6

Electricity and Fire

6

Knowledge Objectives (1 of 3)

- Explain basic electricity.
- Discuss the elements of Ohm's law and how they relate to each other.
- Discuss the role of ampacity in electrical conductors.

6

Knowledge Objectives (2 of 3)

- Describe the components of a building's electrical system.
- List the conditions that must exist for ignition from an electrical source.

6

Knowledge Objectives (3 of 3)

- Describe how to interpret damage to electrical systems.
- Explain static electricity.

6

Skills Objectives (1 of 2)

- Complete calculations based on Ohm's law.
- Determine whether a circuit has proper overcurrent protection.
- Identify which circuits have overcurrent or are overloaded based on a blown fuse or tripped circuit breaker in a panel.

6

Skills Objectives (2 of 2)

- Examine fire damaged electrical conductors, and determine whether the damage is the result of electrical activity or a result of the fire.

6

Introduction (1 of 2)

- Knowledge of electricity and electrical systems
  - Determine whether damage is from electrical activity or fire
- Electricity can be defined by how it behaves.
- A qualified individual should assist the investigator if the investigator is not qualified to perform electrical analysis.

6

Introduction (2 of 2)

- Treat systems initially as if they are energized ("live").
  - Use NFPA 70E as a guide for electrical safety.
  - Assess the HRC prior to analysis.

6

Basic Electricity (1 of 2)

- Closed hydraulic system comparison to electrical
  - Pump/Generator or battery
  - Pressure/Voltage (*E*)
  - Water/Electrons
  - Flow/Current (*I*)

6

Basic Electricity (2 of 2)

- Closed hydraulic system comparison to electrical (cont'd)
  - Valve/Switch
  - Friction/Resistance (*R*) measured in ohms (Ω)
  - Friction loss/Voltage drop
  - Pipe or hose size/conductor size

6

Ohm's Law (1 of 2)

- Voltage = current × resistance, or
- Volts = amperes (amps) × ohms
- Most useful measurement in working with postfire circuits is resistance

6

Ohm's Law (2 of 2)

Table 6-2 **Ohm's Law Relationship**

Value	Symbol	Units
Voltage	*E*	Volts
Current	*I*	Amperes (amps)
Resistance	*R*	Ohms
Power	*P*	Watts

Note the difference between symbols and units, as well as the relationship between the unit values when analyzing electrical circuits.

6

Power

- Electrical power is the rate of doing work in an electrical circuit.
- Power(*P*) = voltage × current
- Power is measured in watts.

6

Relationship Among Voltage, Current, Resistance, and Power (1 of 2)

- The Ohm's law wheel is useful for determining one parameter in terms of any two others.

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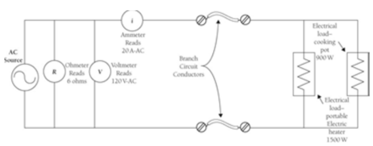
Relationship Among Voltage, Current, Resistance, and Power (2 of 2)



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Overload Situations

- Overload persists for a longer time
  – Can cause dangerous overheating
- In contrast , a short duration fault is called an overcurrent
  – Not usually serious
- Warning signs:
  – Past circuit breaker tripping
  – Household wiring that is poorly connected

6

Wire Gauge

- Given by AWG (American Wire Gauge)
- The smaller the AWG number, the larger the wire diameter .
- Common household wiring: 14 and 12 AWG
- Large appliances: 6, 8, or 10 AWG

6

Ampacity

- Current flow is measured in amperes.
- Ampacity is how much current a conductor can carry without exceeding its temperature rating.

6

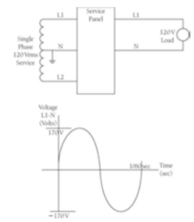
Alternating Current and Direct Current
(1 of 3)

- AC is most common in buildings, structures, and dwelling units.
  - Current flows in and out in a cycle
  - Voltage is also alternating, from – to +
- Root mean square (RMS)
  - Converts AC to DC

6

Alternating Current and Direct Current
(2 of 3)

- Single phase AC sine wave for 120 V RMS use.



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Alternating Current and Direct Current
(3 of 3)

- DC system has current with one polarity only
  - Used when controlled voltage levels are required
  - Some appliances and industrial control systems
  - Mobile or portable equipment such as electric vehicles and wheelchairs

6

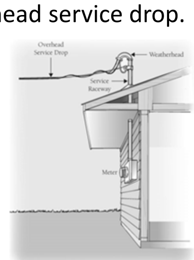
Single-Phase Service (1 of 2)

- Requires three conductors:
  - 2 line conductors (“hot legs”)
  - 1 neutral conductor, grounded near the source transformer outside the building
- Residences and small commercial buildings
- Cables delivered overhead (service drop) or underground

6

Single-Phase Service (2 of 2)

- Triplex overhead service drop.



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Three-Phase Service

- Requires four conductors:
  - 3 hot; one neutral and grounded
- Industrial and large commercial buildings
- Large multifamily dwellings
- Transformers are used to step down or step up voltages to meet needs of the building.

6

Building Electrical Systems

- Service entrance (meter and base)
- Grounding
- Overcurrent protection
- Circuit breaker panels
- Branch circuits
- Conductors
- Outlets and special fixtures/devices

6

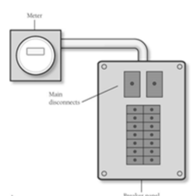
Service Entrance (1 of 3)

- Point where electrical service enters building
- Consists of:
  - Weatherhead
  - Meter base
  - Meter
- Service equipment includes main disconnect

6

Service Entrance (2 of 3)

- Service entrance and breakers.



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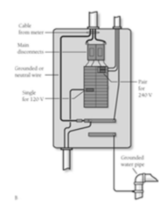
Service Entrance (3 of 3)

- Main electrical panel.



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Grounding

- Electrical connection between system and ground
  - Provides safe return pathway if fault occurs
- At service entrance, breaker or fuse panel is connected to:
  - Bare cold water pipe
  - Grounding electrode

6

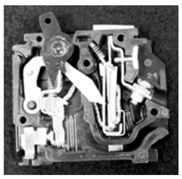
Overcurrent Protection (1 of 4)

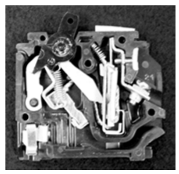
- Provided by a series-connected, current-interrupting device
- Circuit breakers, fuses
  - Stop flow of electricity when abnormally large current flow is detected
- Once protective device is tripped, cause must be identified

6

Overcurrent Protection (2 of 4)

- A 15 A residential-type circuit breaker in closed (ON) position, left, and in the open (OFF) position, right.





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Overcurrent Protection (3 of 4)

- Interrupting current rating is the maximum amount of current the device is capable of interrupting.
- Types of circuit protection devices:
  - Fuses and circuit breakers are most common
- The time current curve for breakers and fuses defines the amount of time required for a device to interrupt at a level of current.

6

Overcurrent Protection (4 of 4)

- Special kinds of circuit breakers:
  - GFCI breakers sense when current is returning via unexpected path (used in bathrooms and other rooms where water is present)
  - AFCI breakers monitor current for abnormal conditions

6

Circuit Breaker Panels

- Blow holes may occur in panel wall
  - If the separations and insulation are not maintained
- Arcing damage to panel may be:
  - Source of fire
  - Result of fire

6

Branch Circuits

- Distribute electricity from circuit breaker or fuse panel throughout building
- Each circuit should have its own overcurrent protection device.
  - Called branches
  - Single connection point in the service panel and conductor going to multiple loads

6

Conductors (1 of 2)

- The larger the AWG number, the smaller the wire diameter.
- Conductors may be larger—but not smaller—than required.
- Common materials: copper, aluminum, copper-clad aluminum
- Conductors are insulated.

6

Conductors (2 of 2)

- Conductor's color typically indicates function
  - Green: grounding conductor (neutral)
- Assume all conductors are hot until proven otherwise.
- Carry a voltage stiffer.

6

Outlets and Special Fixtures/Devices

- Circuits terminate at, or connect to:
  - Switches
  - Receptacles
  - Appliances
- Lighting fixtures are usually connected to junction boxes in the wall or ceiling.
- GFCI outlets are used in bathrooms, kitchens, other wet locations

6

Ignition by Electrical Energy (1 of 2)

- Occurs if:
  - Power is on
  - Sufficient heat and temperature are produced
  - Combustible material is present
  - Heat source and combustible fuel are close enough for a sufficient period of time

6

Ignition by Electrical Energy (2 of 2)

- Some cases where sufficient heat may be generated:
  - Resistance heating (heating element or resistive connection)
  - Ground fault or short circuits
  - Parting arcs
  - Excessive current
  - Proximity of combustibles to heaters

6

Heat-Producing Devices, Excessive Current, and Poor Conditions

- Some devices are designed to generate heat.
  - Where heat cannot dissipate, ignition is possible.
- Excessive current can allow heating elements to exceed their design limit.
- Poor connections can heat at the connection point.
  - Keeping connections in an electrical box or appliance enclosure reduces chances of ignition.

6

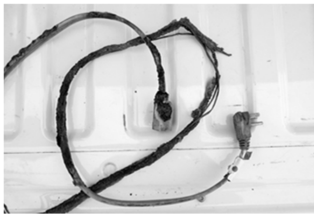
Overcurrent (1 of 2)

- Temporary excessive flow of current due to:
  - Fault (e.g., short circuit)
  - Too many loads on circuit (e.g., too many appliances)
- Fire potential is determined by magnitude and duration of overload.

6

Overcurrent (2 of 2)

- Electrical cord fire damage.



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Arcs (1 of 2)

- High-temperature discharges across a gap where conductor is missing
- May cause ignition if ignitable vapors are present or if certain solid fuels are present
  - Cotton batting, dust, lint

6

Arcs (2 of 2)

- High-voltage arcs: produced at transformer connection or due to lightning
- Parting arcs: brief discharges created by opening a switch or pulling a plug
- Arc tracking: path of electrical current builds up on surfaces of non-combustible material over time
- Sparks: metal particles thrown out by arcs

6

High-Resistance Faults

- Current flow is not sufficient to trip protective device, but generates heat
- May ignite combustibles
- Hard to find evidence after a fire

6

Interpreting Damage to Electrical Systems (1 of 2)

- Whether electricity played a role in causing a fire can often be determined by:
  - Arc mapping
  - Short circuit and ground fault parting arcs
  - Arcing through char
  - Overheating connections

6

Interpreting Damage to Electrical Systems (2 of 2)

- Whether electricity played a role (cont'd):
  - Overload
  - Melting by electrical arcing
  - Melting by fire
  - Alloying
  - Mechanical gouges

6

Arc Mapping

- Identifies arcs that occurred within a circuit
  - First arcing usually occurs farthest from power source
  - Additional arcing occurs sequentially toward power source

6

Short Circuit and Ground Fault Parting Arcs

- Parting arc melts metal only at point of contact
  - Surface of arced contact point appears notched or beaded (melted under microscopic examination)
  - Companion point of damage confirms that fault occurred between the two points
- “Arced and severed”
  - Wires break into segments.

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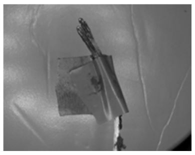
Arcing Through Char

- Charred insulation may become more conductive, allowing sporadic arcing between energized conductors.



Courtesy of Jason Mignano, CFEI

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Overheating Connections (1 of 3)

- Poor connections are likely places for overheating.
- Can often be verified by
  - Color changes
  - Deformed or destroyed potions of the metal

6

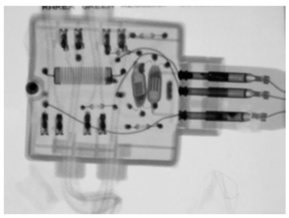
Overheating Connections (2 of 3)

- Photo of poor contact connections.

6

Overheating Connections (3 of 3)

- X-ray of poor contact connections.



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Overload

- Overload happens when overcurrents are large enough and persistent enough to cause damage.
  - Most likely to occur on stranded cords
  - Overheating may cause sleeving.
  - May cause ignition of fuels in the vicinity
  - Conductor may melt

6

Melting by Electrical Arcing

- Sharp line of demarcation occurs
- Techniques used to detect:
  - Gloves that snag on small notches on the conductor
  - Magnification to detect damage
  - Evidence of dislodged material that has collected on nearby surfaces
  - Metallurgical analysis

6

Melting by Fire (1 of 3)

- Solid copper conductors
  - Fire blisters and distorts surface
  - Some hanging droplets
  - Irregular globules of resolidified copper
  - No distinct line of demarcation

6

Melting by Fire (2 of 3)

- Stranded conductors
  - Stiffen as they reach melting temperature
  - Individual strands melt together.
  - Continued heating leads to conditions similar to those seen in solid conductors

6

Melting by Fire (3 of 3)

- Aluminum conductors
  - Low melting temperatures
  - Melt in any fire; solidify into irregular shapes
  - Are of little help in determining fire's cause

6

Alloying (1 of 2)

- Alloying is the combining of metals of different physical properties.
- Copper/aluminum alloy
  - Lower melting point than either pure metal
  - Brittle and may break easily

6

Alloying (2 of 2)

- Copper/zinc = brass
- Copper/tin = bronze
- Copper/silver alloy
  - May be seen on relays, thermostats, and contactors

6

Mechanical Gouges

- Can be distinguished from arcing marks by microscopic examination
- Usually show scratch marks, dents in insulation, or deformation of conductors
- Do not exhibit fused surfaces

6

Considerations and Cautions (1 of 2)

- Some prior beliefs about the following subjects have been updated after being tested scientifically:
  - Undersized conductors
  - Nicked or stretched conductors
  - Deteriorated or damaged insulation

6

Considerations and Cautions (2 of 2)

- Some prior beliefs about the following subjects have been updated after being tested scientifically (cont'd):
  - Overdriven or misdriven staples
  - Short circuits
  - Beaded conductors

6

Collecting Evidence (1 of 2)

- Document damaged conductors before disturbing them:
  - Location of damage in room
  - Switches, outlets, collections, and branch circuit that are connected to the damaged conductor
  - State of overcurrent protection for that branch
  - Photograph and sketch the scene.

6

Collecting Evidence (2 of 2)

- If damaged conductor is cut away from the circuit:
  - Make cuts far away from the damaged area
- Label pieces of evidence with locations where found
- Avoid cleaning conductors
  - This may remove evidence.

6

Static Electricity (1 of 2)

- Results from buildup of a stationary charge caused by rubbing or movement of one object on another
- Can be caused by conveyor belts moving over rollers, flowing liquids

6

Static Electricity (2 of 2)

- Spraying operations, especially high-pressure ones, can produce significant static charges.
- Static can build up when a flowing gas vapor is mixed with metallic oxides, scale particles, dust, and liquid droplets or spray.

6

Controlling Accumulations of Static Electricity

- Charges can be removed or dissipated through humidification, bonding, and grounding.
- Bonding reduces electrical potential differences between two conductive objects.
- Grounding reduces electrical potential differences between objects and the earth.

6

Conditions Necessary for Static Arc Ignition

- Five conditions are necessary:
  - A means of static charge generation
  - A means of accumulating and maintaining charge
  - A discharge arc with sufficient energy
  - A fuel source with the right air mixture and with small enough ignition energy
  - Co-location of arc and fuel source

6

Investigating Static Electric Ignitions

- May require gathering circumstantial evidence
- The five conditions listed on previous slide must exist.
- Eyewitness reports can help determine the location of the fire.

6

Lightning (1 of 2)

- Can enter a structure in four ways:
  - Striking a metal object on top of a structure
  - Striking the structure itself
  - Striking a nearby tall structure or the ground and moving horizontally to the structure
  - Striking overhead conductors

6

Lightning (2 of 2)

- Damage may be to the structure or to the electrical system.
  - Pay attention to any point where the building object may be grounded.
  - Both line-voltage (120 V AC) and low-voltage (< 50 V DC) are susceptible to lightning damage.

6

Summary (1 of 9)

- Understanding the basic principals of electricity, including Ohm's law, calculation of power, and current flow in a circuit, helps to quantify the electrical energy available in a circuit.
- With the amount of energy known, you can focus on the distribution (conductors) and load part of the circuit.

6

Summary (2 of 9)

- Establishing the ampacity (or current capacity) of the conductors allows the investigator to determine whether an overcurrent condition exists, resulting in increased heat.
- Characteristics of the different types of conductors include size (AWG), type of metal, and stranding, which affect the ampacity of the conductor.

6

Summary (3 of 9)

- Overcurrent protection protects the electrical distribution system, primarily the conductors, but can also protect upstream equipment, such as transformers, and downstream loads, such as motors.

6

Summary (4 of 9)

- Understanding the different types and ranges of overcurrent protection devices helps to identify problems arising from improper selection such as overfusing.

6

Summary (5 of 9)

- Circuit protection must be installed in the ungrounded or hot side of the load to prevent shock hazards.
- An overfused circuit should be checked as a potential heat generator.

6

Summary (6 of 9)

- A competent ignition source, high temperature, acceptable combustible material, and proximity are requirements for a fire.
- To be an electrical caused fire, the energy source must be electrical, and the heat must be due to electrical current in the conductors and the load, whether intentional or not.

6

Summary (7 of 9)

- Understanding the voltages, connections, and entrance equipment is important because this is where the energy originates.
- The most common systems in residential and commercial structures are 120/240-volt, single-phase, and sometimes three-phase electrical systems.

6

Summary (8 of 9)

- Voltages are expressed in RMS and current in amps, and typically, AC voltages are used that have a sine waveform.
- Careful documentation of arcing, melting, and severed connections can provide clues as to whether damage is the result of electrical activity or the fire.

6

Summary (9 of 9)

- A map showing electrical activity can aid the investigator in determining the origin and progression of a fire.
- Other sources of electrical energy, static charge, and lightning can play a significant role in a fire, and their creation and characteristics should be understood.