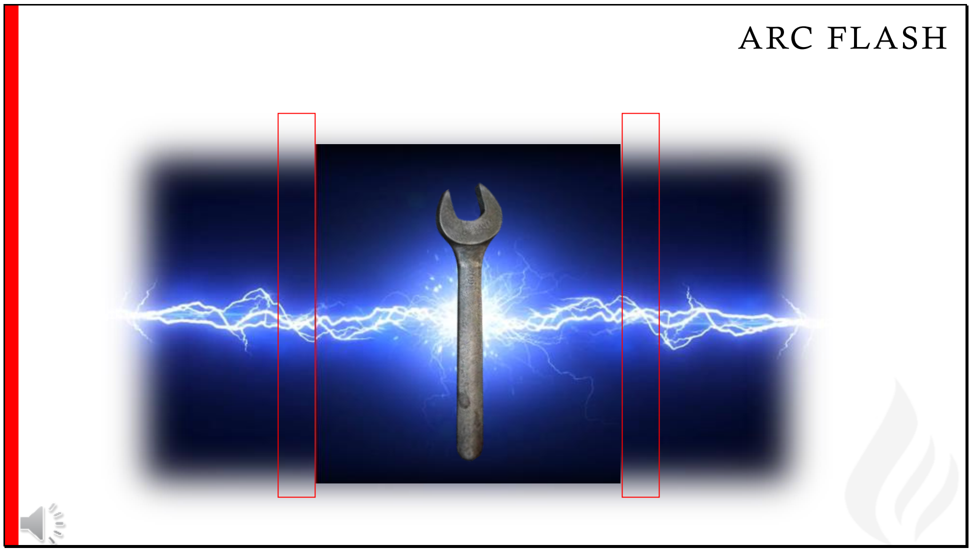
An arc fault circuit interrupter or AFCI is a overcurrent device that provides overload and overcurrent protection as well as arc fault protection. Built into an arc -fault breaker is special electronic circuitry that senses a arc fault and opens the circuit. In recent editions the Canadian electrical code has required arc fault breakers to be installed on circuits that supply receptacles in bedrooms, the 2015 Canadian electrical code broadened the use of arc fault breakers to incorporate most circuits that feed receptacles in a dwelling unit with a few exceptions.

Slide 25



In an electrical system there are two types of arc faults. There are parallel arc faults which occur between two circuit conductors, and there are series arc faults that occur across a break in a conductor. Early arc fault breakers only protected against parallel arc faults however the 2015 Canadian electrical code has required combination protection or protection against both types. Newer versions of the arc fault breaker offer combined protection. This can be distinguished by the color of the test button on the face of the breaker. Specific manufactures data must be checked to properly determine the type of protection offered.

Slide 26



An arc flash is a rapid release of energy dew to an arcing fault between two conductors or a conductor and ground. Arc faults require a catalyst such as insulation failure or introduction of a tool or body to compromise the distance between energized components.

Slide 27

Arc flash's produce intense heat which causes the air surrounding the arc to expand rapidly resulting in a blast of pressurized air. Arc flash can cause minor injuries, third degree burns, as well as other injuries including blindness, hearing loss, nerve damage and potentially death.

Slide 28

ARC FLASH

Although the risk of shock is always present injury can also occur at a distance for this reason the NFPA 70E describes a flash protection boundary as an imaginary sphere that surrounds the potential arc point, within which a person could receive a second degree burn if an electrical arc flash were to occur. Also the blast wave generated has been known to knock people off their feet this can be another cause of injury.

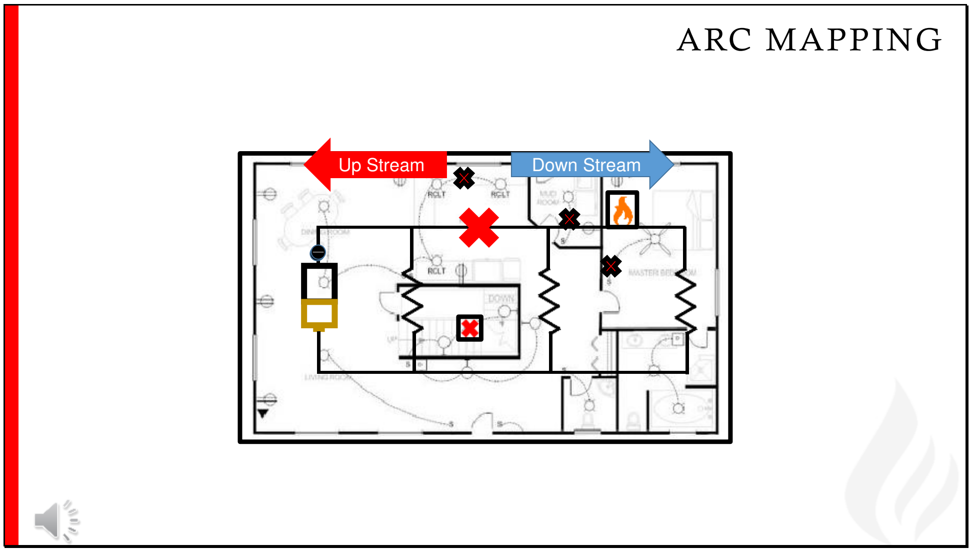
Slide 29

If there is a risk of arc flash appropriate PPE is required as laid out in the NFPA 70E.

Slide 30

The term arc tracking refers to the establishment of a path for unintentional current flow as a result of some form of contamination. For instance if a line conductor of a 120v circuit was to contact a piece of wood that was grounded it is probable that no current would flow because the high resistance of the wood effectively insulates the line conductor from ground. However if a contaminant such as salts, conductive dusts or liquids are introduced or if the surface is contaminated with water containing dirt, dusts, salts or minerals a path for current flow can be established and a arc can be produced. Often the heat from the arc may evaporate water leaving behind the contaminants over time as more water is introduced and evaporated the contaminants build up producing a path for the arc to follow. Arc tracking is more prevalent in DC circuits as it maintains a steady voltage as opposed to the pulsating nature of an AC system.

Slide 31



Arc mapping is a technique used by investigators to help determine the place of origin or possible path of a fire. It uses evidence of arcing among circuit conductors to determine a sequence of events. If a conductor is severed, flow of current is impossible downstream from the break in relation to the source that would be considered to be upstream. However components upstream from the break could still be energized as long as the overcurrent device has not operated. Typically evidence of arcing furthest from the source can be considered as the first fault to have occurred, since power down stream should have been interrupted by the fault it self or the operation of a overcurrent device. Mapping the evidence of arc faults across all circuits can help establish a point of origin and path of the fire. It is important that arcing could be a cause or a symptom of a fire and an expert opinion should be obtained before considering evidence to be conclusive.

Slide 32

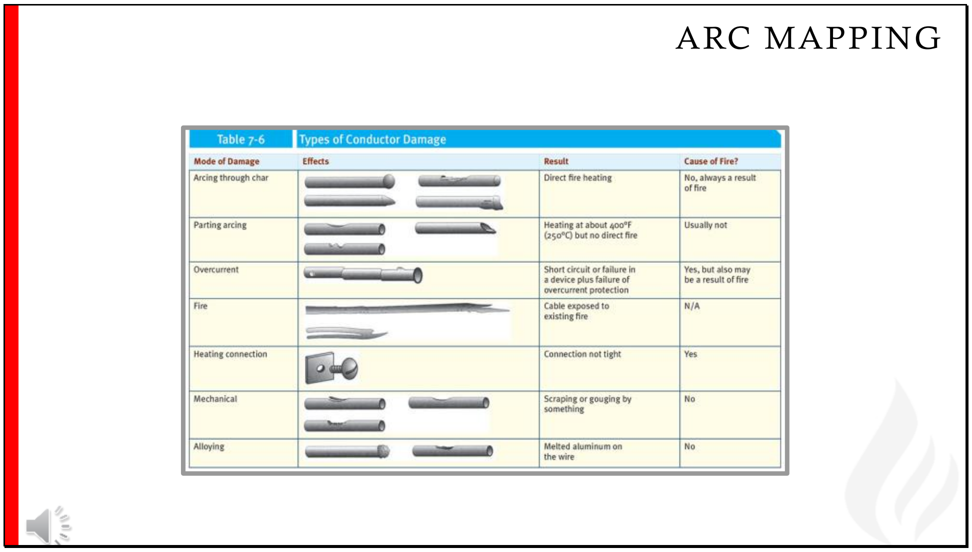
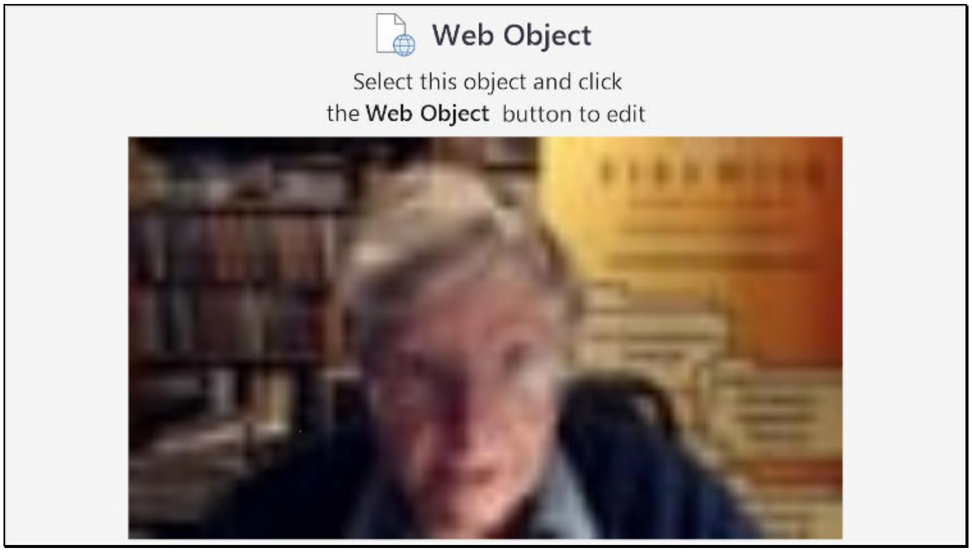


Table 7-6 Types of Conductor Damage

Mode of Damage	Effects	Result	Cause of Fire?
Arcing through char		Direct fire heating	No, always a result of fire
Parting arcing		Heating at about 400°F (250°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

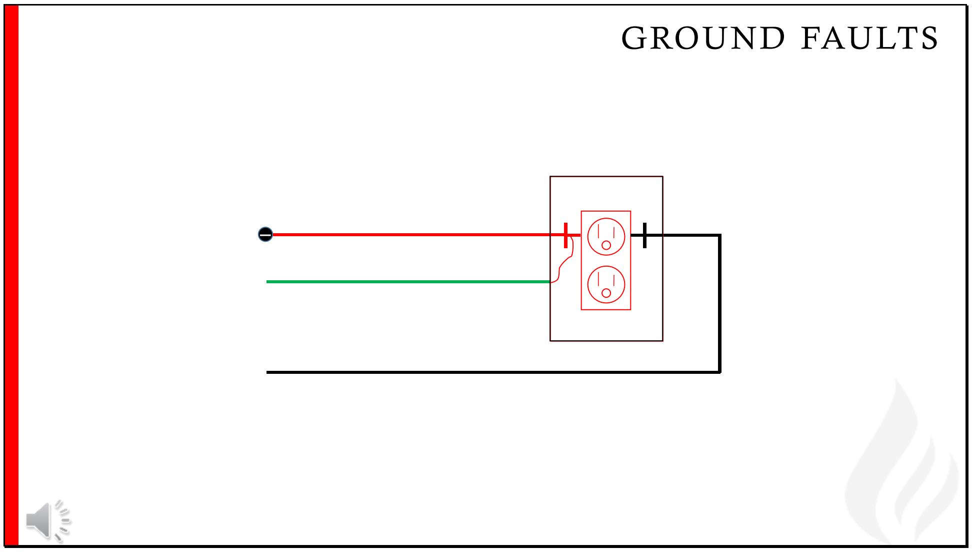
Examining evidence of damage to conductors can help in determining if electricity played a role in the ignition of a fire. This is a table taken from Jones and Bartlett’s Fire Investigation manual and is meant to aid in identifying different types of conductor damage and if it is a probable cause. However again it is strongly recommended that a subject matter expert be consulted before conclusions are drawn.

Slide 33



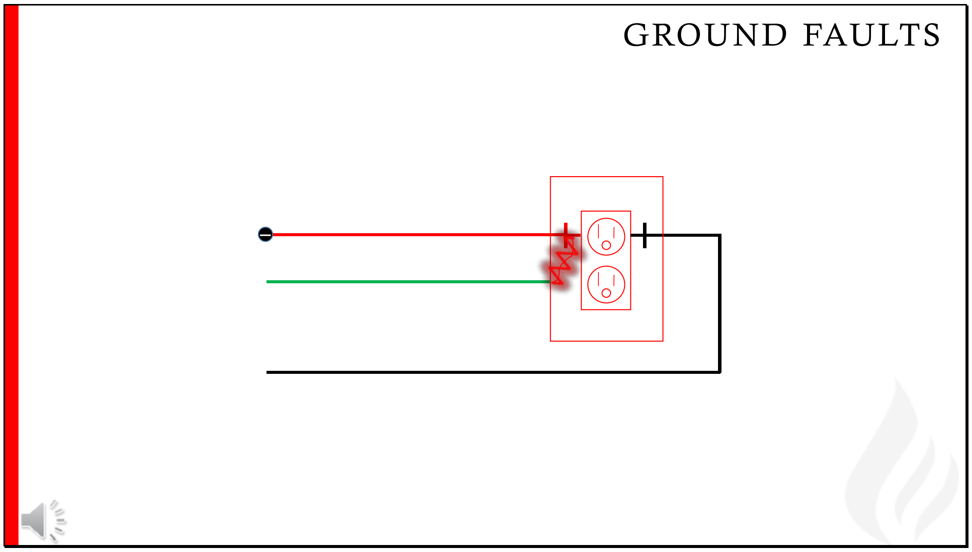
Dehaan video – Arc mapping

Slide 34



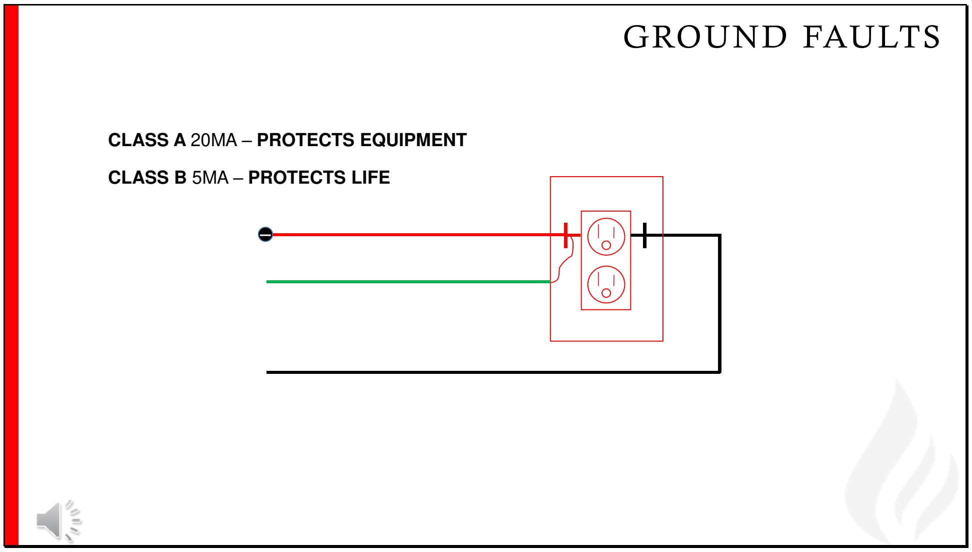
A ground fault is a fault that occurs between a line conductor and a grounded part or object. If the resistance of the fault path is low enough, a high current is produced and the circuit overcurrent protection will operate.

Slide 35



However, if the fault path offers a high resistance current my be limited to a values that my delay or negate operation of the circuit overcurrent device. This is referred to as a high resistance ground fault.

Slide 36



A GFCI or ground fault circuit interrupter is required on specific circuits to protect against ground faults. There are two classes of GFCI's, A class A is a device that is meant to protect equipment from ground faults and will allow approximately 20 milliamps of ground current to flow before operating, this type is used in higher ampacity services such as apartments and is often incorporated into the main service overcurrent device while a class B device is meant to protect life from shock hazard and is set to trip at only 5 milliamps. This is commonly found within a dwelling units electrical system.

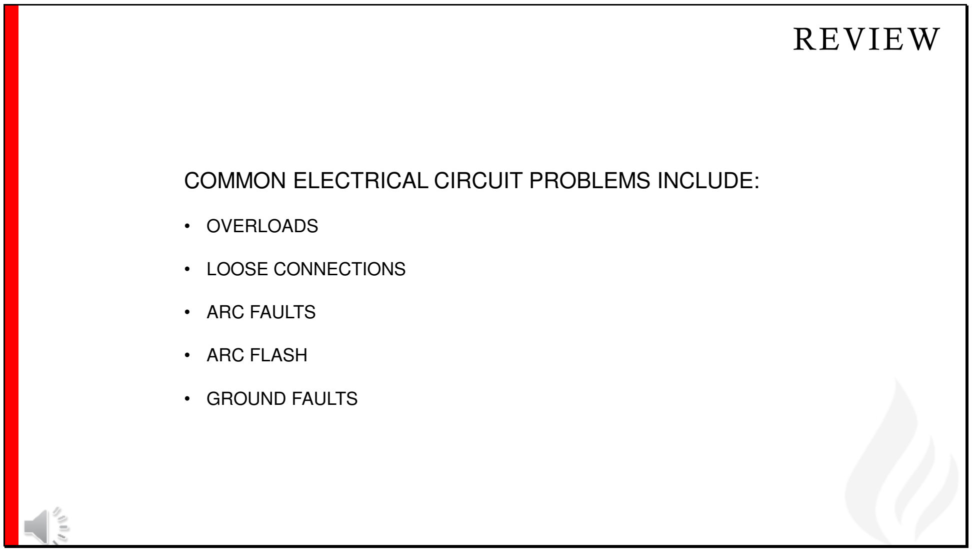
Slide 37

Like AFCI's, GFCI's also come in the form of a over current device that offers overcurrent and short circuit protection as well as ground fault protection.

Slide 38

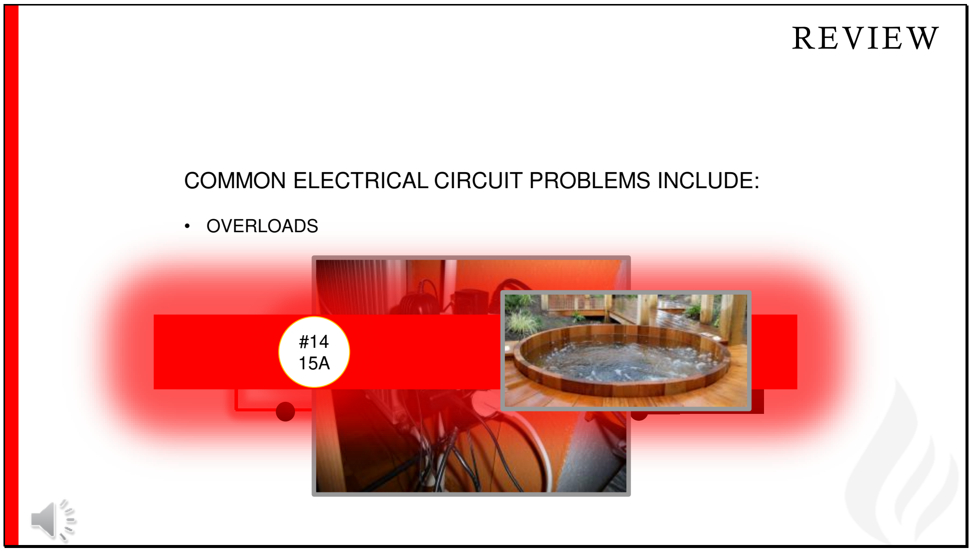
Both AFCI’s and GFCI’s are also available in the form of a receptacle. These offer only arc fault or ground fault protection to devices plugged into them and devices that are down stream in the electrical circuit, and do not offer overcurrent or short circuit protection.

Slide 39



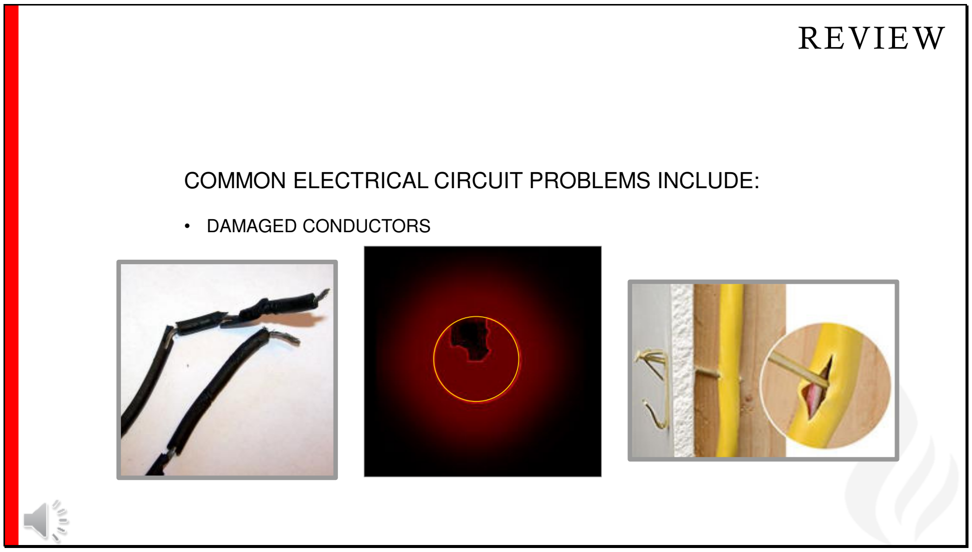
Let’s review, Common electrical problems include: Overloads, loose connections, arc faults, arc flash,
And ground faults the next few slides will review each of these problems.

Slide 40



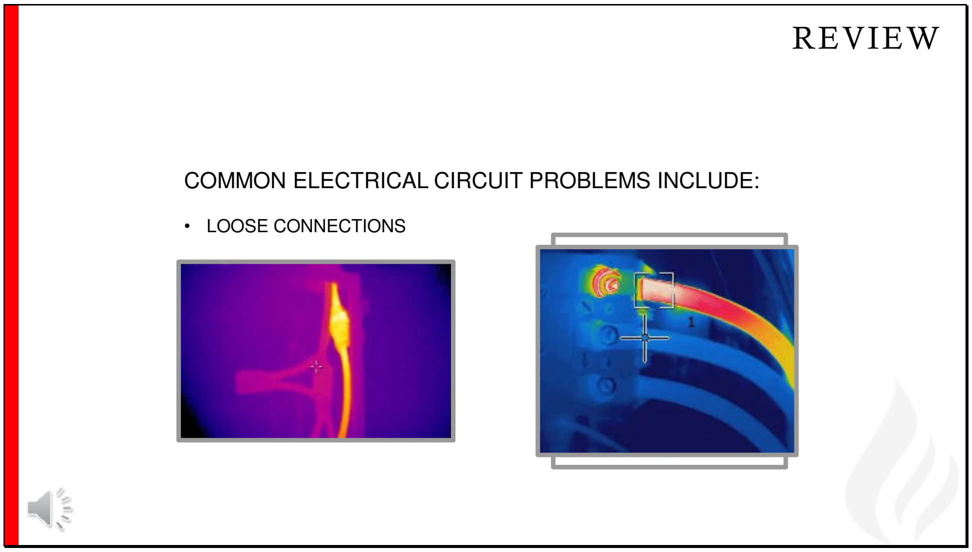
Common electrical problems include: overloads which is any situation in which a conductor carriers more current than it was intended for. Overloads are caused by things such as plugging in to many devices at one outlet, adding too may devices to a circuit during design or renovation, or under sizing conductors feeding an electrical load.

Slide 41



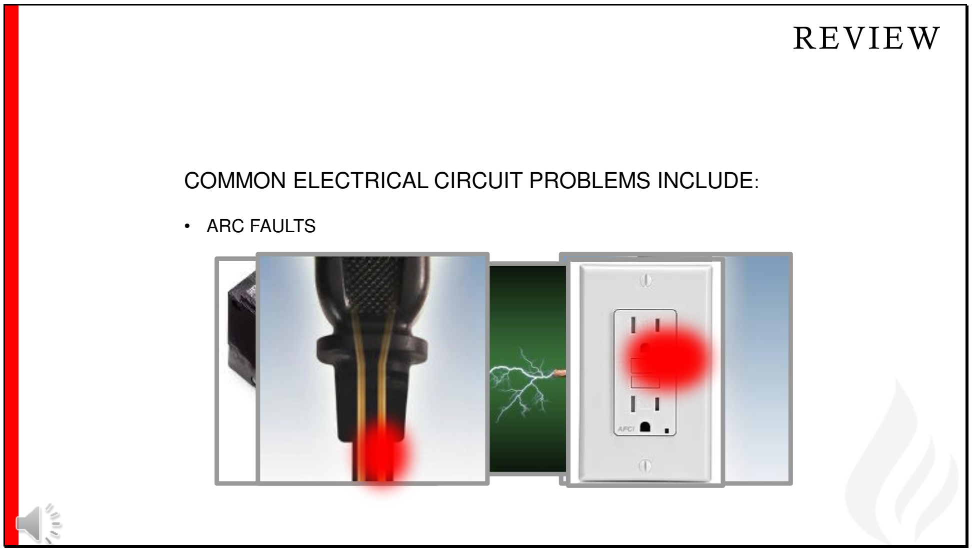
Damaged conductors, damaged conductors reduce the current carrying capacity of a conductor producing a localized hotspot. Damage to conductors happens in various ways.

Slide 42



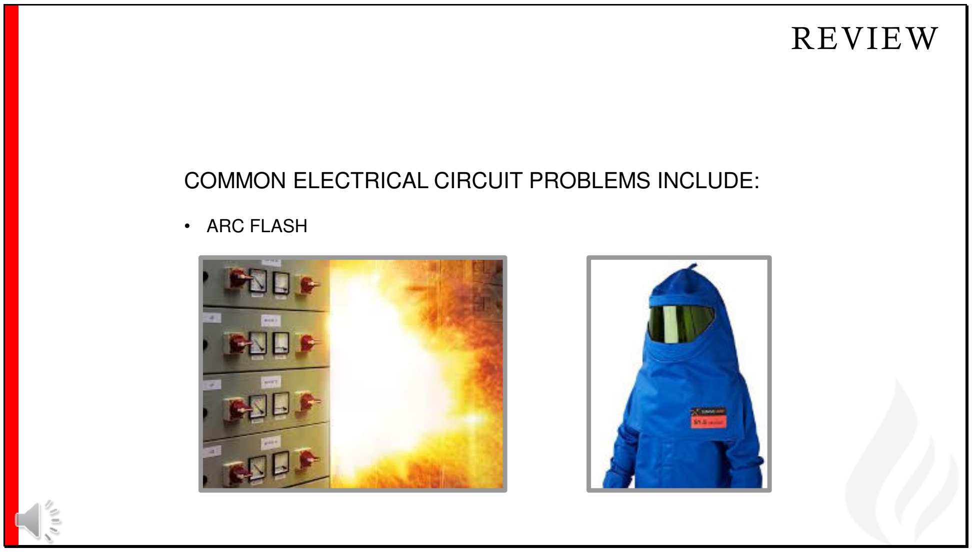
Loose connections. Loose connections produce heat at splices and terminations. Aluminum wiring is prone to developing loose and corroded connections if not properly terminated.

Slide 43



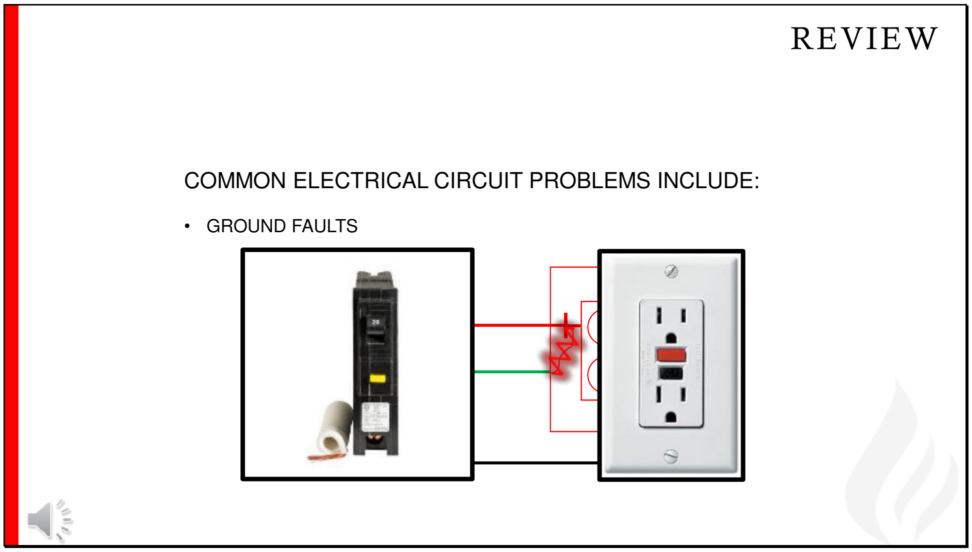
Arc faults…Arc faults occur when the resistance between conductors has been overcome by voltage. Arc faults can be series or parallel and produce significant heating. Arc faults are protected against using AFCI breakers and receptacles.

Slide 44



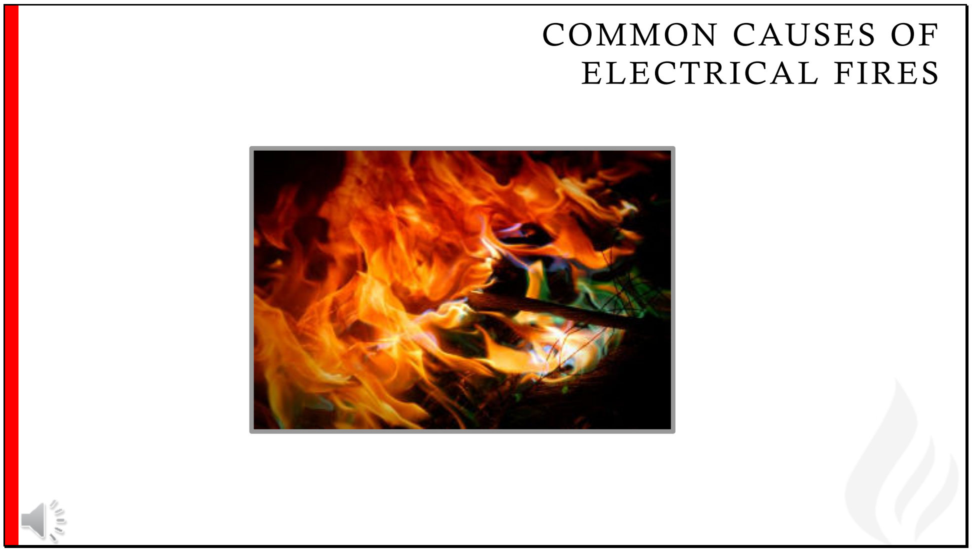
Arc Flash… An arc flash is a high energy electrical explosion that produces extreme temperatures and blast wave. PPE is required if any risk of arc flash is present.

Slide 45



Ground faults… A ground fault is a is a fault that happens between a line conductor and ground. A high resistance ground fault occurs when the path to ground possesses enough resistance to significantly limit current. This resistance could be in the connection to the grounded equipment or in the grounding system it self. GFCI breakers and receptacles protect against ground faults.

Slide 46

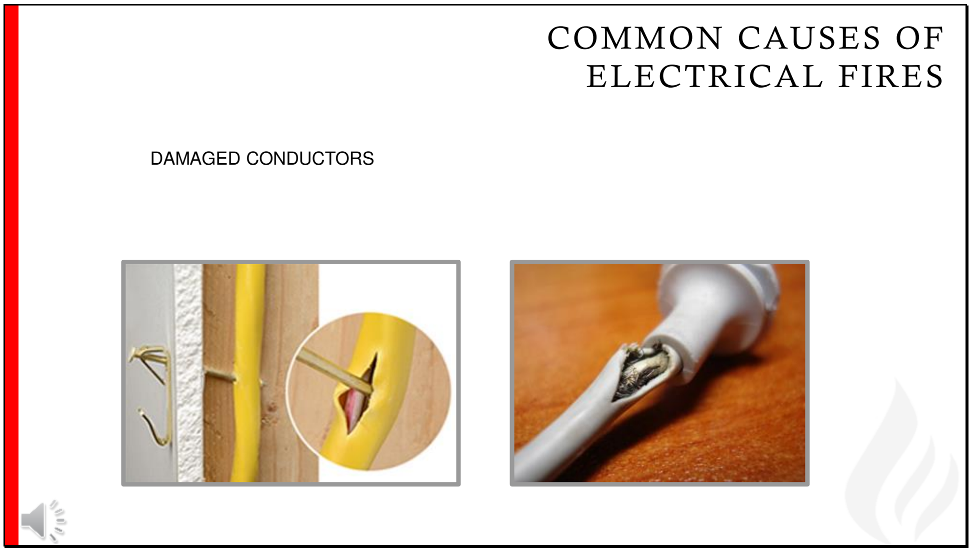


Common causes of electrical fires.

Slide 47

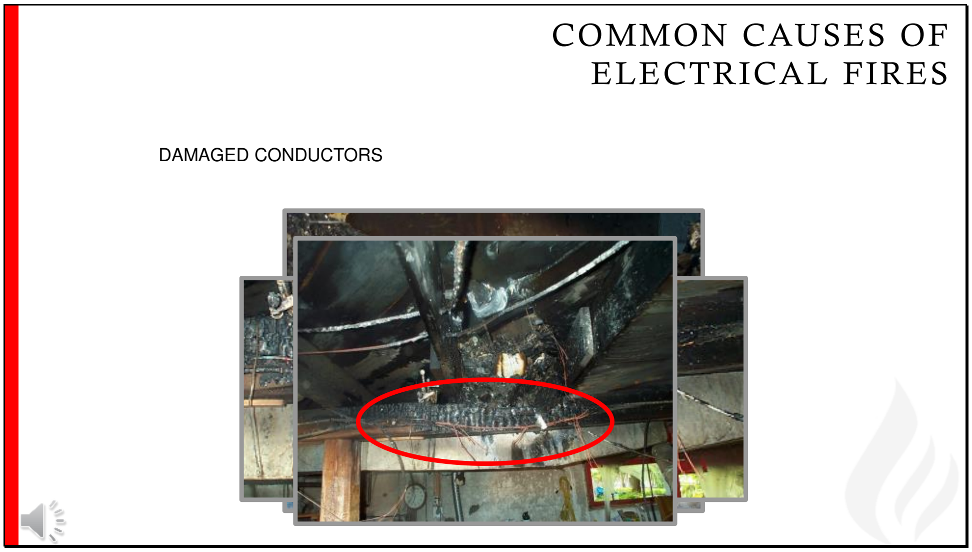
Common causes of electrical fires include: Overloads. Often overloads occur in the electrical components of appliances. Such as coffee makers and dishwashers amongst others. Cheaply made electronics and power bars produced for discount retailers are often knocked off unapproved products and can be prone to failure and sometimes overloads are simply caused by ignorance.

Slide 48



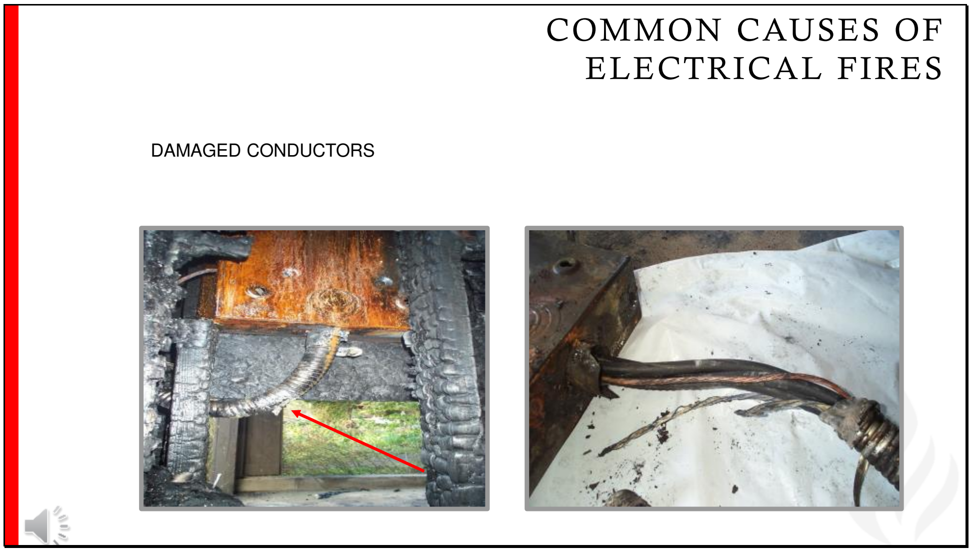
Damaged conductors… Damaged conductor produce localized heating either by resistive heating or an arcing fault and can be an ignition source. Damaged and frayed cords that supply things like lamps can are a known fire starter.

Slide 49



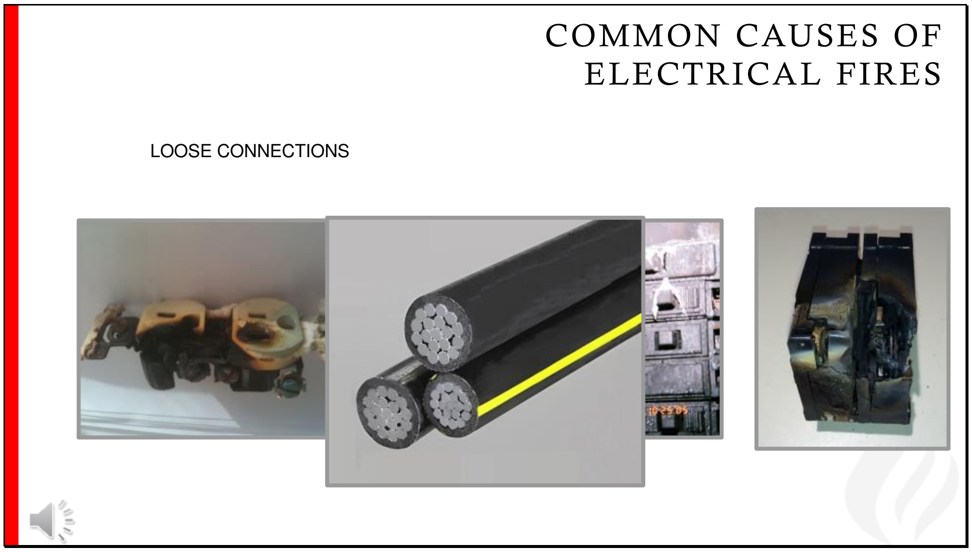
Damage to a conductor caused by a nail was determined to be the source of ignition in a fire death. During the fire investigation, it was determined that the fire originated just below ceiling level on a beam in the basement of the house. The fire travelled through the basement floor into the living room above. On closer examination electrical wires were identified in the area of origin of the fire. After taking a number of photographs, the investigators cut the beam out and took it to a woodworking shop where they use a planner to remove the char layer. After replacing the beam the electrical wires were put back into place and there was an obvious nail whole where the wires had broken. A nail was placed in the hole to graphically demonstrate the cause of the fire. It should be noted that an electrical inspector and an electrical engineer both confirmed that resistance heating by electricity was the cause.

Slide 50



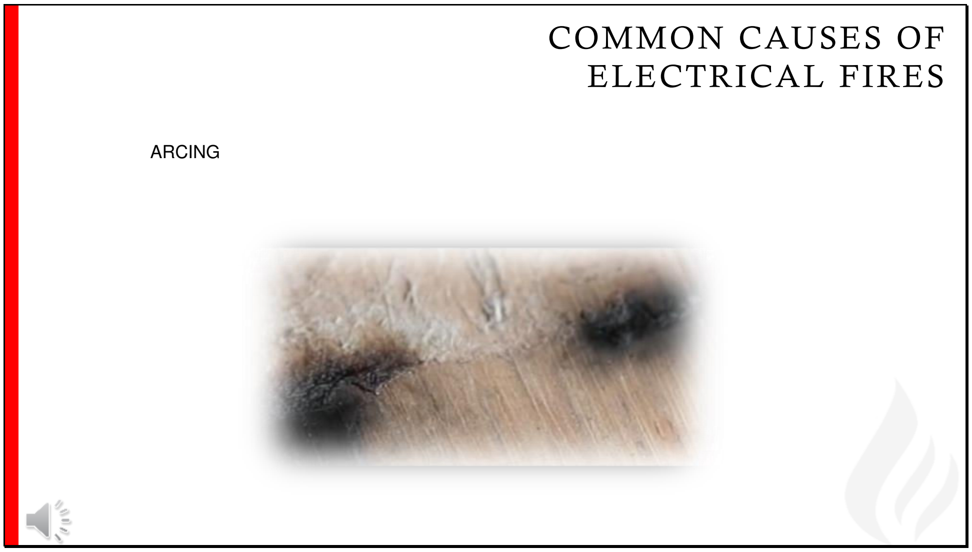
Don’t be fooled. In this case damage to the armor of a electrical cable led to suspicion as to the cause of a fire. However the fire investigator did not disturb the conductor and had a electrical inspector investigate. It was found that the conductors within the armor were undamaged and the conductor was discluded as a possible cause.

Slide 51



Loose connections… Significant heat can be developed at loose connections. This could be at the branch circuit level or at the electrical panel. Aluminum wire is prone to loose connections and in modern electrical systems is usually only found to be used for service conductors, an sub feeders that supply sub panels.

Slide 52



Arcing… Arcing produces significant heat and ignite surrounding combustible materials. Arcing can be the result of failed insulation, loose connections, contamination by conductive elements or a ground fault just to name a few.

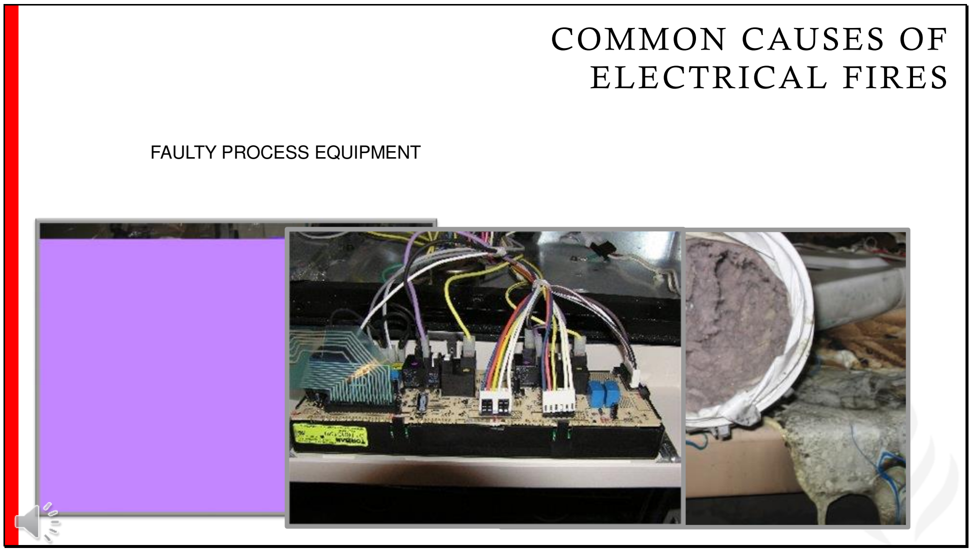
Slide 53

COMMON CAUSES OF ELECTRICAL FIRES

FAULTY OVERLOAD EQUIPMENT

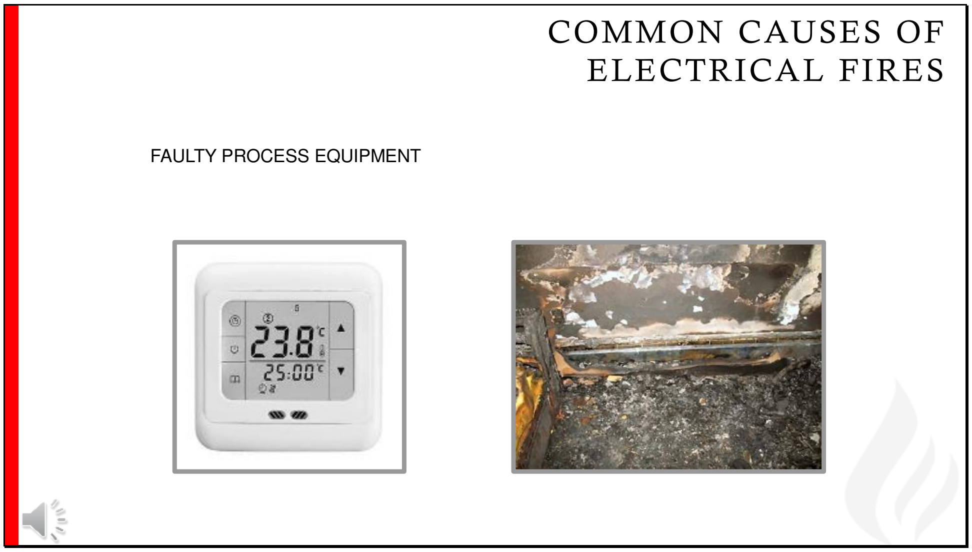
Faulty overload equipment. Occasionally breakers fail. This can lead to overloads that are never interrupted resulting in fire. It is not uncommon for a line of breakers to be recalled. I have even heard of knock off breakers being sold at wholesalers that were little more than a switch that offered no overload protection.

Slide 54



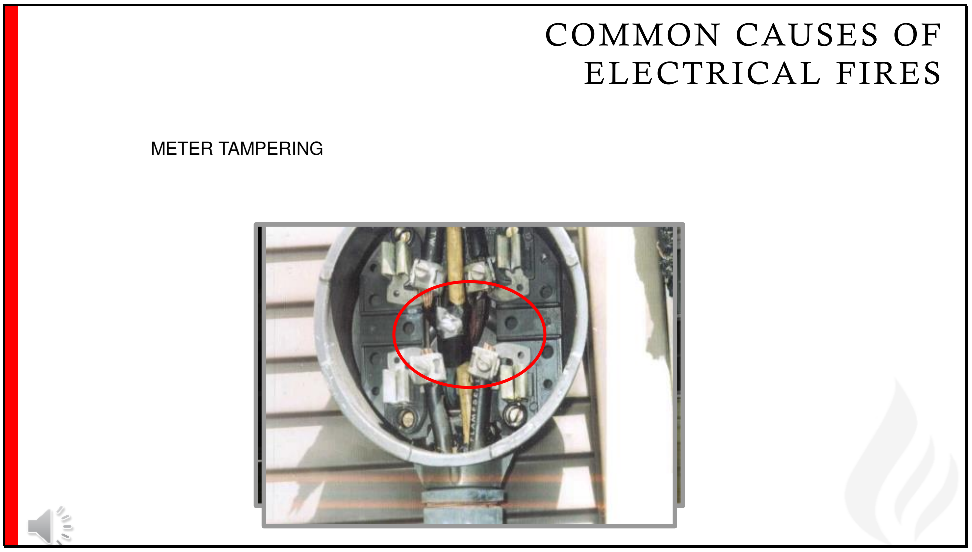
Faulty process equipment… Appliances and equipment increasingly rely on electronic process control. A fault dew to arc tracking or erroneous signal in a circuit board can cause a failure to shut down in response to a high temperature. A classic example of this is a dryer fire where a clogged dryer vent results in a trapped heat, the high temperature limit failed to operate and the result was a fire.

Slide 55



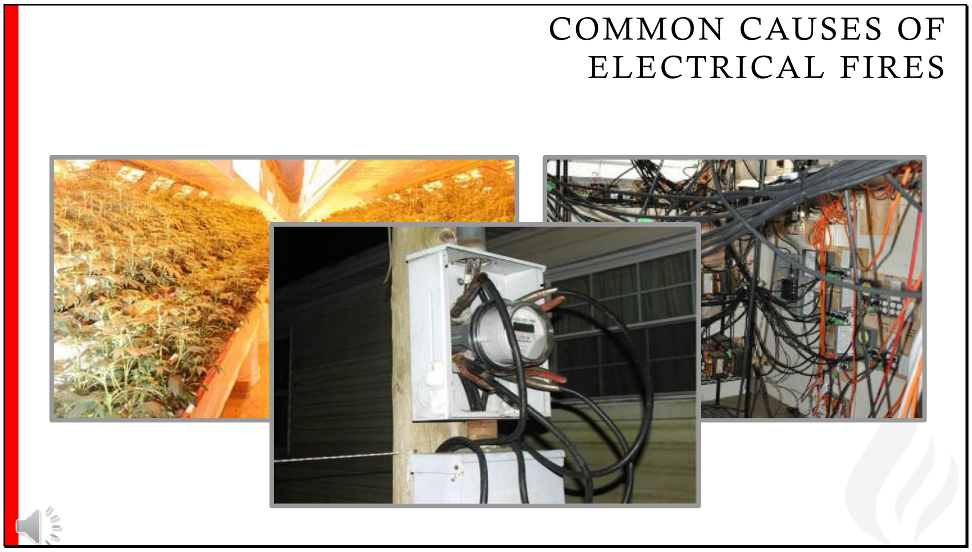
Another example of a process control fault is a malfunctioning thermostat causing it to continuously call for heat because of a damaged electronic component. This can result in a failure of heating equipment or subjecting adjacent combustible material to excessive heat.

Slide 56



Meter Tampering… Electrical meters are sometimes by-passed in order to steal electricity. This is a particularly bad idea as there is no overcurrent protection between the transformer at the street and the main over current device. Meter by-passes are done illegally with out oversite or by knowledgeable people resulting in pour workmanship and undersized equipment that exacerbates the danger.

Slide 57



Meter tampering is associated with Illegal marijuana grow opts. Manny other unsafe electrical practices and general questionable judgments is associated with this activity.

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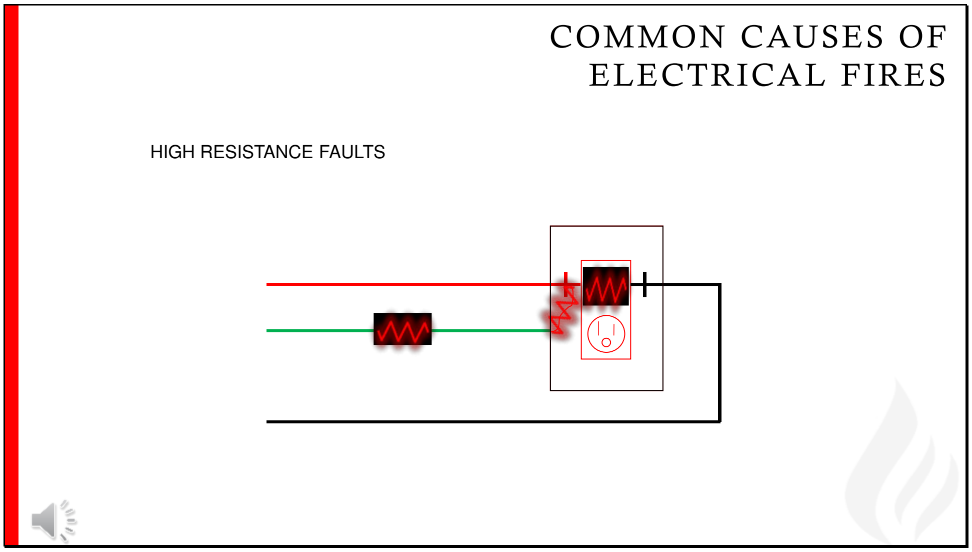

High resistance faults…High resistance faults can be another source of ignition. High Resistances can be found in the fault connection or in the ground system itself as well as in electrical devices or appliances that connect to them.

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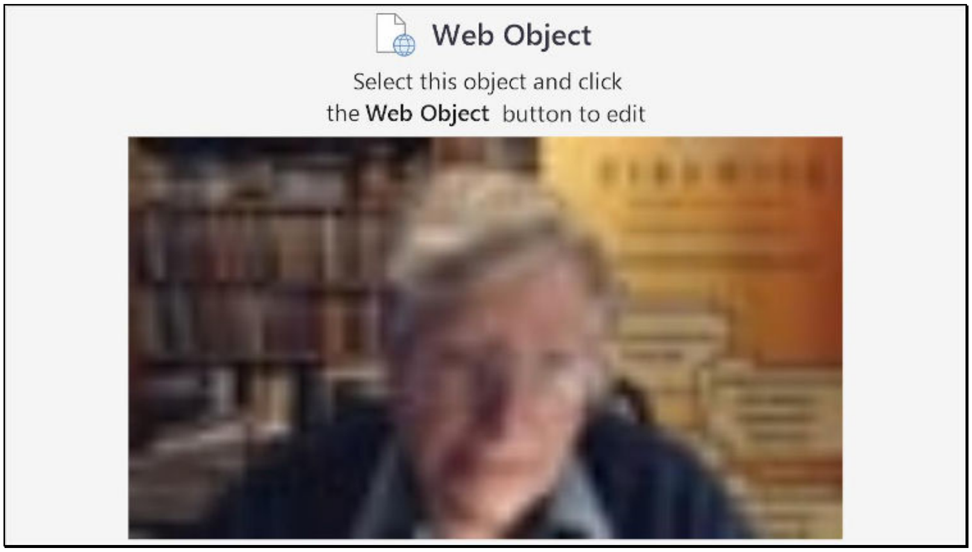
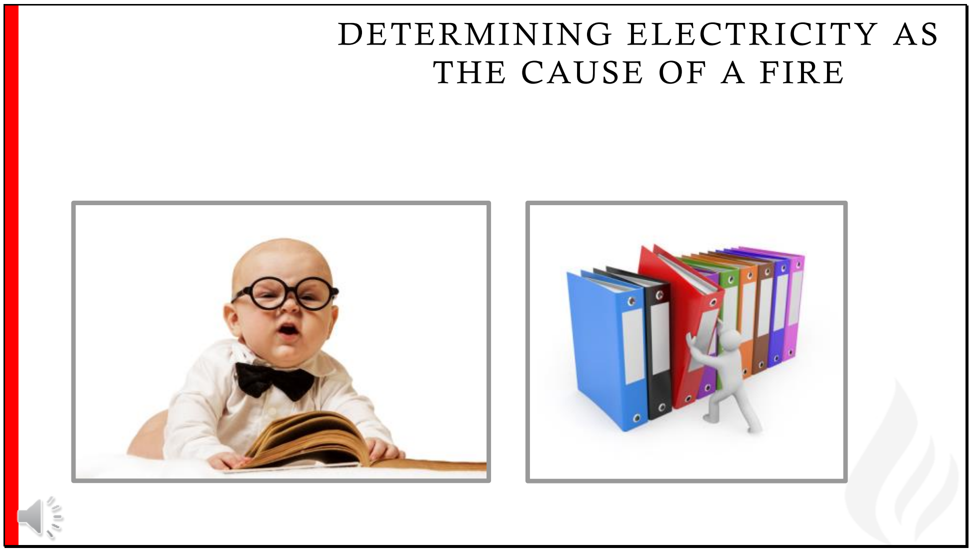


Dehaan video Dr. DeHaan: Easiest to Blame Cause of Fire

Slide 60



When determining electricity as the cause of a fire an expert opinion should be obtained . Documentation should include location of the fire damage, location of outlets and switches, the size and type of conductor used to supply the circuit and any damage to it, and the rating of the overcurrent device that was protecting the conductor.

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Dr. DeHaan video Dr. DeHaan: Qualifications and Determining Electrical Cause

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REVIEW

COMMON CAUSES OF ELECTRICAL FIRES INCLUDE:

- OVERLOADS
- DAMAGED CONDUCTORS
- LOOSE CONNECTIONS
- ARCING
- FAULTY OVERLOAD EQUIPMENT
- FAULTY PROCESS CONTROL EQUIPMENT
- METER TAMPERING
- HIGH RESISTANCE FAULTS

Let’s review, Common causes of electrical fires include: Overloads, damaged conductors, loose connections, arcing, faulty overload equipment, faulty process control equipment, meter tampering and high resistance faults.

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CHAPTER REVIEW

THE BASICS OF ELECTRICITY

OHMS LAW & WATTS LAW

CONDUCTORS & AMPACITY RATINGS

ELECTRICAL TERMS & COMMON PROBLEMS

ARC MAPPING

ELECTRICAL SAFTEY & PPE

COMMON CAUSES OF ELECTRICAL FIRES

In this unit we discussed: The basics of electricity which included the concepts of voltage, current, resistance, power and static electricity. Ohms law and watts law and how they describe they relationship between electrical values. Conductors and common ampacity ratings and how the AWG, length and conductor material affect them. Electrical terms and common problems such as overloads, conductor damage, loose connections, arc faults and flash, ground faults and high resistance faults. Arc mapping and how it can assist in an investigation. Electrical safety and PPE as described in the NFPA 921, and common causes of electrical fires such as overloads, conductor damage, loose connections, faulty equipment, process control failure, meter tampering, and high resistance faults.

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Please move on to part 4