PROCESS SAFETY ENGINEERING (0905477)
10- FIRES AND COMBUSTION

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The superior man, when resting in safety, does not forget that danger may come.... When all is orderly, he does not forget that disorder may come. Confucius (551 BC – 479 BC)

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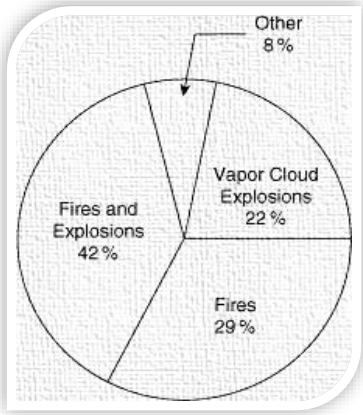
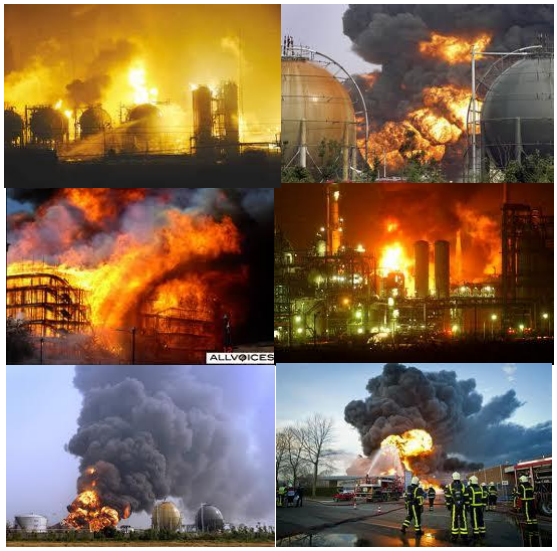
Outline

- The King of All Hazards: Fire
- Combustion and Fire
- Fires and Explosions
- The Fire Triangle
- Fire Tetrahedron
- How Do Fuel Phases Interact with Air?
- Types of Fires
- Stages of Fire
- How Fire Spreads
- Combustion Behavior
- Types of Fire (NFPA)
- Fire Extinguishers
- Different Classification Systems

The King of All Hazards: Fire

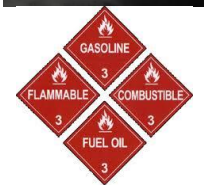


Types of loss for large hydrocarbon-chemical plant accidents. Data from The 100 Largest Losses, 1972–2001.



Combustion and Fire

- Fire is the rapid oxidation of a material in the exothermic chemical process of combustion, releasing heat, light, and various reaction products.
  - Slower oxidative processes like rusting or digestion are not included by this definition.
- Combustion is a chemical reaction in which oxygen is combined **rapidly** with another substance resulting in the release of energy. This energy appears mainly as heat – sometimes in the form of flames.
- The igniting substance is normally, but not always, a Hydrocarbon compound and can be solid, liquid, vapour or gas.
- The terms '**flammable**', '**explosive**', and '**combustible**' are usually interchangeable.



Fires and Explosions

- **Explosion**: Bursting or rupture of an enclosure or a container due to the development of internal pressure from deflagration.
- The distinction between fires and explosions is the rate of energy release.
  - **FIRE**: release energy slowly, rapid exothermic, oxidation, with flame.
  - **EXPLOSION**: higher energy release rate with pressure or shock wave.
- Fires can result from explosions, and explosions can result from fires.

Explosions

Deflagration

- Subsonic combustion (M < 1)
- Pressure wave moves away from reaction front at speed of sound.
- About 5-10 atm pressure rise.
- Associated with low explosives e.g., black powder.
- Main hazard is heat/thermal damage.
- Timescale in the order of milliseconds

Detonation

- Supersonic combustion (M > 1)
- Pressure wave is slightly ahead of reaction front moving at same speed.
- 15-50+ atm pressure rise.
- Associated with high explosives e.g., RDX and TNT.
- Main hazards are heat/thermal damage and excessive pressure.
- Timescale in the order of microseconds

Fires and Explosions

- **EFFECTS**
  - ❖injuries / casualties
  - ❖property losses
  - ❖process interruption

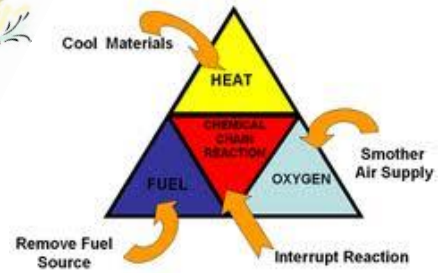
  Thermal radiation, asphyxiation, toxic products, blast, fragments

- **REQUIRED KNOWLEDGE FOR PREVENTION**
  - ❖Material properties
  - ❖Nature of fire and explosion process
  - ❖Procedures to reduce hazards (Ch. 7)

The Fire Triangle

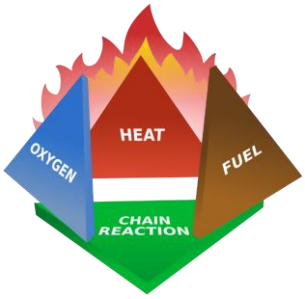
Fire: when all sides are connected.
No fire: when any one side is missing (broken).

Oxidant may not be oxygen rather and oxidizing agent!



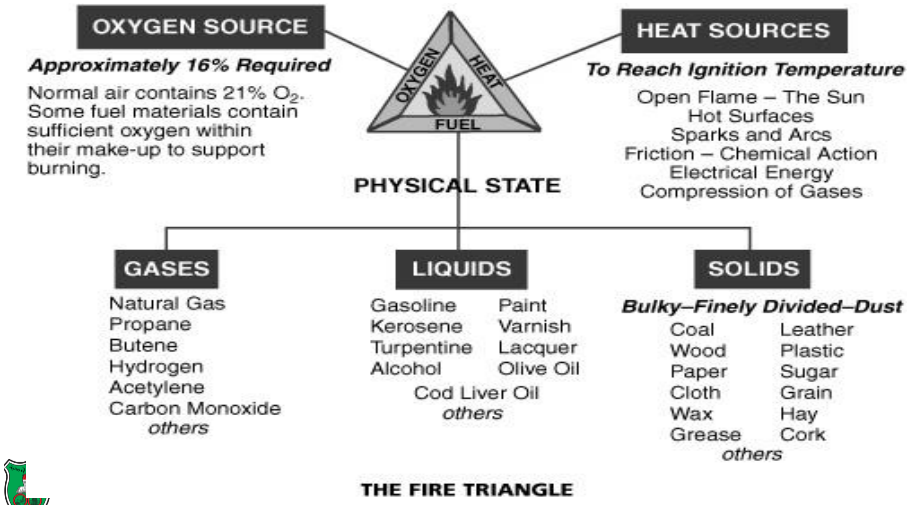
Fire Tetrahedron

- In more recent years, a fourth component – the uninhibited chain reaction – has been added to explain fire.
- This chain reaction is the feedback of heat to the fuel to produce the gaseous fuel used in the flame.
  - The chain reaction provides the heat necessary to maintain the fire.
  - More accurately describes the mechanism for fire suppression by clean agent halon replacements which break up the uninhibited chain reaction of combustion.



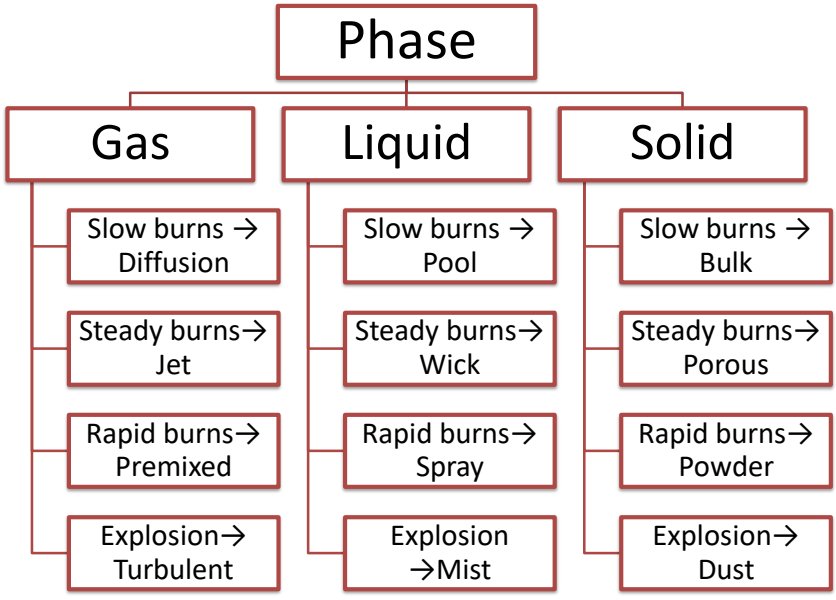
Combustion Basics

Gases: O_2, F_2, Cl_2
Liquids: H_2O_2, HNO_3, $HClO_3$
Solids: Peroxides

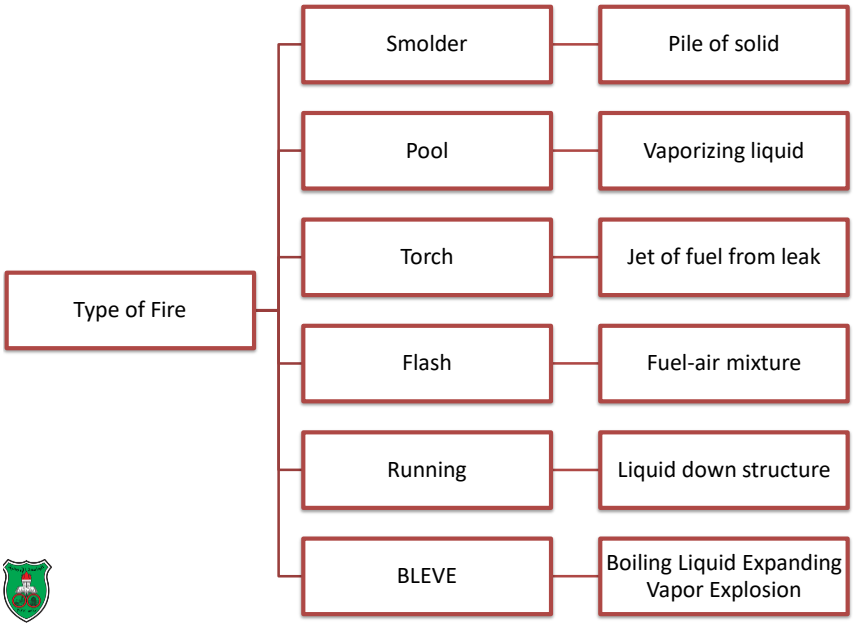


THE FIRE TRIANGLE

How Do Fuel Phases Interact with Air?



Types of Fires



Stages of Fire

Ignition: Fuel, oxygen and heat join together in a sustained chemical reaction.

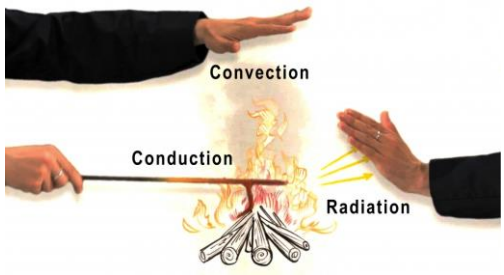
Growth: Initial flame as a heat source, additional fuel ignites. Convection and radiation ignite more surfaces. The size of the fire increases and the plume reaches the ceiling. Hot gases collecting at the ceiling transfer heat, allowing all fuels in a room to come closer to their ignition temperature at the same time.

Fully developed: Fire has spread over much if not all the available fuel; temperatures reach their peak, resulting in heat damage. Oxygen is consumed rapidly.

Decay (burnout): The fire consumes available fuel, temperatures decrease, fire gets less intense.

How Fire Spreads

- Fire spreads by transferring the heat energy from the flames in three different ways.
  - **Conduction**: The passage of heat energy through or within a material because of direct contact, such as a burning wastebasket heating a nearby couch, which ignites and heats the drapes hanging behind, until they too burst into flames.
  - **Convection**: The flow of fluid or gas from hot areas to cooler areas. The heated air is less dense, and rises, while cooler air descends. A large fire in an open area produces plume or column of hot gas and smoke high into the air. But inside a room, those rising gases encounter the ceiling. They travel horizontally along the ceiling forming a thick layer of heated air, which then moves downward.
  - **Radiation**: Heat traveling via electromagnetic waves, without objects or gases carrying it along. Radiated heat goes out in all directions, unnoticed until it strikes an object. Burning buildings can radiate heat to surrounding structures, sometimes even passing through glass windows and igniting objects inside.



Combustion Behavior – Most Hydrocarbons

Smoke and fire are very visible!

Combustion Behavior – Carbon Disulfide

No smoke and fire, but heat release rate just as high.

Combustion Behavior – Methane

Methane burns mostly within vessel, flame shoots out of vessel.

Combustion Behavior – Dusts

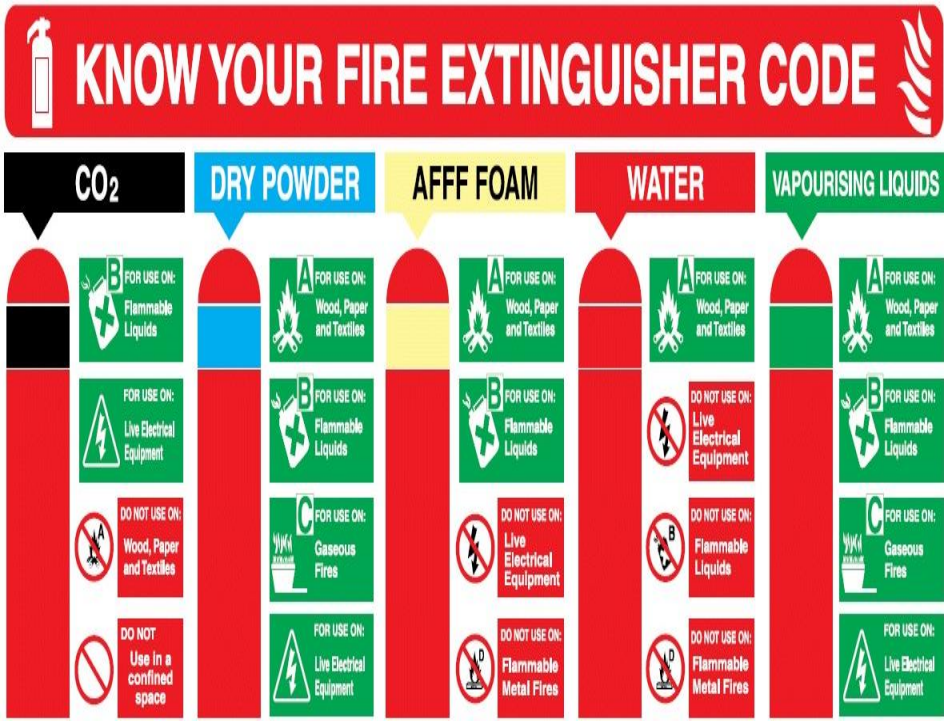
Much of the dust burns outside of the chamber

Fire Prevention

1. Inerting (Smothering) → no oxygen
2. Fuel → Remove (isolate).
3. Ignition source → prevent it (Cool).

Types of Fire (NFPA)

Class	Description	Symbols
A	Involve solid materials of an organic nature such as wood, paper, cloth, rubber and plastics that do not melt.	
B	Involves liquids. They include petrol, diesel, thinners, oils, paints, wax, cooking fat and plastics that melt.	
C	Involve electricity.	
D	Involve flammable metals such as magnesium, aluminium, titanium, sodium and potassium.	
K	Involve combustible cooking media such as oils and grease commonly found in commercial kitchens.	



Different Classification Systems

American	European	Australian/Asian	Fuel/Heat source
Class A	Class A	Class A	Ordinary combustibles
Class B	Class B	Class B	Flammable liquids
	Class C	Class C	Flammable gases
Class C	Class F/D	Class E	Electrical equipment
Class D	Class D	Class D	Combustible metals
Class K	Class F	Class F	Cooking oil or fat

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