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Basic Fire Science

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Knowledge Objectives (1 of 2)

- Explain the chemistry of fire.
- Describe the conditions necessary for a fire to exist.
- Describe the changes that materials undergo in response to heating.
- Explain the components of fire dynamics.

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Knowledge Objectives (2 of 2)

- Discuss the roles of fuel items and fuel packages.
- Explain flame spread.

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Introduction

- Humans have used fire for thousands of years.
  - Heating homes, cooking food, waging wars
- Tragic events have occurred as result of fire
- Fire investigators must understand properties of fire

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Fire Chemistry (1 of 6)

- Fire is a chemical reaction
  - Results in light and heat
- Fire usually occurs only in the gas phase
- Solids must be heated first, to decay and produce gases—a process called pyrolysis.

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Fire Chemistry (2 of 6)

- Liquids must be heated to produce ignitible mixtures in air (vaporization)
- For a fire (combustion) to occur, four components must be present:
  - Fuel, oxidizing agent, heat, chemical chain reaction

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Fire Chemistry (3 of 6)

- By eliminating one of the four components, the fire can be extinguished.

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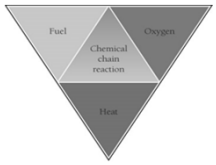
Fire Chemistry (4 of 6)

The fire tetrahedron.



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Fire Chemistry (5 of 6)

- Fuel
  - The material that will be consumed by combustion
  - Organic (carbon-containing) fuels are most common
    - Wood, plastics, petroleum products
  - Gaseous fuels are probably most dangerous

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Fire Chemistry (6 of 6)

- Oxidizing agent
  - Usually the oxygen in air
- Heat
  - Produces energy to create and ignite vapors
- Uninhibited chemical chain reaction
  - Fire burns even after removal of ignition source

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Phase Changes and Thermal Decomposition (1 of 2)

- During fire, materials may change their physical state
  - Called phase change
- Phase change can be:
  - Reversible, as in melting and vaporization
  - Irreversible—called thermal decomposition

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Phase Changes and Thermal Decomposition (2 of 2)

- Flames produced during combustion can be premixed or diffused.
- A balanced air to fuel ratio is called the stoichiometric ratio.
  - Exists above lower explosive limit (LEL) and below the upper explosive limit (UEL)
- Best example of a diffusion flame:
  - Candle flame

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Products of Combustion

- Visible and invisible compounds released when fuel burns
- Smoke is created by combining various products of combustion.
- Products of combustion migrate away from the fire and cool, accumulating on both horizontal and vertical surfaces.

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Smoke and Flame Color

- Neither should be relied on as indicator of what is burning.
  - Can change during various fire phases
  - Fire fighting operations can also change the color.

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Fire Dynamics

- The study of all behaviors of fire
- Requires some understanding of:
  - Fluid flows, heat transfer
  - Ignition and flame spread
  - Fuel packages
  - Heat flux
  - Distinction between fuel-controlled and ventilation-controlled fires

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Fluid Flows

- Fire creates its own buoyant flow
  - As result of hot gases being less dense than cool gases
- Hot gases rise in a plume
  - Entrain, or draw in, cool air
  - Gas flow velocity increases
  - Diameter of plume increases—cone shape results
  - Movement of gases parallel to ceiling—ceiling jet

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Heat Transfer (1 of 3)

- Heat energy naturally transfers from areas of higher temperature to lower temperature
- The rate of transfer (heat flux) is measured in kilowatts per square meter (kW/m^2).
- As a fire progresses, the effects of heat transfer create various fire patterns.

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Heat Transfer (2 of 3)

- Temperature is different from heat.
  - Temperature—A measurement of the amount of molecular activity when compared with a reference or standard.
  - Heat—The amount of energy needed to change an object's temperature; may be transferred by conduction, convection, or radiation.

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Heat Transfer (3 of 3)

- Conduction—occurs when solid objects are heated and energy is transferred from hotter to cooler areas
- Convection—occurs when heat is absorbed from heated gases or liquids
- Radiation—occurs when heat is transmitted by electromagnetic waves

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Fuel Load

- Fuel load: amount of fuel present
- A reflection of potential energy
- Does not determine how fast the fire develops once ignition occurs

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Fuel Items and Fuel Packages

- Fuel item: material consumed during a fire
- Fuel package: fuel items placed close to each other, such that flames can spread
- Common fuel packages
  - Furniture and contents of dorm or bedroom
  - Personal items in commercial storage space
  - Combustible raw materials used in manufacturing

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Heat Release Rate (HRR) (1 of 2)

- HRR is the energy released by the fuels consumed
- An HRR curve indicates the energy released during the incipient, growth, free-burning, and decay stages of a fire.
- Highest value is the peak HRR
- Knowing peak HRR for various fuel packages can assist the investigator.

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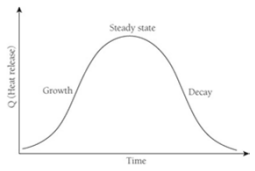
Heat Release Rate (HRR) (2 of 2)

- Idealized HRR curve.



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Flame Height and HRR

- Generally, larger flame heights correspond to higher rates of heat release
- Property of interest is the average flame height, not the highest
- Location of fuel package in the room (wall effect, corner effect) and ceiling height affect flame height

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Ignition (1 of 2)

- Source of ignition is critical in determining fire cause
  - Can be smoldering or flaming, piloted or autoignition
- Factors involved:
  - Fuel form, amount, proximity to heat source
  - Amount of heat generated
  - Duration of exposure

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Ignition (2 of 2)

- Most fuels need to liberate fuel gases for ignition to occur
- Source of heat energy needs to be greater than the ignition temperature
- In smoldering fires flames are absent, but may provide sufficient heat to other fuels that produce flaming combustion.

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Ignition of Flammable Gases

- Gas must be present in concentration that will allow for piloted ignition from spark or flame
  - Called flammable range of a gas
- Flammable gas can also ignite without piloted ignition.
  - Air is heated to autoignition temperature (AIT)

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Ignition of Liquids

- Flash point: lowest temperature to produce flammable vapor
- Fire point: burning will be sustained after removal of ignition source
  - Usually only a few degrees higher than flash point
  - Sometimes may be same as flash point

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Ignition of Solids

- Smoldering ignition
  - May transition to flaming combustion
- Piloted flaming ignition
  - Flammable vapors ignited by arc, spark, or flame
- Flaming autoignition
  - eg, commercial clothes dryers with oily laundry, piles of vegetable material
  - Presence of oxidizing agents increase probability

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Flame Spread

- As fire grows, flames move across fuel surface
- Dependent on fuel properties and position of fuel surfaces
- Flame spread may be the result of melting or dripping materials from a fuel package.
- Radiant heat may accelerate rate of flame spread

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Compartment Fire Spread (1 of 3)

- Fire spreads differently in a compartment than in the open.
- Fire spread may result from direct flame contact or remote ignition.
- Superheated gases and smoke are confined by ceiling
  - Hot gas layer increases in temperature and radiates heat, igniting other fuel items

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Compartment Fire Spread (2 of 3)

- Fuel-controlled burning (ignition and growth phases)
  - There is still sufficient oxygen in the room
  - Venting may allow hot gases to escape
- Flashover
  - Convected and radiated heat ignite other materials in the room
  - "Fire in a room" becomes "room on fire"

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Compartment Fire Spread (3 of 3)

- Ventilation-controlled burning
  - Rate of combustion begins to exceed the amount of air flow into the room
  - As fire destroys doors or creates other new openings, airflow into the room may increase.

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Witness Statements

- Be cautious of statements made by witnesses.
- They describe rate of fire growth from the time they discovered the fire.
  - May be difficult to compare with time of ignition
- Rapid fire growth alone is not a reliable indicator of an incendiary fire.

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Summary (1 of 8)

- For a fire to occur, four components must be present: fuel, oxidizing agent, heat, and an uninhibited chemical chain reaction. This is referred to as the fire tetrahedron.

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Summary (2 of 8)

- During a fire, materials may change their physical state as a result of being heated. These phase changes include melting and vaporization.

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Summary (3 of 8)

- If a fire has a limited amount of air for combustion, an increase in the amount of visible products of combustion, such as soot, smoke, and carbon monoxide, will occur.
- The color of smoke should not be relied on as an indicator of the material burning.

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Summary (4 of 8)

- Fluid flows, heat transfer, ignition and flame spread, fuel packages, heat flux, and the distinction between fuel-controlled fires and ventilation-controlled fires are all components of fire dynamics.

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Summary (5 of 8)

- The power of a fire is determined by calculating its HRR, the energy being released by the individual fuels being consumed. It is measured in either watts or kilowatts.

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Summary (6 of 8)

- An ignition source can be defined as either smoldering or flaming. A source of ignition may also be characterized as either piloted or autoignition.

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Summary (7 of 8)

- Rates of flame spread are not only dependent on the individual fuel properties, but also the position and orientation of the fuel surfaces.

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Summary (8 of 8)

- Investigators should be cautious of statements made by witnesses as they relate to the rate of fire growth because often witnesses describe the rate of fire growth from the time they discover the fire, which may be difficult to compare to the time of ignition.