Eilat Fire and Rescue

The Chemistry and Physics of Combustion

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Overarching Goal

- The student will identify fire risks before and as they develop, and will act to prevent them and extinguish them while safeguarding his own safety and the safety of those around him.

Intermediate Goal

- The student will define what a fire is and will explain how to prevent it.
- The student will describe the risks in areas where there are fire and smoke and how to act in such areas.
- The student will explain what to do when a fire breaks out.
- The student will act to improve safety in his work and living environment under routine circumstances.

Basic Concepts

- Oxidation – A chemical reaction between oxygen and a substance, causing it to decompose (rust, decay).

- Combustion – A rapid or slow oxidation process of a material that maintains itself and is accompanied by the release of heat.

- Fire / Flame – A rapid oxidation process of a material that maintains itself and is accompanied by the release of heat and light.

Basic Concepts – continued

- Heat: Energy transferred from one object to another when the temperature of the two objects differs.

- Temperature: Indicates heat -- is the extent to which an object is hot or cold. It is measured in degrees Celsius or Fahrenheit.

- Calorie: The quantity of heat required to raise the temperature of one gram of water one degree Celsius.

Basic Concepts - continued

•Energy: The ability to perform work.

Work is performed when a force acts on an object over time; in other words, work is the changing of energy from one form to another.

Energy is measured in units such as joules / watts / newtons.

•Chemical energy: Energy released as a result of a chemical reaction, such as combustion.

Basic Concepts - continued

- Mechanical energy: The energy of an object in motion, such as a stone rolling down a slope.

- Electrical energy: Energy that develops when electrons flow through a conductor (current).

- Thermal energy: Energy that is transferred between two objects of differing temperatures.

Basic Concepts - continued

- Nuclear energy: Energy produced by splitting the nucleus of an atom.

- Kinetic energy: Energy of an object in motion.

- Potential energy: Energy that can be released from an object in the future.

- Capacity: The quantity of energy produced for the purpose of work in a given time.

Basic Concepts - continued

Law of Conservation of Energy and Mass:

- Energy is not created and or destroyed, it merely changes from one form of energy to another.

- The change in energy is expressed only as a change in the form of the energy or its location, but the quantity of the energy is always constant.

- As a fire consumes fuel the mass of the fuel is decreased. This drop in the fuel mass is expressed as the release of energy in the form of light and heat and by the creation of combustion products.

Basic Concepts - continued

Heat transfer:

- The transfer of heat from one point or object to another is a basic concept in the study of fire.

- The definition of the term “heat” clarifies that in order for heat to be transferred from one object to another, both of the objects must have different temperatures. The heat is transferred from the warmer object to the cooler object.

- The rate at which the heat is transferred depends on the temperature difference between the objects.

Basic Concepts - continued

Heat transfer:

- Heat conduction is the transfer of heat by means of contact between two objects or within a conductor.

- Heat transfer is the transfer of thermal energy from an object with a higher temperature to an object with a lower temperature.

- Heat transfer takes place in three ways: Conduction, convection and radiation.

Basic Concepts - continued

Conduction:

- Conduction is the transfer of thermal energy from one point to another.
- It takes place when an object is heated as a result of direct contact with a heat source.
- Conduction cannot take place through empty space because there is nothing that enables contact between the molecules.
- When one end of a metal bar is heated, the heat is “conducted” along the length of the bar.

Basic Concepts - continued

Convection:

- Convection is the transfer of energy through the movement of heated liquids or gases.

- When heat is transferred by means of convection there is a cyclical movement or flow – circulation – of liquids and gases from one place to another. As with all types of heat transfer, the heat flows from the warmer place to the cooler place.

Basic Concepts - continued

Radiation:

- Radiation is the transfer of thermal energy in the form of electromagnetic waves without any interference.

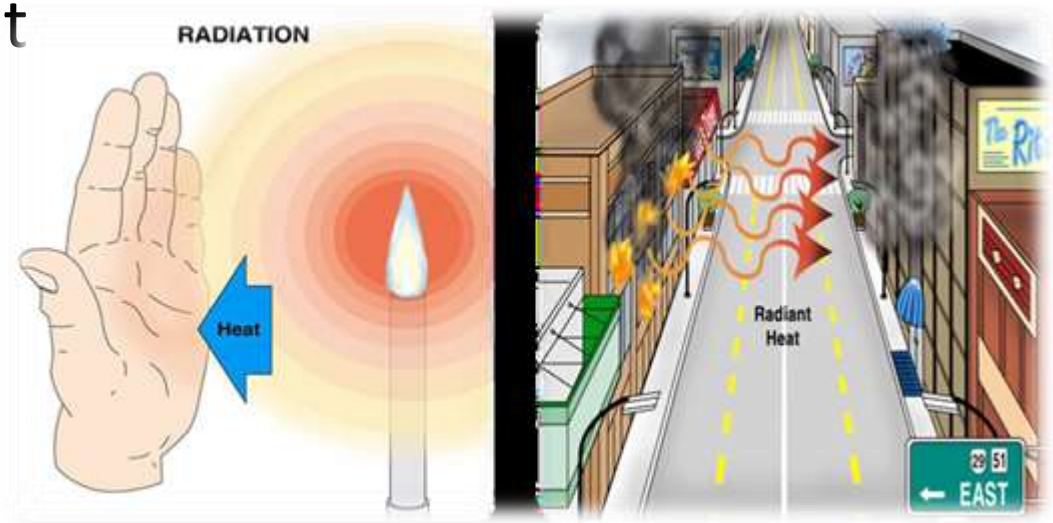
- Since this is an electromagnetic wave, the energy moves in straight lines at the speed of light. All hot objects radiate heat.

- The best example of heat that is transferred by radiation is the heat of the sun. Thermal energy is transferred from the sun and heats the surface of the earth.

Basic Concepts - continued

Radiation – continued:

- In most cases radiation is what causes fires to spread to buildings located near a burning building.
- In large fires the heat being radiated could ignite buildings or combustible materials located some distance from the fire itself.

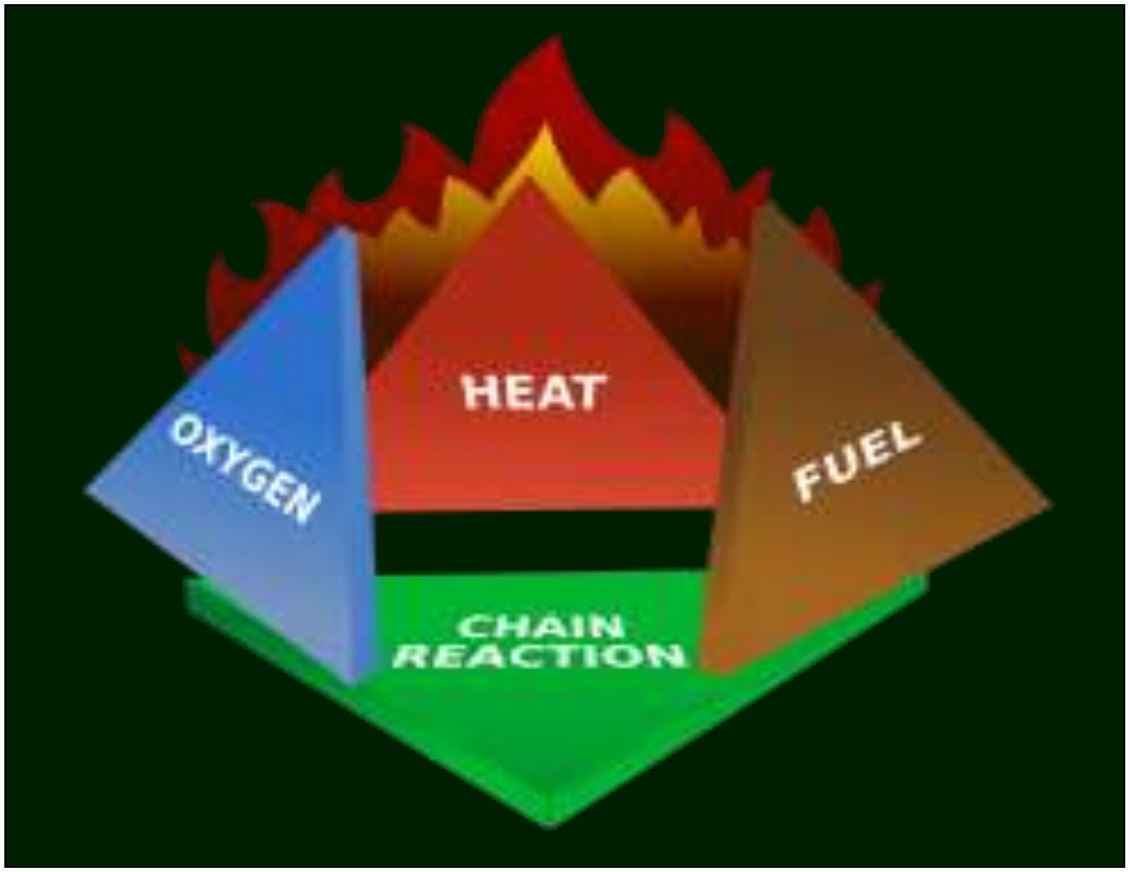


The Fire Pyramid

In order to generate combustion four things are required:

1. Oxygen (oxidizing material)
2. Fuel (flammable material)
3. Heat (flashpoint temperature)
4. Chemical chain reaction (the ability of the material to continue to break down)

The Fire Pyramid



The Fire Pyramid

Oxygen:

- Oxidizers are materials that provide oxygen or other oxidizing gases during the chemical reaction. Oxidizers are not flammable themselves, but they support combustion when combined with fuel. Although oxygen is the most common oxidizer there are other materials found in the same group.

- Oxygen in the air around us. Is considered to be the primary oxidizer. Air contains 21% oxygen. In general, combustion is supported by oxygen concentrations of not less than 14%.

The Fire Pyramid

Oxygen – continued:

- However, research has shown that when temperatures in the room are extremely high even a low concentration of oxygen is sufficient to support combustion that releases flames.

- With highly concentrated oxidizers, such as 100% concentrated hydrogen peroxide compressed in tanks, we would expect the reaction rate to be rapid and could even lead to an explosion.

The Fire Pyramid

Matter:

- The things we see when we look around us are called matter.
- Matter can be distinguished by its physical state, and things such as color and smell.
- Density: A unit of measurement that describes the degree to which the molecules of the matter are close to one another.
- Specific gravity: The ratio between the mass of a given volume of a liquid compared to the mass of the same volume of water.

The Fire Pyramid

Matter – continued:

- Vapor density: The density of gases or vapor in relation to the density of the atmosphere.
- Matter is the fuel that oxidizes or burns during combustion.
- Two factors relating to fuel are important for the development of the combustion process: The state of the matter and its distribution.
- Combustible materials can be in one of three states of matter: solid, liquid or gas. However, in order for them to burn the fuel must usually be in a gaseous state. In order to burn solids and liquids you need energy that will first cause the matter to become a gas.

The Fire Pyramid

Heat:

- Heat is the energy component of the Fire Pyramid. When heat comes into contact with combustible materials, the energy reinforces the combustion reaction in the following ways:

1. It causes pyrolysis or vaporization of the solid or liquid fuel and the creation of flammable gases or vapors.

2. It provides the energy required for ignition.

3. It causes the continuous creation and ignition of combustible vapors or gases so that the combustion reaction can continue.

The Fire Pyramid

<u>The chemical chain reaction</u>:

- Combustion is a complex reaction that requires combustible matter (in a gaseous state or as vapor), an oxidizer and thermal energy, all of which combine in a very specific manner.

- From the moment there is burning with flames, defined as a fire, it can continue to exist provided there is enough thermal energy to produce a sufficient supply of fuel vapors or gases.

- Scientists call this type of reaction a chain reaction.

Fire Extinguishing Pyramid

- Cooling: Adsorption of the heat at a faster rate than the production of heat.

- Isolation: Removing the burning matter from other substances or vice versa.

- Suppression: Reducing the percentage of oxygen in the area of the fire to less than 14%.

Classes of Fires

- There are actually five classes of fires, but we categorize them into four classes because the means used to extinguish some of them are identical.

- From this we understand that the classes of fires are determined by the methods used to extinguish them.

- The classes of fires are: solids, liquids, gases, electrical and light metals; liquids and gases are usually placed in the same group.

Classes of Fires - continued

1. Solids 

2. Liquids / gases 

3. Electrical 

4. Light metals 

Solid Fires

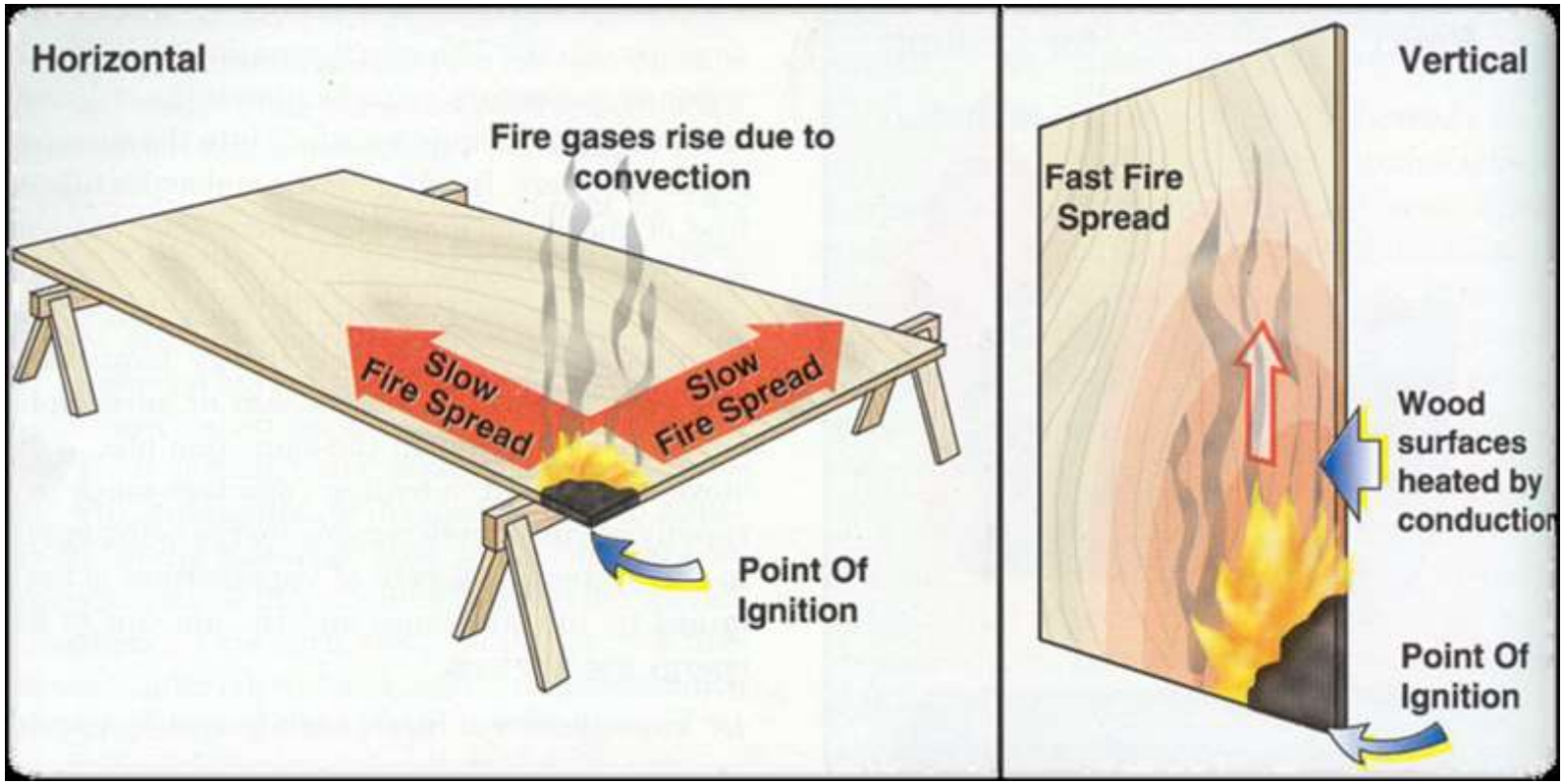
- There are many types of flammable solids, the most common of which are: paper, plastic, cardboard, fabric and rubber.

- The rate at which fire spreads with these solids depends on the type of material, its position in the surrounding area and the ratio between its surface area and its mass.

- These types of fires can be extinguished using isolation, suppression and cooling.

The Rate at Which Fire Spreads in Solids

Fire spreads as a function of the position of the burning object:



The Rate at Which Fire Spreads in Solids

Decomposition of the material and preparation for combustion:

- A flammable gaseous material is created from a solid fuel through a process known as pyrolysis, which is the decomposition of a chemical compound by applying heat. Simply put, when the solid fuel is heated, flammable material is released from the solid compound.

- With flammable liquids combustible gases are formed during evaporation -- that is, when the flammable liquids become gaseous.

- Gaseous fuels are the most dangerous because they are already in the state of matter needed for combustion, and only a small quantity of energy is require [illegible] the material to combust.

The Rate at Which Fire Spreads in Solids

Surface to mass ratio:

The greater the surface area and the smaller the mass, the greater the potential for igniting a fire.

Liquid Fires

- There are numerous types of flammable liquids, the most common of which are fuel (gasoline, diesel, oil), alcohol, fat, tar, paint thinner.

- The density of these liquids is less than 1 and therefore they are lighter than water.

- A fire of this type can be extinguished using suppression.

Example of a Common Liquid Fire:

<u>Cooking oil:</u>

1. Do not attempt to lift/move the pot from its place.
2. Shut off the source of heat (gas, electricity).
3. Wet a towel / take off the pot cover.
4. Carefully place it on the top of the pot.
5. Wait until the pot has cooled off.

Never use water to extinguish this type of fire!!!

Gas Fires

- There are many types of flammable gases, the most common of which are LPG, propane, methane, hydrogen, acetylene and natural gas.

- Flammable gases can ignite and even explode, depending on their concentration in the air. The explosive limit is what determines the risk. The broader the limit or the lower the flashpoint, the more dangerous the material.

- A fire of this type can be extinguished using suppression.

Example of a Common Gas

<u>Liquefied petroleum gas (LPG) – cooking gas:</u>

1. A by-product released during the process of refining crude oil.
2. Consists of a mixture of 20% butane and 80% propane (this can vary).
3. Used for cooking, heating and powering motor vehicles.
4. Colorless and odorless (ethyl mercaptan is added to give it a detectable odor).
5. It is 2.5 times heavier than the air.
6. Explosive limit is 2%-9%.

Electrical Fire

- An electrical fire is not only the burning of an electrical appliance or an electrical panel, but any fire where electricity is flowing nearby: A building connected to the electricity grid, electrical appliances that are plugged into an outlet, electricity panels, electrical poles and transformers, generators, uninterruptible power supply systems and more.

- The basic assumption is that any fire in an urban area is an electrical fire and the power must be disconnected before making any attempt to extinguish it.

Electrical Fires – Remember!

- If the electricity has not been disconnected – do not use water! Using water could cause injury or even death.
- Transformers and chargers – even if they are not being used if they are connected to the electricity they are considered as using electricity and therefore they could fail.
- If the fuses are down in an electrical panel, electrical power is still being fed to the main breaker.

Light Metals

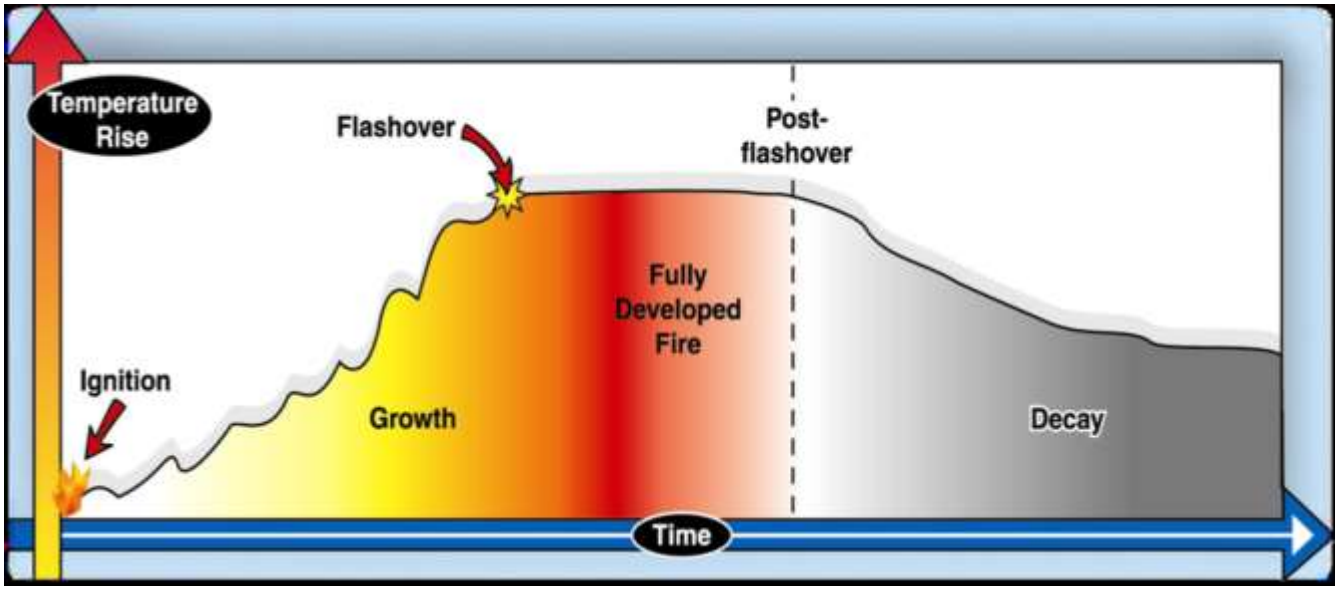
- As technology advances there are more and more types of light metals in our environment: magnesium, aluminum, lithium, titanium and more.

- These metals produce high temperatures when they burn (around 1000 degrees Celsius); attempting to extinguish them using water will cause the water to break down into its component elements (hydrogen is explosive, oxygen will fuel the combustion).

- The presence of these metals in flammable areas contributes to the spread of the fire to numerous spots and makes it more difficult to extinguish, raising the danger that civilians and fire fighters can be trapped.
- Extinguish these fires using specially designated materials only.

Stages of Fire Development in a Closed Space

- There are five stages in the development of fires in closed spaces: Ignition, growth, flashover, fully developed fire and decay. The rate at which the fire develops and the transition from one stage to another depends on several factors:



Factors that Influence the Development of a Fire

- The size of openings to release smoke and heat, their number and arrangement.
- Size of the space.
- Shape of the space and height of the ceiling.
- Thermal characteristics of the closed space.
- Primary fuel location.
- Fuel characteristics (rate of heat release), location and quantity.

The End