Product 3

Fire Safety Awareness and Emergency Preparedness

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Acronyms

Acronym	Full Name
AED	Automated External Defibrillator
AIDS	Acquired Immunodeficiency Syndrome
BLEVE	Boiling Liquid Expanding Vapour Explosion
BOFA	Basic Occupational First Aid
CAAM	Civil Aviation Authority of Malaysia
CAD	Coronary Artery Disease
CCC	Certificate of Completion and Compliance
CHD	Coronary Heart Disease
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COVID-19	Coronavirus Disease 2019
CPR	Cardiopulmonary Resuscitation
CPU	Central Processing Unit
CPU	Central Processing Unit
DNR	Do Not Resuscitate
DOSH	Department of Safety and Health
DRCAB	Danger, Response, Chest Compression, Airway, Breathing
DSU	Distress Signal Unit
EAC	Emergency Action Code
EEG	Electroencephalogram
eFEIS	Electronic Fire Inspection System
EMRS	Emergency Medical Response Service
EMS	Emergency Medical Services
ERT	Emergency Response Team
EU	European Union
HAZMAT	Hazardous Material
HCN	Hydrogen Cyanide
HIRARC	Hazard Identification, Risk Assessment and Risk Control
HIV	Human Immunodeficiency Virus

Acronym	Full Name
LAST	Locate, access, stabilize, and transport
LEL	Lower Explosive Limit
LFL	Lower Flammable Limit
MASTEM	Malaysian Society for Traumatology and Emergency Medicine
MRI	Magnetic Resonance Imaging
IP	Ingress Protection
ISO	International Organization for Standardization
kPa	Kilopascal
MS	Malaysia Standard
NFPA	National Fire Protection Association
NIOSH	National Institute of Occupational Safety and Health
OSHA	Occupational Safety and Health Act
PASS	Personal Alert Safety System
PEL	Permissible Exposure Limit
PPE	Personal Protective Equipment
PSI	Pounds per Square Inch
R&D	Research and Development
RELA	Jabatan Sukarelawan Malaysia
SCA	Sudden Cardiac Arrest
SCBA	Self-contained Breathing Apparatus
SCUBA	Self Contained Underwater Breathing Apparatus
SIRIM	Standard and Industrial Research Institute of Malaysia
SOP	Standard Operating Procedure
TLV	Threshold Limit Value
TWA	Time Weighted Average
UBBL	Uniform Building By-Laws
UN	United Nations
WHO	World Health Organization

1.Chemistry of Fire

Objective of Lesson

The objective of this lesson is to understand the general principles of fire. These principles include elements required for a fire to burn, definitions pertaining to fire effects which is essential to understanding fire and putting it out.

1.1. What is a fire?

There are 3 states of matter, which are solid, liquid, and gas. There are also several terms to know in the topic of fire chemistry.

1.1.1. How Fire Occurs

- Fire occurs when a substance combines with fuel and has adequate oxygen. It gives off heat, smoke, and bright light. Stored chemical energy is converted to energy in the form of heat and light. The energy comes from the breaking and formation of chemical bonds.
- In other words, it is a chemical chain reaction which takes place with the evolution of heat and light.
- for a fire to exist, a combustible substance must be present, the temperature must be high enough to cause combustion, and enough oxygen must be present to sustain rapid combustion.
- Fires will continue to burn until their supply of oxygen is depleted , the fuel is removed or consumed, or someone extinguishes the fire.

1.1.2. Facts about fire

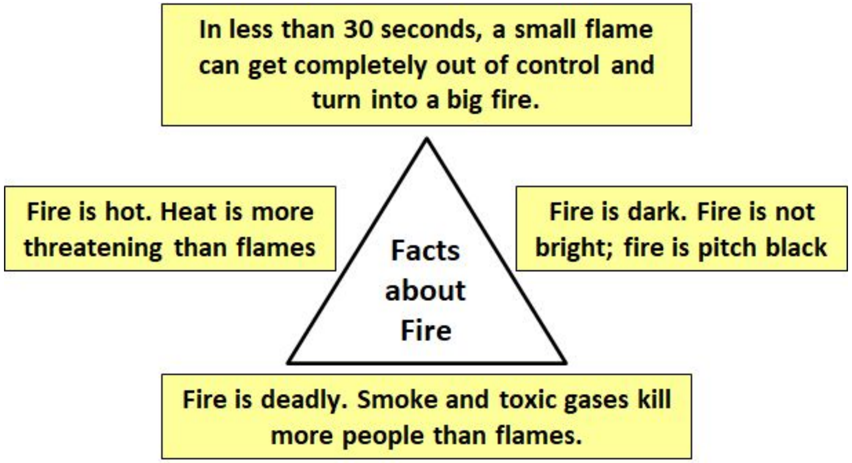
- In less than 30 seconds, a small flame can get completely out of control and turn into a big fire;
- Fire is hot. Heat is more threatening than flames;
- Fire is dark. Fire is not bright. fire is pitch black;
- Fire is deadly. Smoke and toxic gases kill more people than flames

1.1.3. Why does a fire need fuel?

- The fire triangle represents elements necessary for a fire to start. The four elements of a tetrahedron are fuel, an oxidising agent, usually oxygen, heat energy and an uninhibited chain reaction.
- Fuel refers to a flammable or combustible material necessary to start the combustion process. Fuel can be a solid, such as wood, liquid, such as gasoline or gas, such as, propane.
- The materials will only burn when in the vapour phase. This means that in order for fire to start, combustible gas-phase must exist.
- The gas-phase is achieved when a material is heated beyond its flashpoint in order to exert a vapour pressure that can ignite in air and aid combustion.
- Wood is a compound which has high molecular weight molecules that include materials like lignins and naturally occurring carbohydrate cellulose.
- So, for wood to reach the necessary gas-phase, these materials must undergo thermal decomposition by pyrolysis which means decomposition brought about by high temperatures. This occurs when the wood is heated pass its flashpoint, which causes the cellulose and other materials to decompose into small molecules that can exist in gas-phase. When these gases reach their ignition temperature, burning begins.

1.1.4. Heat Energy

- Heat energy is required to start the ignition of the fuel and to get it to the minimum temperature required for it to become self-sustaining. This is referred to as the Ignition Temperature.
- Heat energy is generated during combustion because the reaction is exothermic. Heat is released when chemical bonds are broken and formed during chemical reactions. Since these reactions are continuous, combustion releases more heat than is required to sustain a fire. This makes a fire self-perpetuating and also what makes it hot.
- Electricity, wood, sun, and candle wax are some of the sources of heat energy.



1.1.5. Exothermic Reaction

Fire gives out heat and light because the chemical reaction producing the flames is exothermic. An exothermic reaction is a chemical reaction that entails the release of energy in the form of heat or light. As such, endothermic reaction is cooler than the surroundings.

1.1.6. Oxidising agent

Oxidising agent is required to support burning by reacting with fuel. Oxygen is the most common oxidising agent. Once the volatile gases released by fuel reaches the ignition temperature, the compound breaks apart and recombine with oxygen to form water vapour, carbon dioxide, various combustion products and more heat. This process is called oxidation and can be seen by burning and smoke.

1.1.7. Uninhibited Chain Reaction

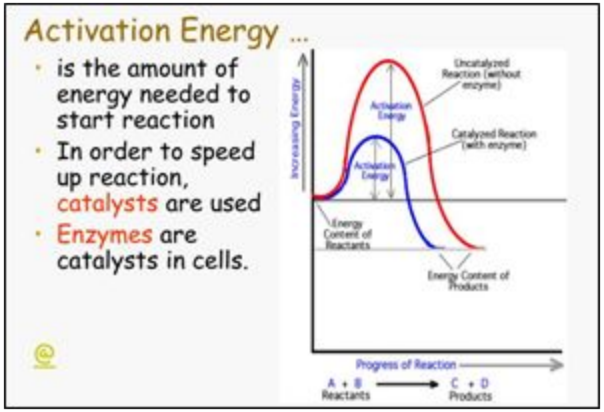
- An uninhibited chain reaction is enabled by the reaction between fuel, heat, and oxygen. An uninhibited chain reaction refers to the self-perpetuating capability of combustion.
- Due to the continual reactions going on between fuel and oxygen, which generate surplus amounts of heat energy, the flame will always be hot enough to keep the fuel at ignition temperature. Therefore, the fire will continue to burn as long as there is enough fuel and oxygen available. This process similarly finishes when these sources have been expended.

1.1.8. Conflagration: How a Fire Spreads

- The danger of chemical reactions is the fact that they are self-sustaining. Fire can spread because of the uninhibited chain reaction that occurs from combustion, and from the heat energy that keeps the fuel above ignition point.
- Thus, the heat of the flame is able to heat the surrounding fuel. If this fuel is heated pass its flashpoint, volatile gases will be released as the fuel enters into its gas-phase.
- The flame is able to ignite the gas and spread. As long as there are fuel and oxygen available, the fire is able to spread.
- To explain how fire travels, it all comes down to gravity. The hot gases in the fire is hotter and less dense than the surrounding air.
- Therefore, they move upward, where there is lower pressure and is why fire travels uphill and also why flames are pointed.

1.1.9. Activation energy

- Another important term to know is Activation Energy. Activation energy is the minimum energy necessary for a specific chemical reaction, like matches sparking, electrical discharging, and chemicals reacting.



1.2. Varieties of flame colours

- By the way, there are varieties of colours associated with flames. These depends on the chemical composition of burning fuel, the reaction products generated, and the heat at which it is burning.
- For example, the colour blue in flames, is due to the presence of carbon and hydrogen and also indicates that it is the hottest part of the flame. If there were copper compounds being burned, the flame would be green.
- Colour variation in a flame is due to the different temperatures. An example of this is when a fire undergoes incomplete combustion. This occurs when there is not enough oxygen to keep up with the burning of fuel, as is commonly seen in campfires. This is because there is only twenty-one percent oxygen in the atmosphere. While this is enough to cause oxidation, it is not enough to keep up with multiple chemical reactions that takes place during combustion.
- When they are unable to react with oxygen, some of the fuel carbonises with itself to create soot. Soot gets extremely hot and begins to emit a white light. The soot particles that rise in the air begin to cool, causing their emission spectrum to shift to infrared. This is why the top of a fire is usually red while the bottom is more yellow-white. When there is complete combustion, meaning that there is a sufficient supply of oxygen, the flame will burn blue.

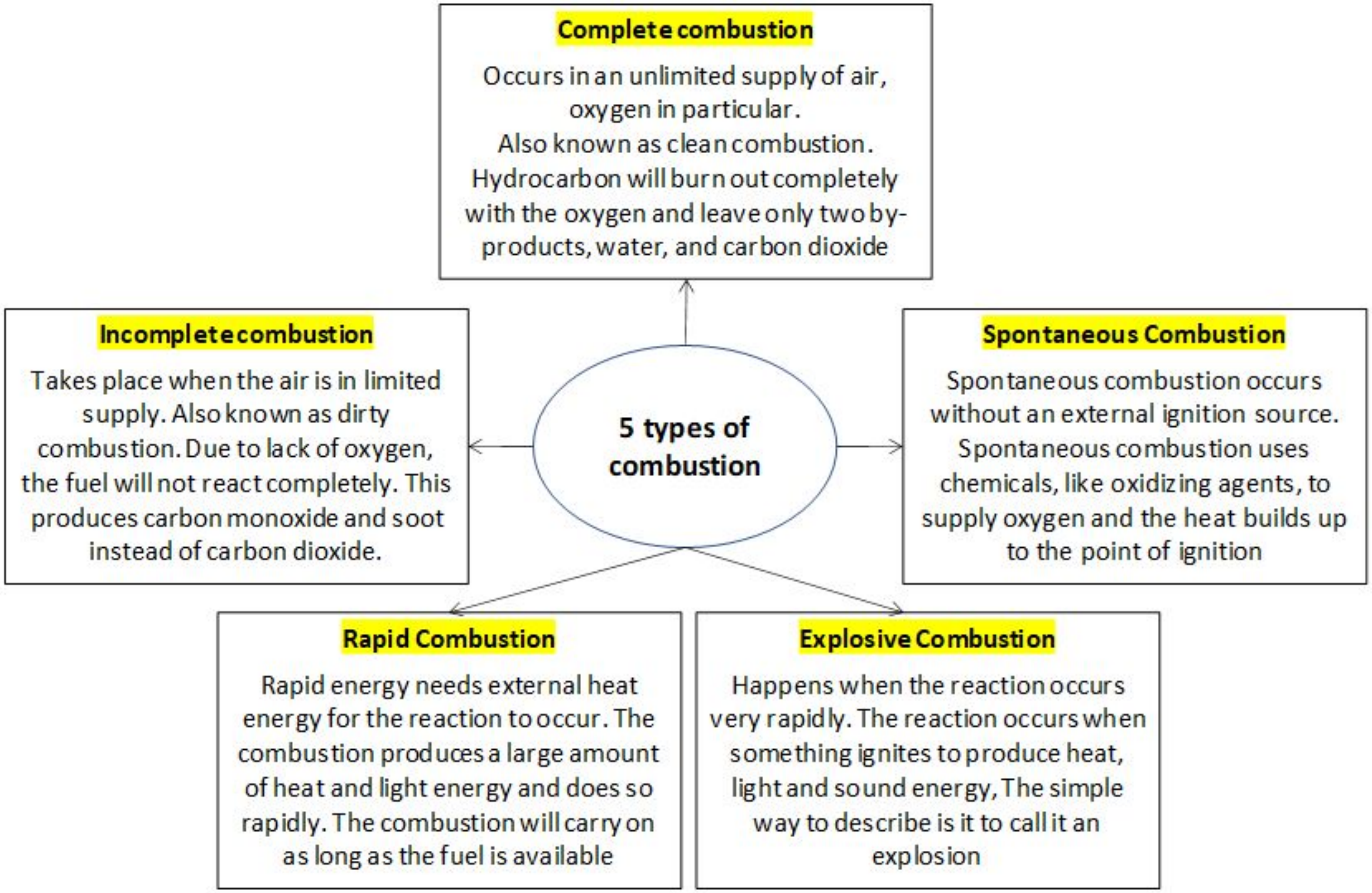
1.2.1. Composition of dry air

As we delve deeper, we find that air is a mixture of gases. Three elements make up over 99.9 percent of the composition of dry air. These are nitrogen, oxygen and argon.

Nitrogen	78.08 percent
Oxygen	20.95 percent
Argon	0.93 percent
Carbon Dioxide	0.04 percent
Neon	0.02 percent
Helium	0.00 percent
Methane	0.00 percent

1.3. What is Combustion?

- Combustion is a chemical process or a reaction between Fuel (Hydrocarbon) and Oxygen. When fuel and oxygen react, it releases heat and light energy. Heat and light energy then result in the flame. The formula for a Combustion reaction is Hydrocarbon + Oxygen = Heat energy.



1.3.1. Complete Combustion

- Complete combustion occurs in an unlimited supply of air, oxygen in particular
- Complete combustion is also known as clean combustion
- Here the hydrocarbon will burn out completely with the oxygen and leave only two by-products, water, and carbon dioxide
- An example of this is when a candle burn. The heat from the wick will vaporize the wax which reacts with the oxygen in the air. The two products of the reaction are water and carbon dioxide. In an ideal situation all the wax burns up and complete combustion takes place

1.3.2. Incomplete Combustion

- Incomplete combustion takes place when the air is in limited supply
- Also known as dirty combustion
- Due to lack of oxygen, the fuel will not react completely. This, in turn, produces carbon monoxide and soot instead of carbon dioxide
- An example is burning of paper. It leaves behind ash (a form of soot) as a by-product. In a complete combustion, the only products are water and carbon dioxide. Also, incomplete combustion produces less energy than complete combustion.

1.3.3 Rapid Combustion

- Rapid combustion needs external heat energy for the reaction to occur
- The combustion produces a large amount of heat and light energy and does so rapidly
- The combustion will carry on as long as the fuel is available
- An example is when you light a candle. The heat energy is provided when we light the candle with a matchstick. And it will carry on till the wax burns out. Hence it is a rapid combustion

1.3.4. Spontaneous Combustion

- Spontaneous combustion is when combustion occurs without an external ignition source
- Spontaneous combustion uses chemicals, like oxidizing agents, to supply oxygen and the heat builds up to the point of ignition
- The temperature rises above ignition point and in the presence of sufficient oxygen, combustion will happen. The reaction of alkali metals with water is an example

1.3.5. Explosive Combustion

- Explosive Combustion happens when the reaction occurs very rapidly
- The reaction occurs when something ignites to produce heat, light and sound energy, the simple way to describe is it to call it an explosion
- Some classic examples are firecrackers or blowing up of dynamite

1.3.6. Flash Point

The temperature at which a particular organic compound gives off sufficient vapour to ignite in air

- Flash Point is the minimum temperature for liquid fuel to produce enough vapour to ignite if exposed to a spark, but the ignition may not be sustained;
- Anyone storing flammable liquids and gases should be aware of their flash point and make sure they are kept safely below this temperature;
- Fire Point is the lowest temperature where ignition is achieved, and the ignition is sustained for some time;
- The fire point temperature is always slightly higher than the flash point temperature.

1.3.7. Flammable Range

- Flammable Range is the range of composition of fuel-air mixture needed for combustion;
- Hydrocarbon gas mixed with air cannot ignite unless its composition lies within a range of gas in air concentration known as the "flammable range";
- The lower limit of this range, known as the "Lower Flammable Limit" is any hydrocarbon concentration below, with insufficient hydrocarbon gas to support combustion;
- The upper limit of this range, known as "Upper Flammable Limit" is any hydrocarbon concentration above, with insufficient air to support combustion.

1.3.8. Flashover

- Flashover is the near-simultaneous ignition of most of the directly exposed combustible material in an enclosed area. When certain organic materials are heated, they undergo thermal decomposition and release flammable gases. Flashover occurs when most of the exposed surfaces in a space are heated to their autoignition temperature and emit flammable gases (see also flash point). Flashover normally occurs at 500°C (932°F) or 590°C (1,100°F) for ordinary combustibles, and an incident heat flux at floor level of 20 kilowatts per square metre (2.5 hp/sq. ft).

- An example of a flashover is the ignition of a piece of furniture in a room. The fire involving the piece of furniture can produce a layer of hot smoke that spreads across the room's ceiling. The hot buoyant smoke layer grows in-depth, as it is constrained by the walls of the room.

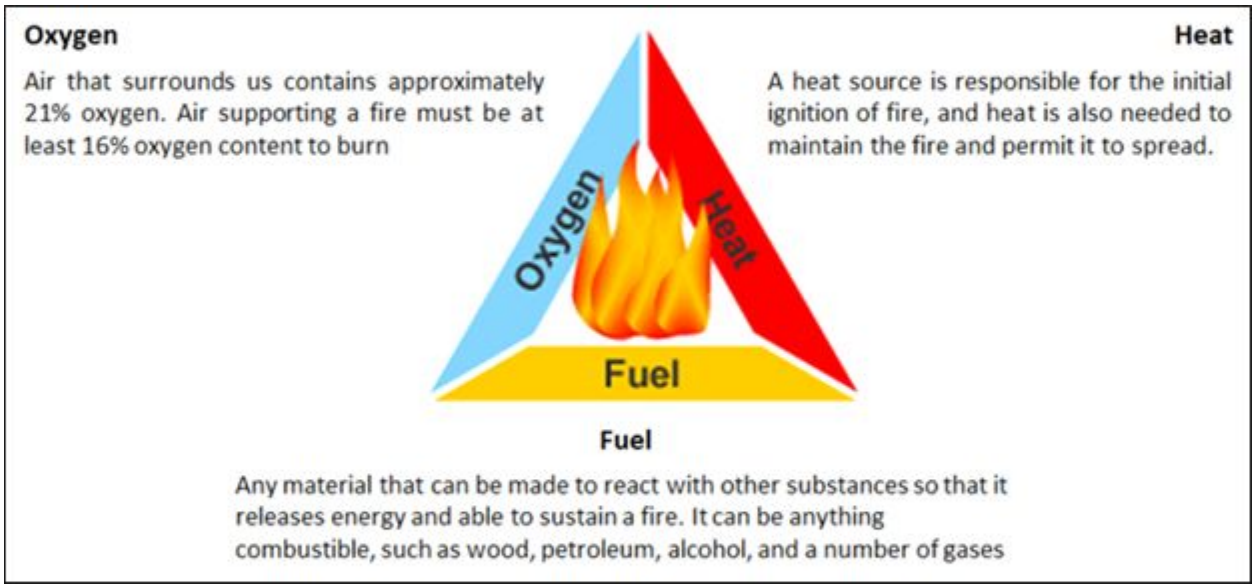
- The radiated heat from this layer heats the surfaces of the directly exposed combustible materials, causing them to give off flammable gases via pyrolysis. When the temperatures of the evolved gases become high enough, these gases will ignite, throughout their extent. Some of the signs that firefighters look for when they want to determine whether a flashover is likely to occur are as follows:

  - The fire is in a ventilated compartment, so there is no lack of oxygen in the room;
  - The neutral plane is moving down towards the floor. In this situation, a flashover is possible;
  - Directly exposed combustible materials are showing signs of pyrolysis;
  - "Rollover" or tongues of fire appear, known as "Angel Fingers" to firefighters;
  - There is a swift build-up of heat given off by the rapidly burning (i.e., deflagrating) gases. This is generally a good indication of a flashover;
  - Thick dark smoke, high heat, rollover, free burning. There is no connection between the colour of the smoke and the risk of flashovers.

1.4. Triangle of Fire

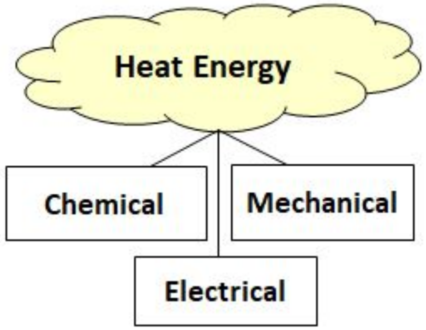
For a fire to start, there need to be 3 elements present. This diagram is commonly referred to as the "Triangle of Fire."

- First is **Fuel**. A combustible substance must be there.
- Second is **Heat**. The temperature must be high enough to cause combustion.
- Third is **Oxygen**. Enough oxygen must be present to sustain rapid combustion.



1.4.1. Fuel

- Fuel is any material that can be made to react with other substances, so that it releases energy and able to sustain a fire. It can be anything combustible, such as wood, petroleum, alcohol and a number of gases.
- Fuels can be solid, liquid or gas. Solid fuels must reach critical temperatures to ignite while many liquids give off flammable vapours, even when cold. Gases are the most hazardous and temperamental state and can combust instantaneously. This is because the more finely divided the fuel is, the more likely it can be ignited.



1.4.2. Ignition Temperature

Every fuel has an ignition temperature. Ignition temperature is the temperature to which a combustion and it is also sometimes called the “autoignition” temperature.

1.4.3. Heat

Besides fuel, fire requires heat. Heat will also be continuously generated as the fire burns. For intentional fires, this could be as easy as striking a match.

1.4.4. Accidental Fires

For accidental fires however, ignition can occur because of a machinery’s ventilation being obstructed or because of flammable materials being too close to a heat source.

1.4.5. Heat Energy. Chemical heat energy, electrical heat energy, and mechanical Heat energy makes up the three general categories of heat energy.

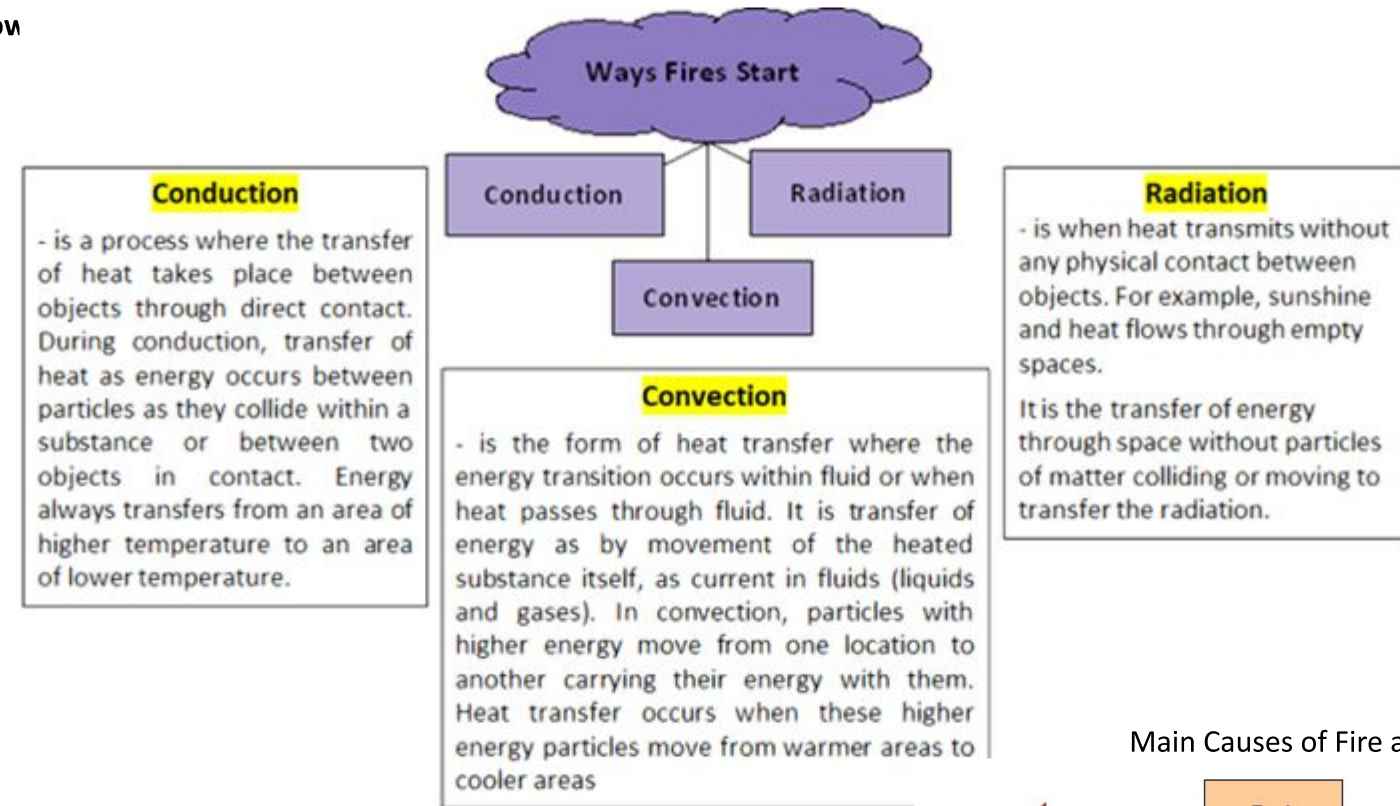
1.4.6. Electrical heat energy can be in the form of resistance heating, dielectric heating, induction heating, heat from arcing, leakage current heating, static electricity, or lightning.

1.4.7. Mechanical heat energy can be frictional heat, frictional sparks, or heat of Compression.

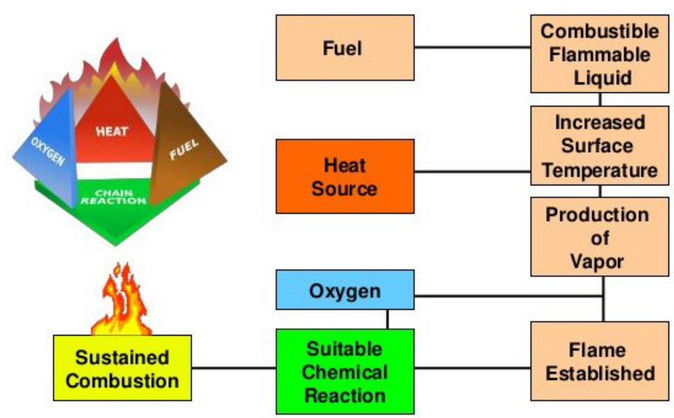
1.4.8. Chemical heat energy happens when two or more chemicals combine to generate heat.

- There are billions of chemicals that undergo an exothermic (energy-releasing) reaction when combined.
- When mixing two materials the reaction between them could generate heat. In extreme cases, this heat could generate pressure waves that lead to an explosion. One example is the addition of water to concentrated acid.
- There are various chemicals that should not be mixed. They may either explode or create poisonous fumes. You might not have heard of or learned of some of these chemicals, but some of these chemicals include:
  - Mixing Hydrogen Sulfide and Nitric Acid;
  - Mixing Chlorine with Ammonia;
  - Mixing Chromic Acid with Acetic Acid;
  - Mixing Chromic Acid with Alcohol;
  - Mixing Ammonium Nitrate with Acids

1.5. How



Main Causes of Fire and Fire Spread

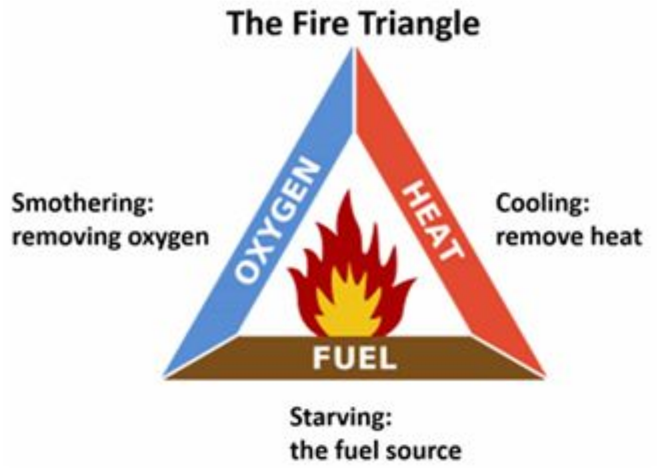


- Oxygen Factor - Talking about the oxygen factor of elements of a fire, the air feeding a fire only needs to be made up of 16 percent oxygen to react with heat and fuel. Generally, at normal altitudes, the level is already over 20 percent.

1.6. There are Three Fire Extinguishing Techniques

Smothering

- Removal or limitation of oxygen to extinguish a fire is called blanketing or smothering. A fire can be doused by removing its oxygen supply. It actually is not necessary to remove all oxygen from heated fuel to put out a fire. A reduction of oxygen from 21% to 15% is sufficient to extinguish flammable liquid fires.



Cooling

- is the removal of heat. Water is most commonly used for cooling a fire because It has the best heat absorbing properties of all liquids. If the rate of heat produced by the fire is lower than the rate of heat absorbed, the fire will go out

Starving

- Starving the fire or extinguishment by fuel removal. A fire will go out if it lacks fuel supply. A fire caused by a gas leak can be extinguished by turning off the supply of gas. Division or removal of items can starve a fire. If pallets are stacked in an open secure area rather than against a warehouse wall and they do catch fire, the warehouse and its contents will be out of danger.

1.7. Classes of Fire

1.7.1. In dealing with fires, it is essential to be able to distinguish one type of fire from another. This way, the correct firefighting techniques, equipment, and extinguishers can be used to specifically deal with the fire.

1.7.2. Three elements of a fire - All three elements of a fire, which are fuel, heat and oxygen are needed to sustain a fire, so in order to extinguish a fire, at least one of these elements must be removed. This is where fire extinguishers come in.

1.7.3. Classification of fire

Classification of fire is the same across different international standards, however, there **ARE** slight differences, such as between the British Standard, American (National Fire Protection Association, NFPA) Standard, and even the Australian Standard.

For comparison, we shall list down the Classes of fire recognized within each region.

Malaysia primarily uses the British Standard to classify fire.

British Standard Fire Classification

Class A	**Solids** wood, cardboard, furniture, paper, textiles and plastic, where there are usually glowing embers during combustion.
Class B	**Liquids or Liquefied Solids** paint, fats or oils. These can be further subdivided
Class B1	Fires that involve the liquids which are solvable in water such as methanol.
Class B2	Fires which involve liquids, not soluble in water, such as petrol and oil.
Class C	**Flammable Gases** Natural gas, or liquefied gases such as butane or propane.
Class D	**Metals** Aluminum or magnesium.
Class F	**Cooking oils, Fats** Fires which involve high-temperature cooking oils or fats.
Electrical fires	Electricity is the source of ignition that will feed the fire until turned off or isolated. But there are some parts of the equipment that can store or save, within the capacitors, lethal voltages even when it is isolated.

American NFPA Standard Fire Classification

Class A	**Solids** Ordinary combustible materials like paper, wood and fabrics, rubber. (designation symbol is a green triangle)
Class B	**flammable liquids and flammable gases** gasoline, oils, greases, tars, paints etc. (designation symbol is a red square)
Class C	**Electrical** live electrical equipment like motors, generators and other appliances. (designation symbol is a blue circle)
Class D	**Combustible Metals** magnesium, sodium, lithium potassium etc. (designation symbol is a yellow decagon)
Class K	**Cooking oils, Fats** vegetable, animal oils or fats

Symbols used for Classification of Fire

1.7.4. Classes of Fire.

Malaysia primarily uses the British Standard to classify fire, which is also equivalent to the European Standard Classification of Fires, which is recognised across the European Union (EU). In Malaysia, it is recognized that there are 6 classes of fire.

Class A – Solid material 	• Solid materials or ordinary combustibles are probably the most common type of fire that occurs when materials become heated to their ignition temperature and will continue to burn as long as there is heat, oxygen, and fuel to burn. • Materials affected by these types of fires include paper, wood, textiles, rubber, some plastics, and other organic carbon-based compounds. • Class A fires are the easiest to extinguish as dousing them with water will cool the fire, removing the heat supply which is essential for fire to burn and put out the fire. Water-based or foam fire extinguishers are the most suitable for putting out ordinary combustible fires.
Class B - Flammable liquids 	• Ignition temperature > 100°C and a low flashpoint, e.g. petrol, kerosene, alcohol, solvents, and paints. • Fires give off a lot of heat, spread very quickly and produce thick, black toxic smoke, which make it difficult to fight. • Foam fire extinguisher are used to smother and extinguish Class B fires. Using water causes the fuel to scatter and spread the fire.
Class C - Flammable gases 	• Butane, propane and petroleum gases have the potential to create an explosion, if triggered by a single spark. • Fires involving flammable gases are extremely dangerous to fight. Before fighting the fire out, make sure that the gas supply is isolated first. • Most fire extinguishers are ineffective on Class C fires, the only type being suitable for use being dry power extinguishers.

Class D - Metals 	• Some metals and powdered metals can burn if ignited, although it requires a lot of heat to ignite most metals, as they are good conductors and transfer heat away quickly to their surroundings. Powdered metals and metal shavings are easier to ignite than solid lumps of metal, so pose a higher fire risk. • Alkali metals such as magnesium, aluminium, and sodium can burn when in contact with air and water. Therefore, putting water or foam onto metal fires will increase the intensity of the flames and result in potentially explosive reactions. • In most cases with industrial fires where there are large amounts of burning metal, the safest approach is usually to let the fire burn itself out. As Class D fires tend to produce a lot of ash, this builds up and eventually starves the fire's oxygen supply. • specialist type D powder fire extinguishers can be effective, although it should be ensured that they are the specific dry powder type, suitable for use on metal fires
Electrical Fires 	• Electrical fires are fires involving potentially energized electrical equipment, short-circuits, overloaded switchboards, defective equipment, and damaged wiring can all cause electrical fires. Electrical fires are not strictly a fire class of their own, as electricity is a source of ignition as opposed to a fuel. • When dealing with an electrical fire, the supply of electricity must be isolated as quickly as possible. As water and foam has the power to conduct electricity, even once the electricity source has been cut off, you should not attempt to put out the fire by putting water on the flames or by using foam and water-based extinguishers. Carbon dioxide and dry powder fire extinguishers are the only types recommended for safely tackling electrical fires.
Class F Cooking Oils and Fats 	• Fires involving cooking oil and fats are common both in homes, businesses, and pantries. They pose an exceedingly difficult challenge to extinguish, due to the high temperatures involved. Trying to cool the fire with water will not work; in fact, using water on a burning pan is likely to cause a rapid spreading out of the flames, making the fire worse and potentially injuring anyone in its vicinity. • It is because of this; special fire extinguishers have been developed to address Class F fires. Wet chemical extinguishers contain a formula which cools the fire and then emulsifies to seal the surface and prevent re-ignition.

1.8. Smoke Hazards

Five times more fire victims die from the effects of smoke and gas than from the flames !
Statistics for fire deaths in most countries tell a tragic story. When the bodies of those who lose their lives in a fire are recovered, it is five times more likely that they died not from exposure to the flames but due to the effects of the toxic smoke and gases that were produced during fires

Smoke Hazards

Smoke is the inevitable result of combustion, as intense heat melts or burns off various ingredients and releases them to the atmosphere. The toxicity of the smoke produced by a fire largely depends on what is burning

Hazardous conditions to exposed humans can cause:

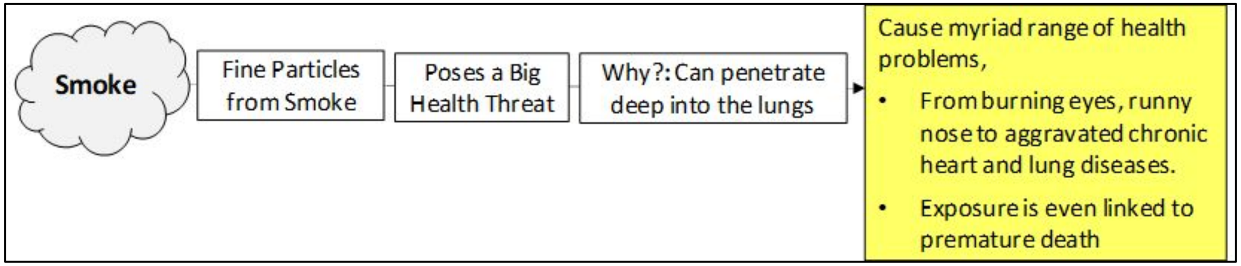
- Impaired vision
- Narcosis from inhalation of asphyxiant gases
- irritation of the upper and/or lower respiratory tracts
- Loss of mental acuity and motor coordination
- Disorientation, panic, and eventually physical incapacity
- Failure to escape may lead to death from inhalation of toxic gases

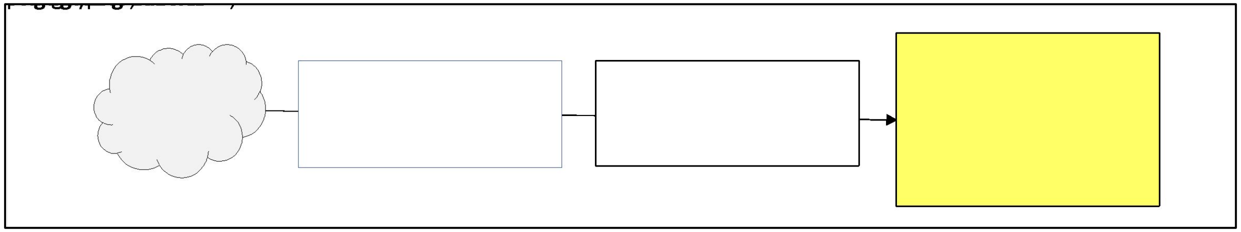
Asphyxiant
A toxicant causing hypoxia

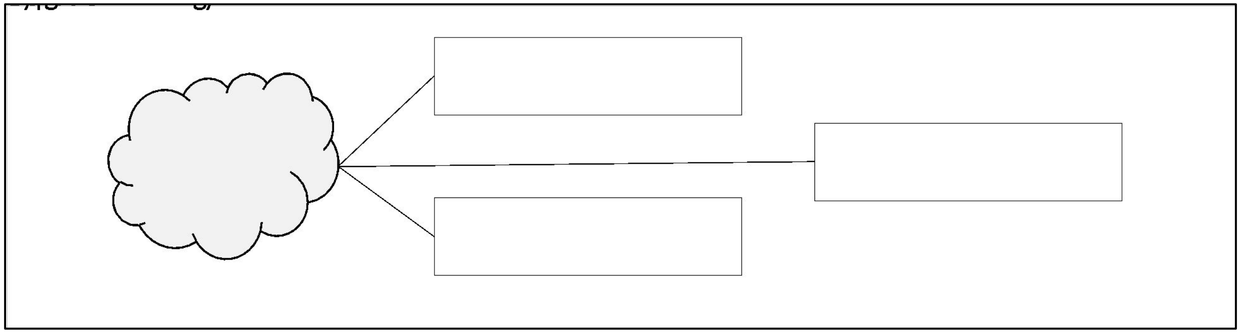
- Hypoxia is a decrease in oxygen supplied to, or utilized by the body tissue, resulting in central-nervous-system depression with loss of consciousness and, ultimately, death
- Carbon monoxide (CO) and hydrogen cyanide (HCN) are the two major asphyxiant gases
- Onset of CO intoxication is slow and insidious, HCN intoxication is more rapid. It is 25 times more toxic than carbon monoxide.

Note - More deaths occur from smoke inhalation than the fire. It is vital to stay low and crawl during a fire to avoid excessive smoke inhalation, which can cause health problems besides death

Smoke Hazards







1.8.1. Every combustible product produces a smoky atmosphere that is toxic and in high concentrations, which may over time, present hazardous conditions to exposed humans. These hazards can cause impaired vision, narcosis from inhalation of asphyxiant gases, and irritation of the upper and/or lower respiratory tracts.

- The effects, often occurring simultaneously in a fire, contribute to loss of mental acuity and motor coordination, disorientation, panic, and eventually physical incapacity. The resulting delay or prevention of escape may lead to subsequent injury or death from further inhalation of toxic gases and/or the suffering of thermal burns.

1.8.2. Asphyxiant

- An asphyxiant is a toxicant causing hypoxia. Hypoxia is a decrease in oxygen supplied to, or utilized by, the body tissue, resulting in central-nervous-system depression with loss of consciousness and, ultimately, death. Exposure to asphyxiant gases is the main cause of incapacitation and death during and immediately after a fire.
- Carbon monoxide and hydrogen cyanide are the two major asphyxiant gases. While the onset of Carbon monoxide intoxication is slow and insidious, hydrogen cyanide intoxication tends to be more rapid. It is, after all, 25 times more toxic than carbon monoxide. A short exposure to a high concentration of hydrogen cyanide is much more hazardous than a longer exposure to a lower concentration.

1.9. Exposure to combustion products

- Toxic or physical effects of exposure to combustion products occur almost immediately on exposure, and the severity of the effect is proportional to the concentration of the substance and its potency. For substances such as asphyxiant gases, the effect depends upon the dose inhaled.
- These are gases or aerosols that stimulate nerve receptors in the eyes, nose, mouth, throat, and respiratory tract, causing varying degrees of discomfort and pain. Though irritant gases do not have a direct lethal effect, they can affect the ability to escape.

1.9.1. Non-combustible products

- Materials incapable of combustion due to an exceptionally low organic content, or products failing to contribute to flaming combustion, are unlikely to support the formation of a large growing, hazardous fire.
- So, because of this, they are unlikely to contribute a significant amount of smoke or heat to a rapidly developing fire hazard.
- Although, keeping fires small should be part of the general approach, it should not be the only route to ensure life safety. The only possible way to ensure complete fire safety of a building's environment, without the consideration of smoke toxicity, would be to prescribe the use of only non-combustible products.

1.9.2. Smoke Inhalation

- Smoke is an unwanted by-product of fire. It occurs during incomplete combustion, which is when there is not enough oxygen to burn the fuel completely. Smoke is the collection of the tiny, unburned particles.

1.9.3. Smoke inhalation is the primary cause of death of victims in indoor fires. The smoke kills by a combination of thermal damage, poisoning and pulmonary irritation caused by carbon monoxide, hydrogen cyanide, and other combustion products.

- More deaths occur from smoke inhalation than the fire itself. Thus, it is vital to stay low and crawl during a fire to avoid excessive smoke inhalation, which can cause health problems besides death.

1.9.4. Particle Pollution. Fine particles from smoke pose a big health threat. These microscopic particles can penetrate deep into the lungs. They cause a myriad range of health problems, from burning eyes and a runny nose to aggravated chronic heart and lung diseases. Exposure to particle pollution is even linked to premature death.

1.9.5 Smoke is made up of particulates, aerosols, and gases. Identifying the characteristics of each of those in a smoke plume can be helpful in fighting fires, as this gives an indication as to what the fire might do next.

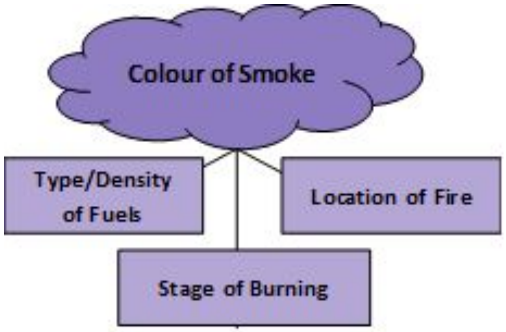
1.10. Colour of Smoke

- Smoke Speed and Flow Takes Precedence Over the Colour of Smoke
- A hot interior fire should be producing fast, black smoke in some form (laminar or turbulent, thick, or thin), but the very products that make smoke black (carbon and hydrocarbons) will stick, cake, or fall onto anything they touch such as walls and ceiling.
- Over distance and when restrictive smoke flows through cracks and seams, the black particulates and aerosols are stripped away or “filtered,” leaving a dirty white smoke. Therefore, do not be fooled by dirty-white smoke that is moving fast.
- The same surfaces that can filter smoke can also serve as a heat sink that will calm turbulent smoke (make it laminar). If you see fast moving dirty-white (filtered) smoke that is still turbulent, you can conclude that the surfaces have lost the ability to absorb heat—a setup for flashover.
- One particularly important factor in predicting fire behaviour is the colour of the smoke emitted. The colour of the smoke tells firefighters the type and density of the fuels involved, what stage of burning is taking place, and where the fire is burning in a building. As a rule, the darker the smoke, the more volatile the fire is.

Colour of Smoke

White smoke

- All solid materials normally give off white smoke when first heated.
- This means moisture and water vapour are being released and that the fire is just beginning to consume the material.
- White smoke can indicate light and flashy fuels, such as grass or twigs.
- As the material starts to dry out, the smoke changes colours



Black smoke

- Thick, black smoke means heavy fuels that are not being fully consumed.
- Black smoke might mean that a man-made material is burning.

Steam

- Firefighters have been, and can be, fooled by steam. Key here are the uniform, bright white colour, and the fact that it dissipates quickly in the outside air. If this is viewed coming from a large building with an activated fire suppression sprinkler system, crews can expect an advanced fire that the sprinkler is struggling to contain.
- There is no connection whatsoever between the colour of the smoke and the risk of flashovers.

Grey Smoke

- Grey smoke can mean that the fire is slowing down, having nearly run its course and is running out of materials to burn effectively.

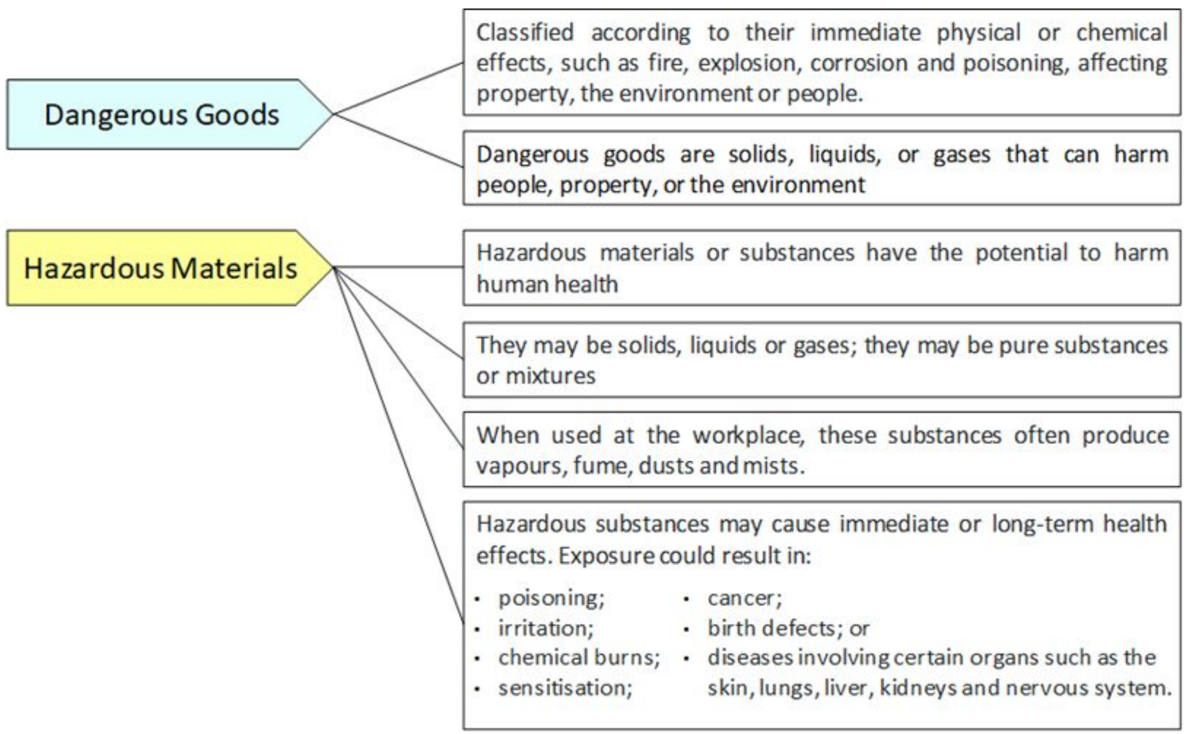
1.11. Dangerous Goods and Hazardous materials

1.11.1. Definition of Dangerous Goods

- Dangerous goods are solids, liquids, or gases that can harm people, property, or the environment. In the United States and sometimes in Canada dangerous goods are more commonly known as hazardous materials. A more professional definition is from dangerous goods regulations. Any goods listed in the dangerous goods list or meeting dangerous goods classification criteria for 9 classes will be regarded as dangerous goods.

- Dangerous goods are subject to the most stringent transport regulations. No person may offer or accept dangerous goods for transport unless those goods are properly classified, packaged, marked, labelled, placarded, described and certificated on a transport document. Dangerous goods are usually assigned with UN number and proper shipping name.

1.11.2. Dangerous or Hazardous? What is the difference?



1.11.3. Dangerous Goods

- Dangerous goods are substances that may be corrosive, flammable, explosive, spontaneously combustible, toxic, oxidising, or water-reactive. These goods can be deadly and can seriously injure or kill people, damage property and the environment.
- Dangerous goods are divided into nine classes, and also several subcategories, on the basis of the specific chemical characteristics producing the risk.

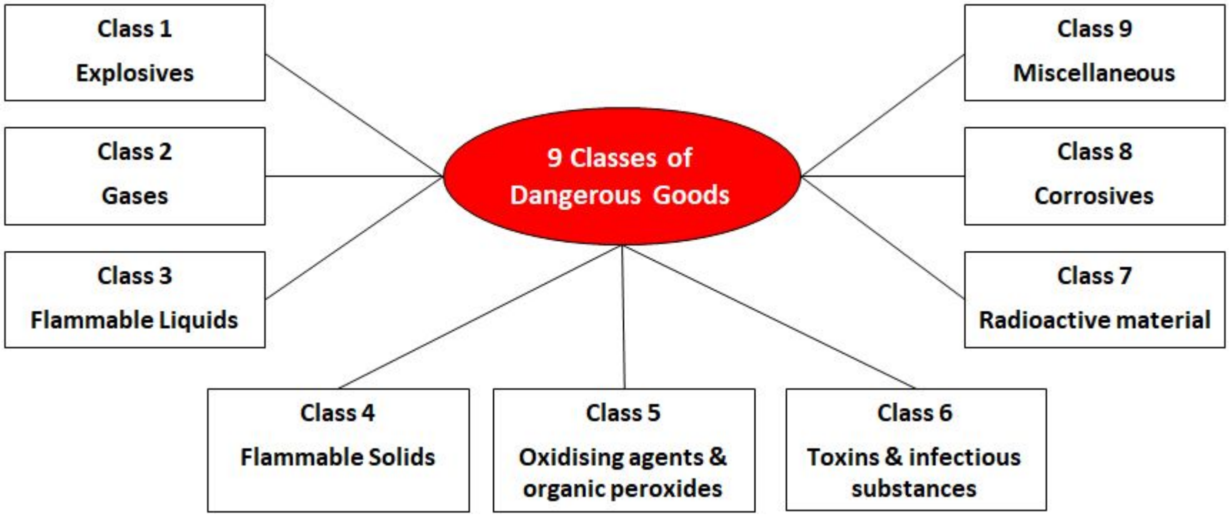
1.11.4. Transportation of dangerous goods by air into Malaysia

In Malaysia, transportation or transit of dangerous goods by air is subject to approval by CAAM. The transporting agent is required to fill in form CAAM/KES/5/01 and submit together with required supporting documents such as:

- DCA Application form
- AELB Permit;
- Police Permit (purchasing license and import/export permit);
- Shipper's declaration for dangerous goods;
- Air waybills;
- Agent's letter of appointment;
- End user certificate/contract/government's request;
- DGR training certificate recognized by CAAM.

1.12. Nine (9) Classes of Dangerous Goods

- Dangerous goods are materials or items with physical and chemical properties which, if not properly controlled, are potential hazards to human health and safety and/or infrastructure. Dangerous goods are separated into categories through a classification system is outlined by the UN Model Regulations. Each dangerous substance or article is assigned to a class.
- There are 9 classes of dangerous goods and the class is determined by the nature of the danger they present:



1.12.1. Class 1 – Explosives

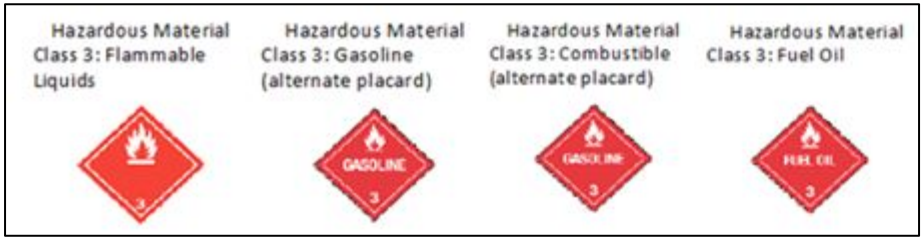
- Explosives are materials which rapidly conflagrate or detonate as a consequence of chemical reaction.
- Explosives are capable by chemical reaction of producing gases at temperatures, pressures and speeds which cause catastrophic damage through force and/or of producing otherwise hazardous amounts of heat, light, sound, gas or smoke.
- Class 1 has 6 sub-divisions

1.12.2. Class 2 - Gases

- Gases are defined by dangerous goods regulations as substances which have a vapour pressure of 300 kPa or greater at 50° C or which are completely gaseous at 20° C, at standard atmospheric pressure. This class encompasses compressed gases, liquefied gases, dissolved gases, refrigerated liquefied gases, mixtures of one or more gases with one or more vapours of substances of other classes, articles charged with a gas and aerosols.
- Gases are capable of posing serious hazards due to their flammability, potential as asphyxiants, ability to oxidize and their toxicity or corrosiveness.
- Class 2 has 3 sub-divisions

1.12.3. Class 3 - Flammable Liquids

- Flammable liquids are defined by dangerous goods regulations as liquids , mixtures of liquids or liquids containing solids in solution or suspension which give off a flammable vapour and have a flash point at temperatures of not more than 60 to 65°C, liquids offered for transport at temperatures at or above their flash point or substances transported at elevated temperatures in a liquid state and which give off a flammable vapour at a temperature at or below the maximum transport temperature.
- Flammable liquids pose serious hazard due to their volatility, combustibility and potential in causing or spreading severe fires
- There are no subdivisions within Class 3, Flammable Liquids.

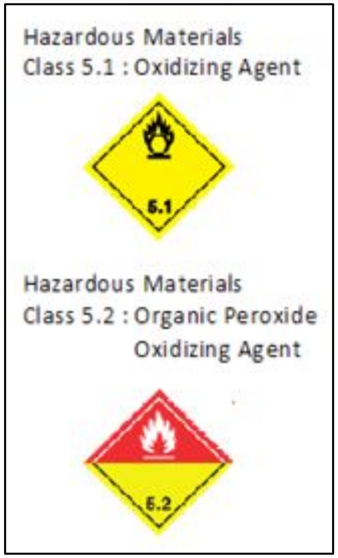


1.12.4. Class 4 - Flammable Solids

- Flammable solids are materials which, under conditions encountered in transport, are readily combustible or may cause or contribute to fire through friction, self-reactive substances which are liable to undergo a strongly exothermic reaction or solid desensitized explosives.
- Also included are substances which are susceptible to spontaneous heating under normal transport conditions, or to heating up in contact with air, and are consequently liable to catch fire and substances which emit flammable gases or become spontaneously flammable when in contact with water.
- Flammable solids pose a serious hazard due to their volatility, combustibility and potential in causing or propagating severe conflagrations.
- Class 4 has 3 sub-divisions

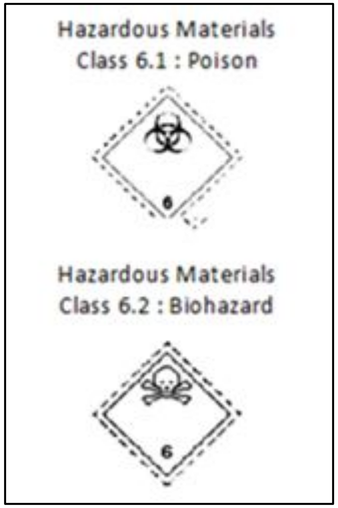
1.12.5. Class 5 - Oxidizing Agents and Organic Peroxides

- Oxidizers are defined by dangerous goods regulations as substances which cause or contribute to combustion, generally by yielding oxygen as a result of a redox chemical reaction. Organic peroxides are substances which may be considered derivatives of hydrogen peroxide where one or both hydrogen atoms of the chemical structure have been replaced by organic radicals.
- Oxidizers, although not necessarily combustible by themselves, can yield oxygen and in so doing cause or contribute to the combustion of other materials. Organic peroxides are thermally unstable and may exude heat whilst undergoing exothermic autocatalytic decomposition. Additionally, organic peroxides may be liable to explosive decomposition, burn rapidly, be sensitive to impact or friction, react dangerously with other substances or cause damage to eyes.
- Class 5 has 2 sub-divisions



1.12.6. Class 6 - Toxic and Infectious Substances

- Toxic substances are those which are liable either to cause death or serious injury or to harm human health if swallowed, inhaled or by skin contact. Infectious substances are those which are known or can be fairly expected to contain pathogens. Dangerous goods regulations define pathogens as microorganisms, such as bacteria, viruses, rickettsia, parasites and fungi, or other agents which can cause disease in humans or animals.
- Toxic and infectious substances pose significant risks to human and animal health upon contact.
- Class 6 has 3 sub-divisions



1.12.7. Class 7 - Radioactive Substances

- Dangerous goods regulations define radioactive material as materials containing radionuclides where both the activity concentration and the total activity exceeds certain pre-defined values. A radionuclide is an atom with an unstable nucleus and which consequently is subject to radioactive decay.
- While undergoing radioactive decay radionuclides emit ionizing radiation, which presents potentially severe risks to human health.
- There are no subdivisions within Class 7, Radioactive Material.

1.12.8. Class 8 - Corrosive Substances

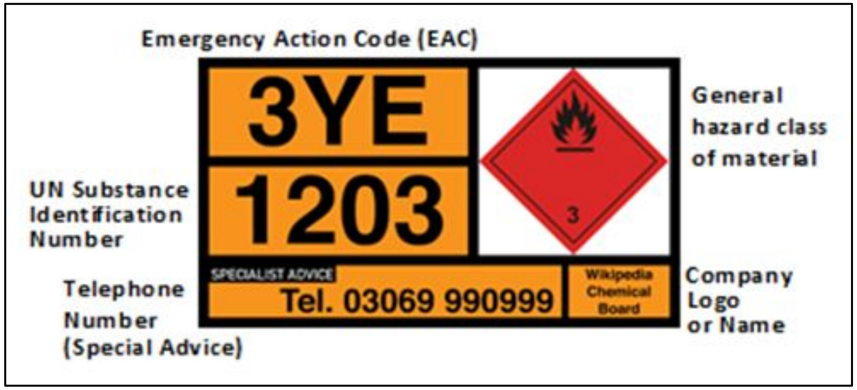
- Corrosives are substances, which by chemical action degrade or disintegrate other materials upon contact.
- Corrosives can cause severe damage when they come into contact with living tissue or, in the case of leakage, damage or destroy surrounding materials.
- There are no subdivisions within Class 8, Corrosives

1.12.9. Class 9 - Miscellaneous

- Miscellaneous dangerous goods are substances and articles which during transport present a danger or hazard not covered by other classes. This class encompasses environmentally hazardous substances that are transported at elevated temperatures, miscellaneous articles and substances, genetically modified organisms and micro-organisms, and magnetized materials and aviation regulated substances.
- There are no subdivisions within Class 9, Miscellaneous Dangerous Goods.

1.13. Hazardous Chemicals

1.13.1 Hazchem warning plate system



Hazchem (from hazardous chemicals) is a warning plate system used in Malaysia for vehicles transporting hazardous substances, and on storage facilities. The system which originated in the UK is also used in countries such as Australia, New Zealand, India and the United Kingdom.

Hazchem (from hazardous chemicals) is a warning plate system used in Malaysia for vehicles transporting hazardous substances, and on storage facilities.

- Top-left section of the plate gives the Emergency Action Code (EAC) telling the fire brigade what actions to take if there is an accident or fire.
- The middle-left section containing a 4-digit number gives the UN Substance Identification Number describing the material.
- Lower-left section gives the telephone number that should be called if special advice is needed.
- The warning symbol in the top right indicates the general hazard class of the material. The bottom-right of the plate carries the company logo or name.
- There is also a standard null Hazchem plate to indicate transport of non-hazardous substances. The null plate does not include an EAC or substance identification.

1.13.3. Emergency Action Code (EAC)

- The Emergency Action Code (EAC) is a three-character code displayed on all dangerous goods classed carriers and provides a quick assessment to first responders and emergency responders (i.e., firefighters and police) of what actions to take should the carrier carrying such goods become involved in an incident (traffic collision, for example). EACs are characterized by a single number (1 to 4) and either one or two letters (depending on the hazard).
- The Dangerous Goods Emergency Action Code (EAC) list is reviewed every two years and is an essential compliance document for all emergency services, local government, and those who may control the planning for, and prevention of, emergencies involving dangerous goods. The current EAC List is 20013. NCEC has been at the heart of the UK EAC system since its inception in the early 1970s

1.13.3. HazChem Fire Suppression

- The number leading the EAC indicates the type of fire-extinguishing agent that should be used to prevent or extinguish a fire caused by the chemical.
- The system ranks suppression media in order of their suitability, so that a fire can be fought with a suppression medium of equal or higher EAC number. For example, a chemical with EAC number 2 indicating water fog - may be fought additionally with media 3 (foam) or 4 (dry agent), but not with 1 (coarse spray). This is especially important for chemicals requiring medium 4 (dry agent), as these chemicals react violently with water and so using lowered-number media will be actively dangerous.

No.	Action
1	Coarse water spray
2	Water fog or fine spray
•2	Alcohol-resistant foam, or fine water spray if necessary*
3	Foam
•3	Alcohol-resistant foam, or normal foam if necessary*
4	Dry agent - never water

** These indicators are used only in product documentation and are displayed on vehicle plates as 2 and 3 respectively.*

1.13.5. HazChem Safety Parameters

- Each EAC contains at least one letter, which determines which category the chemical falls under, and also highlights the violence of the chemical (i.e., likelihood to spontaneously combust, explode etc.), what personal protective equipment to use while working around the chemical and what action to take when disposing of the chemical.
- A common displayed example is 3YE on petrol tankers. This means that a fire must be fought using foam or dry agent (if a small fire), that it can react violently and is explosive, that fire fighters must wear a portable breathing apparatus at all times, or if a white on black Y, only if there is a fire, and that the run-off needs to be contained. It also indicates to the incident commander that evacuation of the surrounding area may be necessary.

Category	Violence	Protection	Substance control
P	V	Full	Dilute
R			
S	V	BA	
S		BA for fire only	
T		BA	
T		BA for fire only	
W	V	Full	Contain
X			
Y	V	BA	
Y		BA for fire only	
Z		BA	
Z		BA for fire only	
E	Consider evacuation		

1.14. Boiling Liquid Expanding Vapour Explosion (BLEVE)

- A BLEVE (boiling liquid expanding vapour explosion) is a hazardous phenomenon that occurs when a vessel containing a pressurized liquid fails, leading to very rapid vaporization of the liquid in the vessel with a large blast effect. The most dangerous BLEVEs concern flammable substances, in particular butane, propane or Liquefied Petroleum Gas (LPG), where a massive fireball is generated after the inflammation of the large vapour cloud.
- This phenomenon has led to many industrial accidents that caused large numbers of fatalities, often including firefighters who were responding to the initial fire that led to the BLEVE.
  - Fuels such as butane and propane are usually stored as pressurized liquids at a temperature higher than their boiling point;
  - An initial event (frequently a jet fire) leads to heat affecting the storage vessel. Pressure inside the tank increases. Liquid in the tank cools down the metal in the lower part of the vessel, but the upper part of the tank may become weaker due to heat;
  - Initially, the vessel fails with only a small hole. Gas leaks from the hole which rapidly lowers the pressure in the tank. The liquefied gas boils violently (its boiling point is pressure-dependent);
  - The boiling liquid vaporizes, increasing pressure in the vessel and ripping it open. A huge volume of gas is discharged into the atmosphere. Massive blast. If the material is flammable, a huge fireball forms with massive heat radiation.