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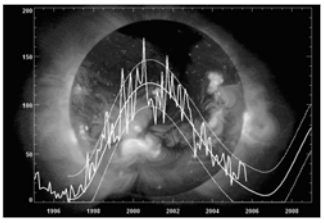
Fire Behavior & Extinguishment Theory



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Objectives (1 of 3)

- Discuss the type of heat measurement.
- Discuss the fire tetrahedron.
- Identify the physical states of matter in which fuels are found.
- Describe the methods of heat transfer.
- Define flash point, flame point, and ignition temperature as they relate to liquid fuel fires.

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Objectives (2 of 3)

- Define the relationship of vapor density and flammability limits to gas fuel fires.
- Define Class A, B, C, D, and K fires.
- Describe the phases of fire.
- Describe the characteristics of an interior structure fire.

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Objectives (3 of 3)

- Describe rollover and flashover.
- Describe backdrafts.
- Describe the principles of thermal layering within a structure.

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Introduction

- Understanding of fire behavior is the basis for all firefighting principles and actions.
- Understanding fire behavior requires knowledge of physical and chemical processes of fire.

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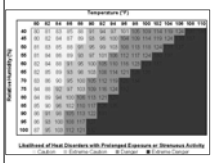
Types of Heat Measurement



- Specific heat is the amount of heat a substance absorbs as its temperature increases
- Latent heat is absorbed as a substance is converted from a solid to a liquid or from a liquid to a gas

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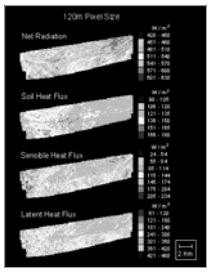
4 Types of Heat Measurement

- Celsius
- Kelvin
- Fahrenheit
- Rankine



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Types

- A Celsius (centigrade) degree (°C) is 1/100th the difference between the temperature of ice melting & water boiling at 1 atmosphere pressure
  - 0°C=melting point
  - 100°C=boiling point
- A Kelvin degree (°K) is the same measurement as the Celsius degree
  - Zero on the Kelvin scale is –459.67°F
  - Absolute lowest achievable temperature
  - Used by scientist

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Types

- A Fahrenheit degree (°F) is 1/180th the difference between the temperature of melting ice & boiling water (1atmosphere pressure)
- 32°F = melting point
- 212°F = boiling point
- A Rankine degree (°R) is the same size as the Fahrenheit degree
- Zero is -459.67°F
  - Also provides an absolute temperature

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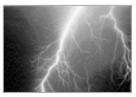
Heat Units

- Joule
  - Energy at work; (1 Newton) moves a body (1 inch)
- Watt
  - Measure the rate of energy release
  - Watt = 1 Joule per second;
- Calorie
  - Amount of heat required to raise 1 gram of water 1°C
- British Thermal Unit (BTU)
  - Amount of hear to raise 1 pd of water 1°F



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Temperature Measurement

- Expansion of a solid, liquid or gas
- Change of state
  - Solid to liquid
- Energy change
  - Changes in electrical potential energy (Voltage)

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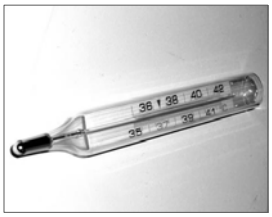
Thermometers

- Liquid expansion
  - Consists of a tube (partially filled with a liquid) which measures the expansion and contraction of the liquid with changes in temperature.



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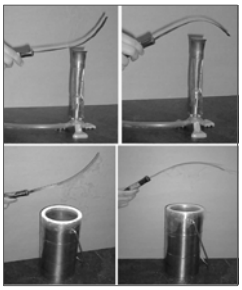
Thermometers



- Bimetallic
  - Contains strips of 2 metals (laminated) with different coefficients of expansion

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Thermocouple

- This thermocouple wire is used to measure the difference in temperature between its two junctions. Its great range makes it ideal for studying flame temperatures.
- A temperature difference will cause a voltage to be developed that is temperature dependent.

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Pyrometer

- Measures the intensity of radiation from a hot object.

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Types of Heat Measurement

- Essentially, ignition is a matter of increasing temperature by adding heat, whereas physical fire extinguishment usually is accomplished through reduction of temperatures by removing the heat. By understanding temperature and the measurement of heat, you will be better able to combat fire with the proper heat removing substance. The four types of temperature units are Celsius, Kelvin, Fahrenheit, and Rankine.

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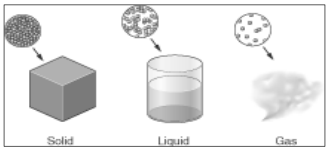
Fuel

- What is actually being burned
- Physical states
  - Solid
  - Liquid
  - Gas
- Combustion occurs when fuel is in a gaseous state.



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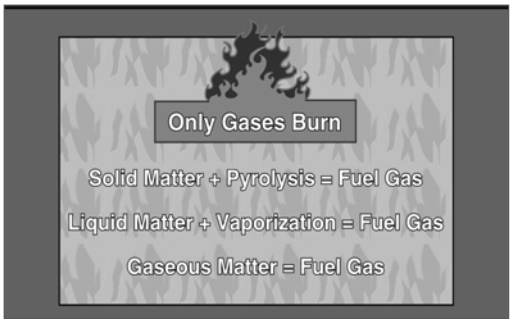
Fuel



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Video

Only Gases Burn #2

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Heat Energy

- Measurement of molecular movement in a substance
- When heat comes in contact with a fuel, the energy supports the combustion reaction.
- States of matter
  - Solid
  - Liquid
  - Gaseous

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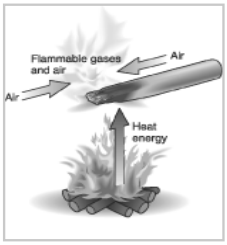
Solids

- Most fuels are solids.
- Pyrolysis releases molecules into atmosphere.
  - Converts solid to a gas
- Solids with high surface to mass ratio combust more easily and rapidly.



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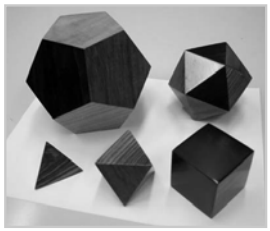
Solids

- Solids
  - Definite size and shape
  - Surface area in relation to mass
  - Increase in surface area to mass, decreases the amount of heat required to cause ignition.



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Liquids

- Assume the shape of their containers
- Specific gravity
  - Water has a specific gravity of one
- Solubility in water
- Liquids with a high surface to volume ratio vaporize and combust more easily and rapidly.

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Liquids

- Vaporization
  - The release of a liquid's molecules into the atmosphere.
  - An increase in surface area to volume, increases the rate of vaporization.

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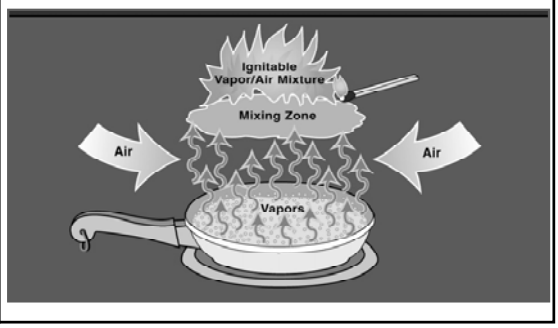
Vaporization



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Gases

- Have neither shape nor volume
- Assumes the shape of their container
- Expand indefinitely
- Fuel to air mixture must be within a certain range to combust.
- Vapor density
  - Air has a vapor density of one

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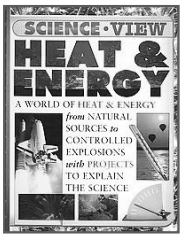
Sources of Heat Energy

- Chemical
- Electrical
- Mechanical
- Nuclear



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Chemical

- Heat of combustion
- Spontaneous heating
  - Oily rags (linseed)
- Heat of decomposition
  - Hay barns
  - Mulch piles
- Heat of solution

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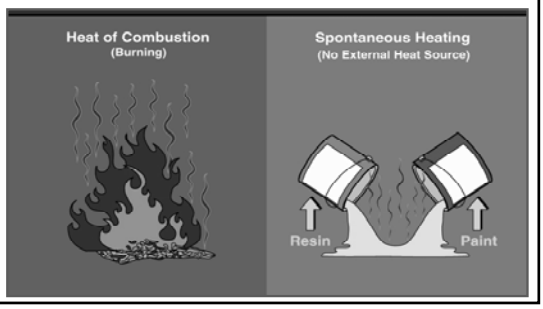
Chemical



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Electrical

- Resistance heating
- Dielectric heating
- Induction heating
- Leakage current heating
- Heat from arcing
- Static electricity heating
- Lightening

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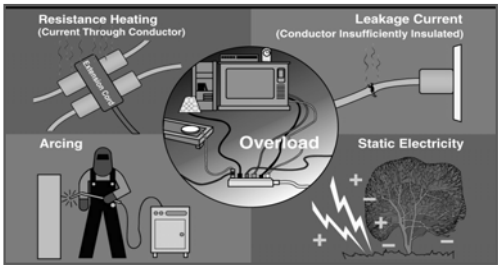
Electrical



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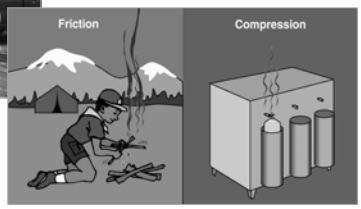
Mechanical

- Heat of friction
- Heat of compression



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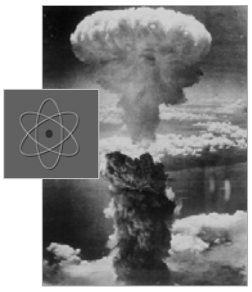
Nuclear Heat Energy

- Release of large quantities of energy from the nucleus of the atom
  - Fission
    - Splitting of atoms
  - Fusion
    - Combining of two atoms



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Sources of Heat Energy

- The process of combustion follows the basic laws of the natural sciences. Heat is a form of energy. It is a measurement of molecular motion in a substance. There are four common sources of heat energy: chemical, electrical, mechanical, and nuclear.

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Oxygen and Oxidizing Agents

- Oxygen is required to initiate and sustain combustion.
- Normal is 21%
  - Minimum to allow free burning is 16%
- Materials classified as oxidizers will support the combustion of other materials, even if no oxygen is present.
- Oxidizing agents are Bromates & Chlorates

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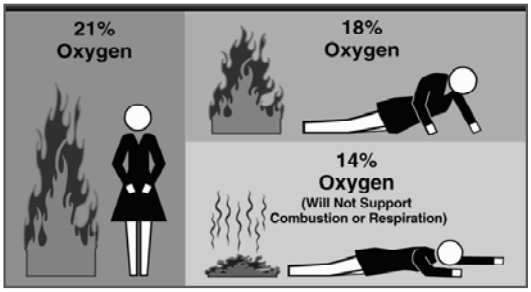
Oxygen



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Heat

- Required to ignite a fire, it is the energy component
- It causes pyrolysis or vaporization of solids & liquids & produces ignitable vapors
- Provides the energy necessary for ignition
- Causes the continuous production of ignitable vapors

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Heat

- Energy to produce an ignition comes from a variety of sources:
  - Mechanical energy
  - Chemical energy
  - Electrical energy

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Chemical Chain Reaction

- Flaming combustion occurs when heat energy produces continuous fuel vapors
  - Called a chain reaction
  - Each reaction adds to the next
    - Example: Runaway nuclear chain reaction
- Chain reactions continue to occur as long as there is sufficient fuel, oxygen, and heat.
- Interrupting the chain reaction puts the fire out.

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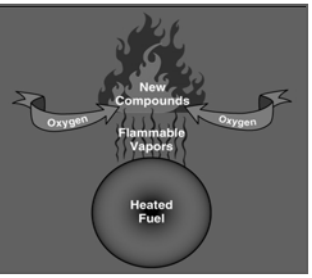
Chemical Chain Reaction

1. Heated fuel releases vapors.
2. Vapors combine to create new compounds.
3. The new compounds combine with oxygen and ignite.



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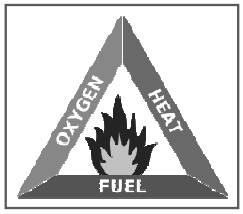
Fire Triangle and Tetrahedron

- Three basic factors required for combustion:
  - Fuel
  - Oxygen (oxidizing agent)
  - Heat
- Chemical chain reactions keep the fire burning.



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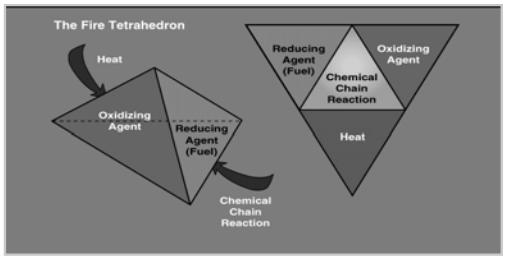
Fire Tetrahedron



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Combustion Process Elements

- Combustion occurs only during the presence of certain elements. It must be understood that the removal of any one of the elements will result in the extinguishment of the fire. These components are described as the fire tetrahedron. Each component must be in place for combustion to occur.

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Products of Combustion

- The specific products depend on:
  - Fuel
  - Temperature
  - Amount of oxygen available
- Few fires consume all available fuel.

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Products of Combustion

- When a fuel burns there are four products of combustion
  - Fire gases
  - Flame
  - Heat
  - Smoke

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Fire Gases

- Determined by the type of material, amount of available oxygen, rate of heating & temperature.
- Refer to as the vaporized products of combustion
- Particles contain carbon

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Fire Gases

- The most common fire gases are:
  - Carbon monoxide
  - Carbon dioxide

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Other Gases

- Numerous gases are released during all phases of combustion
  - Sulfur dioxide
  - Phosgene
  - Nitrogen oxides
  - Herolein
  - Ammonia
  - Hydrogen cyanide
  - Hydrogen sulfate
  - Hydrogen chloride
  - Asphyxiant gases
  - Irritant particles

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Asphyxiant Gases

- Those products of combustion that effect the central nervous system and can result in loss of consciousness or death due to oxygen depletion
  - Carbon monoxide
  - Hydrogen cyanide
  - Carbon dioxide

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Irritant Gases

- Affect
  - Breathing
  - Eyes
  - Skin
- Examples
  - Halogen acids
  - Nitrogen oxides
  - Organic irritants

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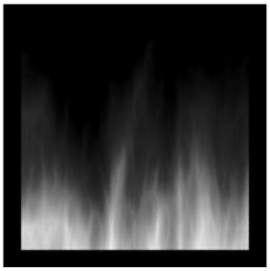
Flame

- Flame is the luminous aspect of burning
- Hotter flame
  - Less luminous
  - More complete combustion
- Not present during smoldering phase



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Heat

- A form of energy that is measured in degrees of temperature to signify intensity
- Heat is the combustion product most responsible for fire spread in a building
- Direct cause of burn injuries
- Other injuries are:
  - Dehydration, heat exhaustion, respiratory tract

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Smoke

- Airborne products of combustion
- Consists of:
  - Particles
  - Vapors
  - Gases
- Inhalation of smoke can cause severe injuries.

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Smoke

- It is a mixture of oxygen, nitrogen, carbon dioxide, carbon monoxide, and mixture of finely divided carbon particles (soot)
- Contents of smoke varies with fuel being burned. Can be hot and/or toxic.
  - Liquid fuels give off dense, black smoke.

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Smoke

- Smoke vapors
  - Small droplets of liquids suspended in air
  - Can be oils from the fuel or water from suppression efforts

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Smoke

- When a material burns, it gives off products of combustion. These are gases, flame, heat, and smoke. Alone or in combination, they can cause serious injury or death to the unprotected fire fighter. Many gases are asphyxiates or irritants. It is, therefore, important that we recognize the dangers inherent in the fire environment and use the appropriate personal protective equipment and equipment in order to operate safely.

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Smokes Physical Properties

- Relative Toxicity
  - Ability of substance to do harm within the body measured in parts per million (ppm)
  - Permissible exposure limits (PEL) determined by ppm
  - Example
    - Carbon monoxide
      - PEL 35ppm

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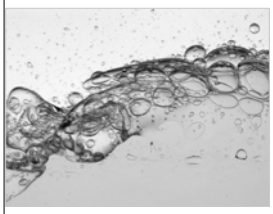
Water solubility



- A liquid's ability to mix with water
- Water soluble liquids
  - Alcohol
  - Corrosives
  - Polar solvents
- Nonsoluble
  - Nonpolar solvents
  - Petroleum products

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Vapor Density

- Weight of a gas in relation to air
  - Air = 1

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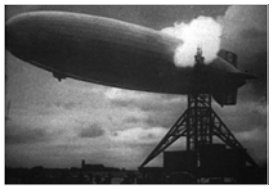
Vapor Density

- Gases lighter than air
  - Helium
  - Ammonia
  - Hydrogen
  - Acetylene
  - Methane
  - Illuminating gases
  - Nitrogen
  - Carbon monoxide
  - Ethylene



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Vapor Density

- Gases heavier than air
  - Gasoline vapor
  - Propane

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Video

Vapor & Fire #3

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Flammability

- Relates to flammable limits or flammable range
  - Flammable explosive limit
    - The concentration level of a substance at which it will burn
  - Flammable range (FR)
    - Ratio of gas to air that will sustain combustion if exposed to an ignition source

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Warning Properties

- Most products of combustion have an adverse affect on the body
- Burning skin
- Burning eyes

- Increase respirations
  - Altered level of consciousness
  - Acrid smells
  - Dizziness
  - Nausea
  - Vomiting

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Physical Properties of Combustion

- It is crucial for the fire fighter to understand and recognize the common combustion gases and their adverse effects. Many toxic by-products of combustion do not have any warning signs. A fire fighter can be exposed to high levels of carbon monoxide and not be aware until it is too late. The fire fighter must also understand that not all gases and liquids weigh the same. This knowledge plays an integral part of fire fighter safety and the decision-making process.

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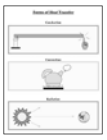
Heat Transfer

- Combustion gives off heat which can ignite other nearby fuels.
- Heat energy always flows from hotter to colder. Object will achieve the same temperature if the remain in contact.
- Three methods of heat transfer
  - Conduction
  - Convection
  - Radiation



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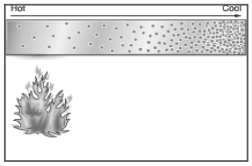
Conduction

- Heat transferred from one molecule to another (direct contact)
- Conductors transfer heat well.
  - Example: Nails, Steel beams, Metal pipe
- Insulators do not transfer heat well.
  - Example: Fiberglass



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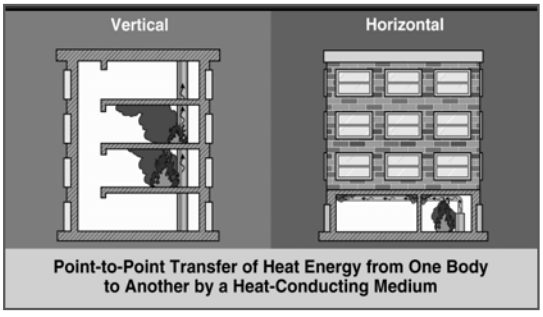
Conduction



Point-to-Point Transfer of Heat Energy from One Body to Another by a Heat-Conducting Medium

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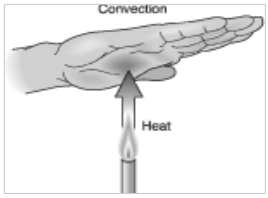
Convection

- Movement of heat through a fluid medium such as air or a liquid
- Heated air rises, cool air sinks
- Primary cause of vertical and horizontal spread
- Creates convection currents



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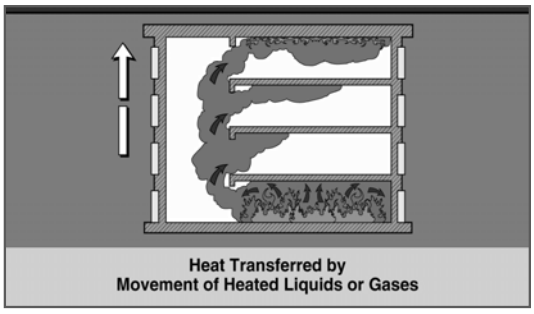
Convection



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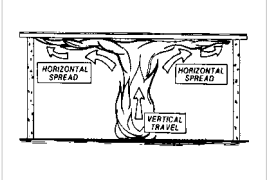
Convection within a Room

- Hot gases rise, then travel horizontally.
- Gases then bank down a wall or move outside the room.
  - Horizontally
  - Vertically



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Radiation

- Transfer of heat in the form of an invisible electromagnetic wave
- Heat radiated to a nearby structure can ignite it.
- Radiated heat passing through a window can ignite an object.

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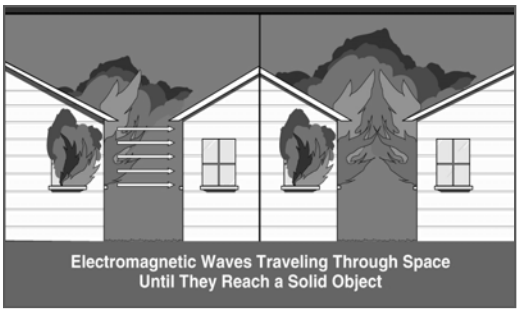
Radiation



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Heat Transfer

- Heat is transferred in three and only three ways. It may be conducted through a substance, convected by a substance, or radiated from one substance to another. An example of conduction is a spoon in a hot bowl of soup. The handle becomes hot by the heat being conducted up the spoon.

CSFM

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Liquid Fuel Fires (1 of 3)

- A liquid must vaporize before it burns.
- A minimum and maximum concentration of vapors must be present to ignite.
- Most flammable liquids can ignite well below their boiling point.

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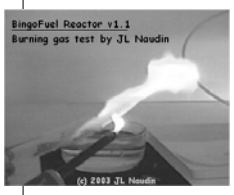
Liquid Fuel Fires (2 of 3)

- Conditions required for ignition:
  - Fuel-air mixture within flammable limits
  - An ignition source with sufficient energy
  - Sustained contact between ignition source and fuel-air mixture



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Liquid Fuel Fires (3 of 3)

- Flash point
  - Lowest temperature at which vapor is produced
- Flame point (or fire point)
  - Lowest temperature at which sufficient vapors are produced to support a small flame for a short time
- Ignition temperature
  - Temperature at which the fuel-air mixture will spontaneously ignite

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Gas Fuel Fires (1 of 2)

- Vapor Density
  - Weight of a gas fuel
  - Gas with vapor density less than 1.0 will rise.
  - Gas with vapor density greater than 1.0 will settle.
  - Knowing vapor density helps predict where the danger of ignition will be.

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Gas Fuel Fires (2 of 2)

- Fuel-air mixtures only burn when mixed in certain concentrations.
- Flammability/explosive limits
  - Below the lower flammability limit
    - Too little fuel = too lean
  - Above the upper flammability limit
    - Too much fuel = too rich

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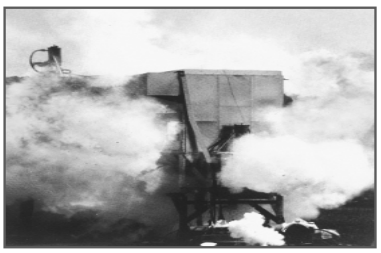
Explosion



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Explosion

- A rapid release of high-pressure gas into the environment
- The high-pressure release, dissipating in the form of a shock wave

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Types & Causes of Explosions

- Physical
  - Most common type
  - Externally heated container
    - Boiler
    - Pressurized gas cylinder
    - Trapped steam
    - Any container that will pressurize with the application of heat

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BLEVE (1 of 3)

- **B**oiling **L**iquid, **E**xpanding **V**apor **E**xplosion
- Occurs when a tank storing liquid fuel under pressure is heated excessively

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BLEVE (2 of 3)

- Sequence:
  - Tank is heated
  - Internal pressure rises beyond ability to vent
  - Tank fails catastrophically
  - Liquid fuel at or above boiling point is released
  - Liquid immediately turns into a rapidly expanding cloud of vapor
  - Vapor ignites into a huge fireball

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BLEVE (3 of 3)

- BLEVEs can injure and even kill fire fighters and civilians.
  - Fireball created by the ignition of expanding vapors
  - Large pieces of the tank propelled great distances

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Video

BLEVE #4

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Physical/chemical

- External heat required to cause endothermic reaction
  - Endothermic=absorbs heat
- Chemical that absorbs external heat to create a chemical reaction
- Chemical reaction creates additional heat which increases gas pressure

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Chemical

- Exothermic
  - Produces own temperature increase
    - Does not require external heat to react
  - The higher the temperature, the faster the reaction, the more gas is produced

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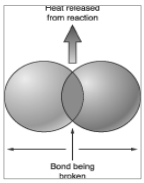
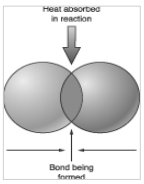
Chemistry of Combustion (1 of 2)

- Exothermic reactions
  - Reactions that result in the release of heat energy
- Endothermic reactions
  - Reactions that absorb heat or require heat to be added





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Chemistry of Combustion (2 of 2)

- Oxidation
  - Chemically combining oxygen with another substance to create a new compound
- Combustion
  - Rapid, self-sustaining process that combines oxygen with another substance and results in the release of heat and light
- Pyrolysis
  - Decomposition of a material caused by external heating

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Classes of Fire (1 of 2)

- Fires classified according to type of fuel
- Extinguishing agents classified to match type(s) of fires they extinguish
- A fire can fit into more than one class.

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Classes of Fire (2 of 2)

- Five classes of fires:
  - Class A
  - Class B
  - Class C
  - Class D
  - Class K

A	Common Combustibles	Wood, paper, cloth etc.
B	Flammable liquids and gases	Gasoline, propane and solvents
C	Live electrical equipment	Computers, fax machines
D	Combustible metals	Magnesium, lithium, titanium
K	Cooking media	Cooking oils and fats

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Class A

- Fuel: Ordinary solid combustibles
  - Wood
  - Paper
  - Cloth
- Extinguishing agents:
  - Water (cools the fuel)

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Class B

- Fuel: Flammable or combustible liquids
  - Gasoline
  - Kerosene
  - Oils
- Extinguishing agents:
  - Foam or carbon dioxide
  - Dry chemicals

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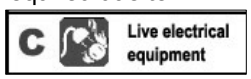
Class C

- Fuel: Energized electrical equipment
  - Underlying fuel is often Class A or Class B
  - Special classification required due to electrical hazards
- Extinguishing agents:
  - Carbon dioxide
  - Use of water is <u>not</u> advised.
    - Be sure to <u>shut off power</u> before using water.



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Class D

- Fuel: Burning metals
  - Potassium
  - Lithium
  - Magnesium

- Extinguishing agents:
  - Special salt-based powders or dry sand
  - Do NOT use water.

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Class K

- Fuel: Combustible cooking media
  - Cooking oils
  - Grease

- Extinguishing agents:
  - Designation is new and coincides with a new classification of Class K extinguishing agents

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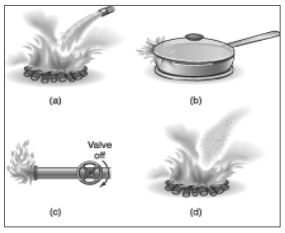
Methods of Extinguishment

- Cool the burning material.
- Exclude oxygen.
- Remove fuel.
- Break the chemical reaction.



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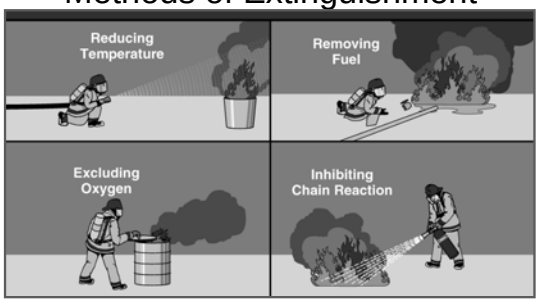
Methods of Extinguishment



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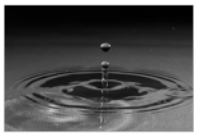
Extinguishing Agents

- Water
  - Extinguishment principles
    - Cooling a solid or liquid
    - Cooling the flame itself
    - Diluting oxygen



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Water Use

- Class A fires
- Class B fires
  - Certain instances
- Class D fires
  - Very limited

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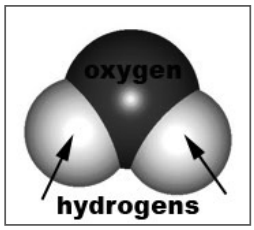
Water Physical Properties

- Freezes at 32°F or 0°C
- Boils at 212°F or 100°C
- Weighs 8.34 pounds per gallon
- Non-compressible
- High surface tension
- Takes shape of container
- Needs expellant force in most cases
- Expands 1700:1, steam



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Advantages of Water

- Absorbs large amounts of heat
- Plentiful
- Can be used with specialized agents

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Disadvantages of Water

- Conductor of electricity
- High surface tension
- Freezes
- Reacts with certain chemicals
- Weight

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Carbon Dioxide (CO_2)

- Extinguishment principles
  - Oxygen reduction
    - Smothering effect
  - Limited cooling effects

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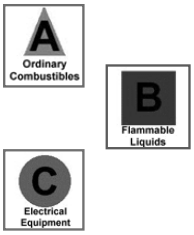
CO_2 Use

- Class A fires
  - Limited instances
- Class B fires
- Class C fires



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CO_2 Physical Properties

- Normally a gas
- Liquefied under temperature & pressure
- 1 ½ times heavier than air
- Solid below - 79°F

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CO_2

- Advantages
  - High expansion ration
    - 1 pd liquid = 8 cf of gas
  - Readily turns from liquid to gas
  - Provides its own pressure
  - Nonconductor
- Disadvantages
  - Slightly toxic
  - Water soluble
  - Limited effect on Class A combustibles

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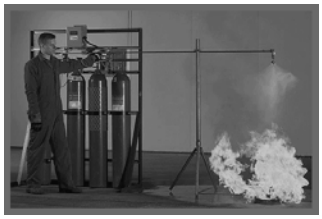
Halogenated Hydrocarbons (Halons)



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Halons

- Extinguishment principles
  - Break the chain reaction
  - Some cooling
- Halos can be use on
  - Class A fires
    - Special instances
  - Class B fires
  - Class C fires

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Phases of Fire

- Four distinct phases:
  - Ignition
  - Growth
  - Fully Developed
  - Decay

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Ignition Phase

- First phase of fire development
- 3 elements of fire are present
  - Fuel
  - Heat
  - Oxygen
- Fuel is heated to its ignition temperature starting the chemical chain reaction.

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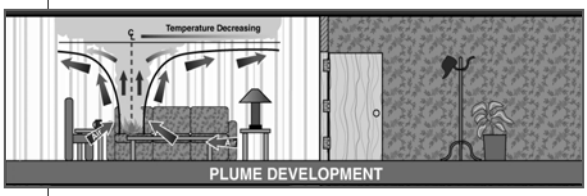
Ignition Phase



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Growth Phase

- Second phase of fire development
- Additional fuel involved
- Fire grows larger
- Convection draws more air into fire
- Thermal layering:
  - Hot gases collect at ceiling and bank downward.

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Growth Phase

- Increasing heat begins to generate
  - Mushrooming & rollover occur
    - Products of combustion reach the outer walls of the compartment
    - Products of combustion bank from the ceiling down

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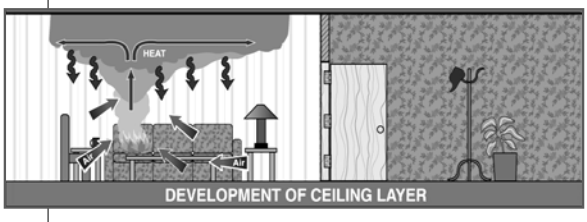
Growth Phase



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Growth Phase

- Increasing heat begins to generate
  - Thermal layering:
    - Gases form in layers according to temperature
    - Hottest gases on top, cooler on bottom
    - The heat from rollover radiates back down and heats uninvolved fuel sources liberating flammable gases contributing to flashover & firefighter injuries

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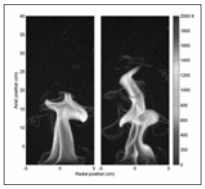
Growth Phase

- Smoke temperature can be up to 900°F
- Room heat will increase proportionately to the time the fire burns
- Fire gases being generated
  - Water vapor (H_20)
  - Carbon dioxide (CO_2)
  - Sulfur dioxide (SO_2)
  - Carbon monoxide (CO)



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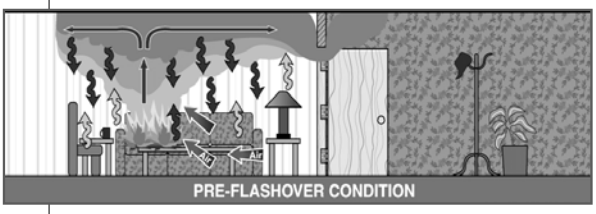
Growth Phase



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Flashover

- The third phase of fire development
- Transition point between growth phase and fully developed phase
- All combustible materials in a room ignite at once.
- Temperatures range from 900°F – 1,200°F.
- Flashovers are deadly!

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Flashover

- Super-heated fire gases have heated nearby unburned combustibles liberating flammable fire gases
- When the temperature reaches the ignition point of another substance in the room, a new chain reaction combustion site occurs and additional heat is added beyond the initial source of the fire
- Flashover is not instantaneous but occurs rapidly

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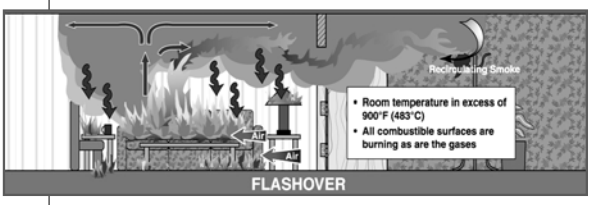
Flashover



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Fully Developed Phase

- Fourth phase of fire development.
- All combustible materials in the room are burning.

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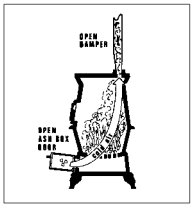
Fully Developed Phase



- Heat produced at maximum rate
- Oxygen consumed rapidly
- Fire will burn as long as fuel and oxygen remain.
- This fire is ventilation controlled.

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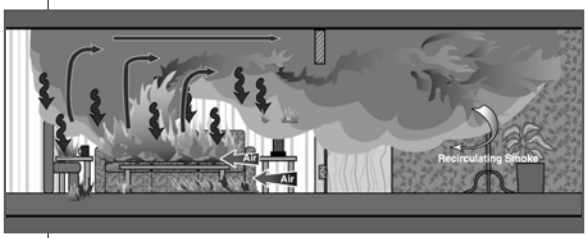
Fully Developed Phase



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Decay Phase

- Firth phase of fire development
- Fuel/oxygen or both is nearly exhausted
- Intensity reduces
- Eventually fire will go out

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Decay Phase

- The fire is now controlled by
  - Fuel
    - Sufficient oxygen with low amount of fuel
  - Ventilation
    - Compartment is not vented
    - There is plenty of fuel heated to its ignition temperature
      - Backdraft

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Video

Phases of Fire #5

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Phases of Fire

- Fire development is defined in five phases: ignition, growth, flashover, fully developed, and decay. Each phase presents dangers that can cause serious injury or death to fire fighters and occupants. As a fire transitions through each phase, its dangers lead to the next. During the flashover phase, fire develops so rapidly that it is a very short time for the fire to enter the fully developed phase. It is crucial for the fire fighter to identify and recognize the different phases to employ proper fire attack tactics.

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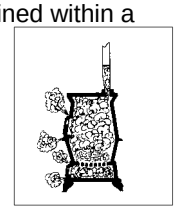
Interior Structure Fire Characteristics

- Fire is fully or partially contained within a building
- Building acts as a box.
- Special considerations:
  - Room contents
  - Fuel load and fire spread
  - Flashover, rollover, backdraft, and thermal layering



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Room Contents

- Many fires burn only the contents, and not the structure itself.
- Modern rooms contain many plastic and synthetic materials.
- Furniture may have little resistance to ignition from flaming sources.
- Wall and ceiling finishes can burn readily.

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Fuel Load and Fire Spread

- Total quantity of combustibles in a room
- Determines how much heat and smoke will be generated
- Size, shape, and arrangement of fuel will affect combustibility and fire spread

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Special Considerations

- Four conditions particular to interior fires that affect fire fighter (and civilian) safety:
  - Flashover
  - Flameover (or rollover)
  - Backdraft
  - Thermal layering and thermal balance

However, before we discuss these in detail we must discuss Pyrolysis.

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Pyrolysis

- Chemical decomposition of matter through the action of heat
- Also known as
  - Pyrophoric action
  - Pyrolysis
  - Pyrophoric carbonization

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Pyrolysis Process

- As a fuel is heated the surface reaches the boiling point of water, & water vapor is released
- As heating continues/increases, the drying process continues
- Early indications of the pyrolysis process in addition to steam is the darkening or discoloration of the surface of the fuel

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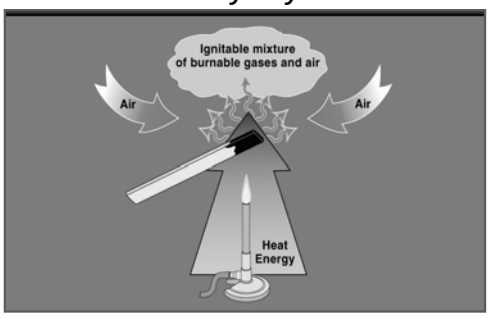
Pyrolysis Process



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Pyrolysis Process **continued**

- As pyrolysis continues combustible gases are released and a black carbon residue remains
- As pyrolysis continues sufficient combustible gases are evolved to produce an atmosphere rich enough to support combustion.

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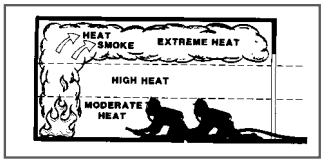
Thermal Layering & Balance

- Superheated gases collect near ceiling.
- Temperatures are lowest near floor.
- Fire streams create steam which expands and rises.



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Thermal Layering & Balance

- Prevention:
  - Coordinate fire attack with ventilation.
  - Use straight streams to minimize steam formation.

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Rollover (Flameover)

- When in a compartment, heated products of combustion are produced
- The seat of the fire continues to heat these fire gases to their ignition temperature where they spread across the ceiling level
- Heat from rollover radiates back down & further heats nonburning material
- This radiant heat is a major contributor to flashover

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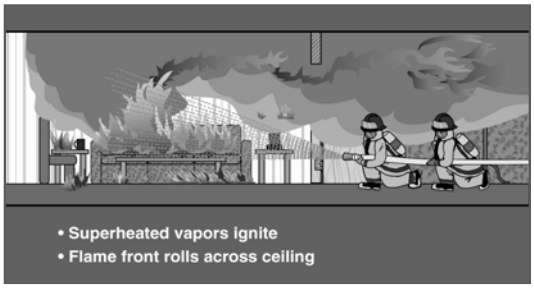
Rollover



- Superheated vapors ignite
- Flame front rolls across ceiling

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Rollover (Flameover)

- A warning sign of imminent flashover
- Licks of flame ignite briefly in upper layers of smoke
- Situation calls for aggressive cooling of atmosphere, immediate exit, or immediate ventilation

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Dangers of Rollover

- Reduces chance of survivability
- Slows interior fire attack to the seat of the fire
- Increases for potential of vertical fire extension

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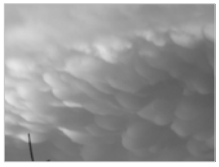
Prevention of Rollover



- Apply short bursts of water to the upper levels of the thermal layer
- Vertical ventilation
  - Removes super-heated gases that contribute to the ignition temperature of combustibles

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Rollover Thermal Layering

- Forms layers of heated gases according to temperature
  - Hottest gases in the top layer, cooler in the bottom
- Also know as heat stratification or thermal balance
- Improper water application may disrupt the thermal layering, bring super-heated gases down to the firefighter

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Rollover

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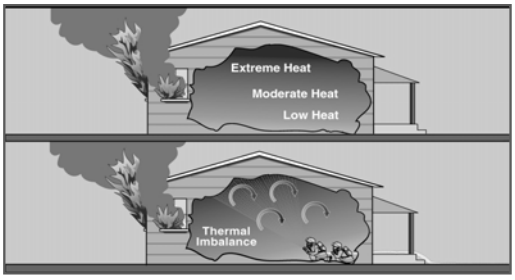
Rollover Thermal Layering



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Flashover

- A transitional phase between the growth stage & fully developed stage of a fire
- Extension of open flames from the original room out through the openings
- Open-flame combustion of all combustible materials in a compartment

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Signs of Flashover

- You are not near the seat of the fire, but there is excessive heat in the smoke
- Thick, hot smoke under pressure
- Rollover & fingers of fire developing in the thermal layer

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Prevention of Flashover

- Early recognition
- Proper ventilation
  - Vertical
  - Horizontal
- Proper use of hose streams to cool super-heated gases
  - Do not disrupt the thermal balance
  - Straight or solid streams to limit steam production
- Extinguish the seat of the fire

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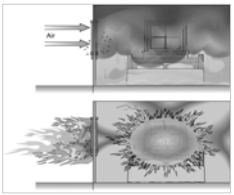
Backdraft (1 of 5)

- Explosion that occurs when oxygen is suddenly admitted to a confined area that is very hot and filled with combustible vapors



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Backdraft (2 of 5)

- Usually occurs when a fire is smoldering (decay phase)
  - Room is filled with carbon monoxide and other products of combustion.
  - The oxygen is consumed before the fuel is consumed
  - Sudden introduction of air will explosively feed the fire.

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Backdraft (3 of 5)

- Signs of an impending backdraft:
  - Little or no flame visible
  - Smoke emanating under pressure from cracks
  - No large openings
  - "Living fire" visible
  - Unexplained change in color of smoke
  - Glass (windows) smoke stained or blackened
  - Signs of extreme heat

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Backdraft (4 of 5)

- Signs of an impending backdraft:
  - Tightly sealed building
  - Smoke pushing out the top of a window at high pressure and being sucked back in from the bottom of the window

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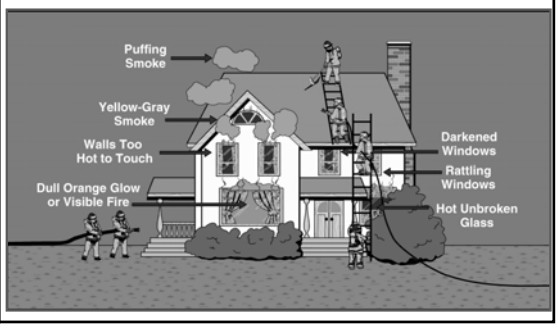
Backdraft



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Backdraft (5 of 5)

- Prevention of backdrafts:
  - Ventilate at a high level to allow superheated gases to escape
    - It is crucial that the vertical opening be made prior to the horizontal opening
      - Well-coordinated fire attack

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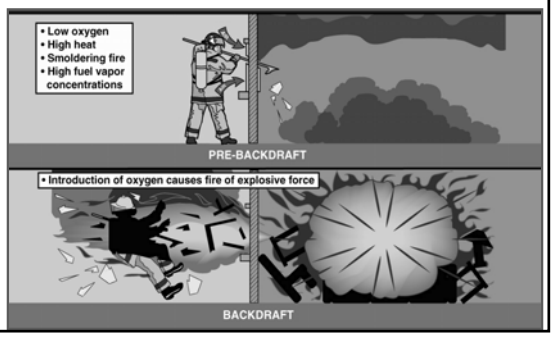
Backdraft



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Video

Backdraft #6

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Backdraft & Flashover

- Backdraft and flashover are two very significant fire conditions that can lead to fire fighter injury and deaths. It is crucial that fire fighters recognize the difference between flashover and backdraft. Although the devastating results are very similar, backdraft and flashover are very different.

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Backdraft & Flashover

- Flashover is the transitional phase of fire between the growth of a fire and it being fully developed. Flashover is associated with heavy fire and super-heated combustibles that reach their ignition temperature.

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Backdraft & Flashover

- Backdraft is associated with relatively no fire and all products of combustion and unburned fuels are already at their ignition temperature. Backdraft is a ticking time bomb awaiting an unsuspecting fire fighter to add a breath of fresh air.

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Summary (1 of 3)

- To be a successful fire fighter you must know fire behavior.
- Characteristics of solids, liquids, and gases are different.
- Fire triangle and fire tetrahedron represent conditions necessary for combustion.

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Summary (2 of 3)

- Five classes of fire require specific extinguishing methods.
- Knowledge of heat transfer is required to understand how fires propagate.
- Typical fires pass through four distinct phases.

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Summary (3 of 3)

- Liquid fuel fires, gas fuel fires, and interior fires have unique characteristics.
- Flashover, rollover, backdraft, and thermal layering are conditions that threaten fire fighters and victims.

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