Electricity & Electrical Fires

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NFPA 921 2017 Chapter 9
NFPA 1033 2014 1.3.7 (16)

Knowledge Objectives (1 of 2)

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

Knowledge Objectives (2of 2)

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

Skills Objectives

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

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.

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.
- Emphasis will be on 120/240 v a/c single phase systems typically found in residential and commercial buildings

Important Rules

- Always determine the area/point of origin first
- Electrical in the area of origin does not = cause, carefully evaluate the electrical components; as a rule used/protected properly electricity is safe
- Fire destroys evidence and alters the appearances of electrical conductors/equipment etc.

NFPA 921 9.1.1 & 9.1.2

Direct Current & Alternating Current

- Direct current (DC) was "mastered" by Edison in 1884.
  - Flows in one direction
- Alternating current (A/C) was (modern) was developed by Nikola Tesla (1884).
  - Flow back and forth and on the 60 hz (60 cycles per second)

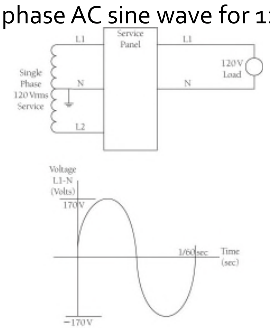
NFPA 921 9.2.2.4

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

Alternating Current and Direct Current
(2 of 3)

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



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

Basic Electricity (1 of 2)

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

NFPA 921 9.2.2.2

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 (AWG)

NFPA 921 9.2.2.1 – 9.2.2.3

Ampacity

- Current flow is measured in amperage
- Amperage a conductor can safely carry without exceeding its temperature rating (ambient temperature basis)
  - Determined by resistance (ohms) per 1000 feet at 70 degrees Celsius
    - 14 ga = 3.1
    - 12 ga = 2.0
    - 10 ga = 1.2

NFPA 921 9.2.3

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

Conductor Conductivity

- Gold – best conductor
- Silver
- Copper – produces much less heat than aluminum
- Aluminum – has more resistance than copper
- Steel

NFPA 921 9.2.4

Ohm's Law (1 of 2)

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

NFPA 921 9.2.5

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.

Power

- Electrical power is the rate of doing work in an electrical circuit. The is a rate of energy which we call power.
  - Electrons are moving!
    - This creates power to our bulbs
    - This creates an unwanted but necessary heat in the conductor and equipment we are powering
- Power(*P*) = voltage × current
- Power is measured in watts.

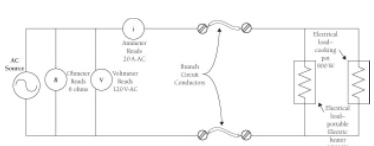
NFPA 921 9.2.6

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.

NFPA 921 9.2.7

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



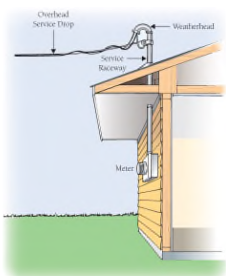
NFPA 921 9.2.7

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

Single-Phase Service (2 of 2)

- Triplex overhead service drop & service lateral.



A. *The service lateral is the underground conductors between the utility electric supply system and the service point.*

Single-Phase Transformer

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.

NFPA 921 9.3.2.2

Three-Phase Transformer(s)

Building Electrical Systems

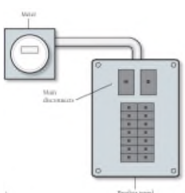
- Service entrance (meter and base)
- Grounding
- Overcurrent protection
- Circuit breaker panels
- Branch circuits
- Conductors
- Outlets and special fixtures/devices

Service Entrance (1 of 3)

- Point where electrical service enters building
- Consists of:
  - Weatherhead
  - Meter base
  - Meter (demand metering 400amp)
- Service equipment includes main disconnect

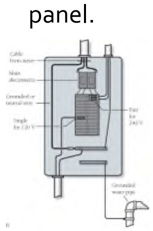
Service Entrance (2 of 3)

- Service entrance and breakers.



Service Entrance (3 of 3)

- Main electrical panel.

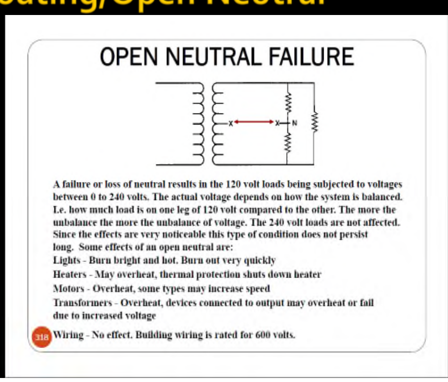


Grounding

- 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

Grounding

Floating/Open Neutral



OPEN NEUTRAL FAILURE

A failure or loss of neutral results in the 120 volt loads being subjected to voltages between 0 to 240 volts. The actual voltage depends on how the system is balanced. I.e. how much load is on one leg of 120 volt compared to the other. The more the unbalance the more the unbalance of voltage. The 240 volt loads are not affected. Since the effects are very noticeable this type of condition does not persist long. Some effects of an open neutral are:

Lights - Burn bright and hot. Burn out very quickly

Heaters - May overheat, thermal protection shuts down heater

Motors - Overheat, some types may increase speed

Transformers - Overheat, devices connected to output may overheat or fail due to increased voltage

318 Wiring - No effect. Building wiring is rated for 600 volts.

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

NFPA 921 9.6.1 – 9.6.2.5

Overcurrent Protection (2 of 4)

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

Overcurrent Protection (3 of 4)

- Interrupting current rating is the maximum amount of current the device is capable of interrupting. 10,000a typical breaker, 100,000a non time delay fuses
- 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.

Breaker Video

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**

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

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

Panel Blow Holes

Branch Circuits

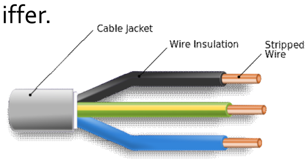
- Distribute electricity from circuit breaker or fuse panel throughout building
- Each circuit should have its own overcurrent protection device.
  - Called branches
  - Single connection point in the service panel and conductor going to multiple loads

Conductors (1 of 2)

- The larger the AWG number, the smaller the wire diameter. (10-14 most common)
- Conductors may be larger—but not smaller—than required.
- Common materials: copper, aluminum, copper-clad aluminum
- Conductors are insulated.

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 sniffer.



Outlets and Special Fixtures/Devices

- Circuits terminate at, or connect to:
  - Switches (single, 3 way, 4 way etc.)
  - Receptacles (rated for amperage carried?)
  - Appliances
- Lighting fixtures are usually connected to junction boxes in the wall or ceiling.
- GFCI outlets are used in bathrooms, kitchens, other wet locations
- AFCI used in pretty much all spaces (2014)

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

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

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.

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.

Overcurrent (2 of 2)

- Electrical cord fire damage.

Arcs (1 of 2)

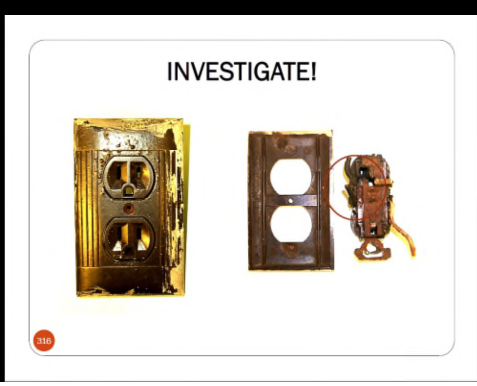
- High-temperature discharges across a gap where conductor is missing
- May cause ignition if ignitable vapors are present or if certain solid fuels are present
  - Cotton batting, dust, lint

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

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



Interpreting Damage to Electrical Systems
(1 of 2)

- Whether electricity played a role in causing a fire can often be determined by:
  - Arc mapping (4th **origin determination method**)
  - Short circuit and ground fault parting arcs
  - Arcing through char
  - Overheating connections

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

Arc Mapping (4th means of Origin Determination

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

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.

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

Loose Connection

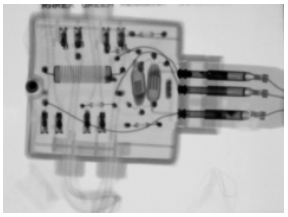
Loose Connection

Overheating Connections (2 of 3)

- Photo of poor contact connections.

Overheating Connections (3 of 3)

- X-ray of poor contact connections.



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

Cord Demo

Melting by Electrical Arcing

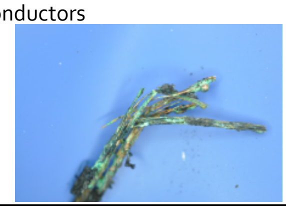
- Sharp line of demarcation occurs
- Techniques used to detect:
  - Gloves that snag on small notches on the conductor
  - Magnification to detect damage
  - Evidence of dislodged material that has collected on nearby surfaces
  - Metallurgical analysis

Melting by Fire

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

Melting by Fire

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



Melting by Fire

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

Thy Glob

Arcing Through Char

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

Arc Through Char

Alloying (1 of 2)

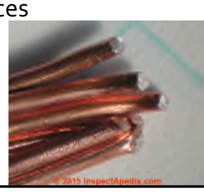
- Alloying is the combining of metals of different physical properties.
- Copper/aluminum alloy
  - Lower melting point than either pure metal
  - Brittle and may break easily

Alloying (2 of 2)

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

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



Considerations and Cautions

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

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.

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.

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

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.

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.

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

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.

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

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.