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| **What is combustion ?**  Combustion is the act or process of burning. For combustion to occur, fuel, oxygen (air), and heat must be present together.  The combustion process is started by heating the fuel above its ignition temperature in the presence of oxygen. Under the influence of heat, the chemical bonds of the fuel are split. If complete combustion takes place, the elements carbon (C), hydrogen (H) and sulphur (S) react with the oxygen content of the air to form [carbon dioxide](http://www.habmigern2003.info/future_trends/infrared_analyser/carbon-dioxide.htm) CO2, water vapour H2O and [sulphur dioxide](http://www.habmigern2003.info/19_flue-gas-contents.html) SO2 and, to a lesser degree, sulphur trioxide SO3.  Three things are required in proper combination before ignition and combustion can take place **Heat, Oxygen** and **Fuel**.   |  |  | | --- | --- | |  | **1.**There must be **Fuel** to burn.  Any combustible material - solid, liquid or gas. Most solids and liquids must vaporise before they will burn.  **2**. There must be Air to supply  **Oxygen”**.  Sufficient oxygen (at least 16%) must be present in the atmosphere surrounding the fuel for fire to burn. This is usually not a problem since the air we breathe is about 21% oxygen.  **3.** There must  be **Heat**  (ignition temperature) to start and continue the combustion process. Sufficient heat energy must be applied to raise the fuel to it's ignition temperature  However by adding in a fourth element, you have a fire "tetrahedron".  **4. Chemical chain reaction** - This reaction can occur when all three of the above elements are present in the proper conditions and proportions. Fire (rapid oxidisation) is the result of this chemical reaction. |   By removing any one of these four elements there will be no potential for fire or an existing fire will be extinguished. In essence fire extinguishers put out fire by taking away one or more elements of the fire triangle or fire tetrahedron.     1. The most common element to be removed is heat. Water is commonly used because it absorbs heat extremely well and is cost efficient. 2. During fire operations you may see objects being placed outside a structure. Though this is commonly referred to as salvage operations, it also acts to remove any fuel from the fire. Without the objects exposed to heat there can be no flammable gasses given off to burn. 3. Oxygen is usually the hardest to remove. Oxygen removal is accomplished when a Carbon Dioxide extinguisher is used on a fire. More extreme cases may be to use explosives on a fire. The explosion will use up the oxygen in the immediate area. 4. Finally the last element is the chemical chain reaction (or reaction of the fuel with the oxygen. An example of an extinguishment method by hindering the chemical chain reaction is a Halon gas extinguisher.   **Fire Requirements**  **Fuel**  Any combustible matter used to maintain a fire. Fuel generally is classified in one of three states of matter:  ·         solid combustibles like paper, furniture, clothing and plastics  ·         flammable liquids like petrol, oils, kerosene, paints, solvents and cooking oils / fats  ·         flammable gases like natural gas, LPG, acetylene  The temperature of the fuel must be raised to an activated state.  **Heat**  A form of energy that is transferred by virtue of a temperature difference:  ·         The heat given off by the oxidation reaction sustains the fire once it is established. But first, a heat source is required to produce ignition  ·         Heat always flows from higher to lower temperatures.  ·         Heat is transferred by one or more of three methods:   1. Conduction 2. Convection 3. Radiation   **Identifying sources of ignition**  These sources of heat could include:   * smokers' material; e.g. cigarettes and matches * naked flames * electrical, gas or oil-fired heaters (fixed or portable) * hot processes (such as welding or grinding) * cooking * engines or boilers * machinery * faulty or misused electrical equipment * lighting equipment * hot surfaces and obstruction of equipment ventilation, e.g. office equipment * friction, e.g. from loose bearings or drive belts * static electricity * metal impact (such as metal tools striking each other)   **FLAME TEMPERATURE**  Disassociation**Adiabatic** is a term used to describe a combustion reaction in which all heat generated is retained in the products of combustion. Adiabatic flame temperature is the theoretical temperature that would be attained by the products of combustion provided the entire chemical energy of the fuel, the sensible heat content of the fuel and combustion above the datum temperature were transferred to the products of combustion. This assumes that there is no heat loss to surroundings and no dissociation  **Dissociation** is a reaction involving the breakdown of chemical compounds. In the case of combustion, these are water vapour and carbon dioxide.  Disassociation is a combustion reaction that can be viewed as reverse combustion. You mix fuel and air and burn them to produce CO2 and water vapour, only to find that at really high flame temperatures, some of those combustion products break down and reabsorb the combustion energy they gave off when they were formed  **Sensible Heat**is the portion of heat which, when applied in heating or cooling, changes only the temperature of a substance. The heat gained or lost can be ‘sensed’ directly by a corresponding rise or fall in temperature.  **Common Flames**  In daily life, the vast majority of [flames](http://en.wikipedia.org/wiki/Flames) one encounters are those of [organic compounds](http://en.wikipedia.org/wiki/Organic_compound) including [wood](http://en.wikipedia.org/wiki/Wood), [wax](http://en.wikipedia.org/wiki/Wax), [fat](http://en.wikipedia.org/wiki/Fat), common [plastics](http://en.wikipedia.org/wiki/Plastic), [propane](http://en.wikipedia.org/wiki/Propane), and [gasoline](http://en.wikipedia.org/wiki/Gasoline). The constant-pressure adiabatic flame temperature of such substances in air is in a relatively-narrow range around 1950°C.  A combustion process without heat loss or gain is adiabatic.  The adiabatic flame temperature of some common fuel gases like hydrogen, methane, propane and octane with oxygen or air as oxidizers can be found below.     |  |  |  | | --- | --- | --- | | Fuel | Adiabatic Flame Temperature (K) | | | Oxygen as Oxidizer | Air as Oxidizer | | Hydrogen - H2 | 3079 | 2384 | | Methane - CH4 | 3054 | 2227 | | Propane - C3H8 | 3095 | 2268 | | Octane - C8H18 | 3108 | 2277 |   **OVERVIEW OF BUILDING FIRE SAFETY**  Building fire safety comprises a "package" which incorporates construction methods, mechanical and electrical devices, management practice and organised human response tailored to reduce the impact of fire upon the occupants, the building, its contents, the attending fire fighters and any neighbouring property. In the context of building fire safety, fire impact is considered to be any threat to life and property caused by heat or smoke and may include adverse environmental impact from toxic products stored on the premises.  Building fire safety cannot be defined as a "single system", it relies upon a group of "sub systems" to form a complete "package". More often than not, if one of the "sub systems" is removed, the whole "package" will collapse and the occupants within the building will face an unacceptable risk in the event of outbreak of fire. For simplicity, the "package" can be broken down into nine principle "sub systems", comprising:   * occupant training and education * means of escape from the building * ignition potential * fire load * compartmentation and structural fire resistance * fire fighting systems * fire detection, alarm and communication systems * smoke management systems * fire brigade response.   **Occupant Training and Education**  An essential part of any building fire safety system (probably the most important part) is training and education of the occupants in matters of fire safety. Every conceivable device that technology can devise can be placed in a building but if the occupants are ignorant of what a fire alarm sounds like, what are safe and unsafe work practices or where the exits are, then the devices will not achieve a fire safe building.  **Means of Escape from the Building**  This is an essential part of the fire safety system. A safe, illuminated, well identified way out of the building is required in order that the building occupants can escape a fire (or other) emergency. Often more than one escape route is required so that occupants have an alternative exit if one cannot be reached because of smoke or fire. These exits must be kept clear and operable at all times. The BCA covers the number, type and location of fire exits.  **Compartmentation and Structural Fire Resistance**  If the fire is contained within a room or space (known as a compartment) by the nature of its construction, its impact on other parts of the building will be minimised. Naturally the people in the compartment will need to get out before the fire effects them. A room of solid brick with no windows and a sturdy door would be a good fire compartment, because it would be difficult for the heat and smoke to escape. A room constructed of glass would be a poor fire and smoke compartment because, as the fire grows, heat would shatter the glass thus letting heat and smoke out and the fire to spread.  Compartmentation is a called a "PASSIVE" system (ie. just by being there it inhibits the spread of fire). It relies upon structural stability under fire conditions; the ability to withstand the effects of fire without collapse.  **Fire Fighting Systems**  Fire fighting systems are those which intervene in the fire growth process once fire has occured. Such systems can be used by trained occupants or attending fire fighters and include a fire extinguisher, fire hose reel, or fire hydrant. Other systems may be automatic such as a fire sprinkler system. Automatic systems are considered to be superior, because they do not rely on people to manually operate them. Fire fighting systems are known as "DYNAMIC" systems because they do something; they actively intervene in the rate of fire growth.  The greater the extinguishing capability of the system and the earlier in the fire growth period it can be applied, the lower the fire impact, hence, the preference for sprinkler systems by most fire engineers and fire fighting professionals.  **Fire Detection Alarm and Evacuation Warning Systems**  The simplest fire detection and alarm system is the residential smoke alarm now installed in most Australian homes. The smoke alarm alerts the building occupants that a fire has been detected. A fire detection system may, in addition to alerting occupants, automatically notify the fire brigade of the fire. If fire detection and alarm systems operate very early in the fire growth stage, building occupants may be able to extinguish a small fire.  **Smoke Management Systems**  In many buildings occupied by the public, especially large buildings such as shopping centres, smoke from a fire can spread and descend so as to block exits and make occupant escape difficult or, in the extreme, impossible. In such instances, the installation of a smoke management system, which will slow down the rate of smoke spread, is recommended. Such systems often involve exhausting the smoke at ceiling level where hot smoke will naturally collect because it is hot and therefore lighter than the surrounding air. Other methods employ the opening of apertures in the roof or panels at high level in the walls of a building. Provided fresh air is allowed to naturally flow into the building below any smoke layer, these measures will permit the smoke to escape from the building rather than fill it up. Another way to stop smoke infiltrating from floor to floor in a multi-storey building is to pressurise the non-fire floors with fresh air at a pressure higher than that of the fire floor.    **Fire Brigade Response**  The sub system taken for granted and often overlooked is the fire brigade response (notification, dispatch and travel time to the fire scene). How effective this response will be in saving life and property depends on how long the fire will have been burning before they are notified, how long they will take to arrive, how fast the fire will grow, how much equipment they will bring with them and how much water will be available for fire fighting. Generally, compared to metropolitan areas, the time taken to arrive in rural areas is longer, not as much equipment is initially available and water is often in limited supply. However, as time passes in both rural and metropolitan areas, more and more fire fighters and equipment will arrive as resources are brought in from further afield.  **Classes of Fire**  Not all fires are the same and not all extinguishing agents are compatible with all types of fuel. If you use the wrong type of fire extinguisher on the wrong class of fire, you can, in fact, make matters worse (eg water used on a flammable liquid fire is likely to increase the rate of burning dramatically and to disperse the fuel to cover a greater area. It is therefore very important to understand the six different classes of fires.  Fires are normally classified according to the fuel involved; however, any fire that involves energised electrical equipment is always classified as a class (E) until the electrical circuit is disconnected. It is then reclassed according to the type of material that is burning.  Most fire extinguishers will have a pictograph label telling you which fuels the extinguisher is designed to fight. For example, a simple water extinguisher should have a label indicating that it should only be used on Class A fuels and never on Class B fuels (flammable liquids) and class (E), electrical fires.  **FIRE CLASSES**   |  |  | | --- | --- | | **Class A** | **-**Ordinary combustible or fibrous material such as wood, paper, fabric, coal, leather, sugar, rubber and some plastics. | | **Class B** | **-**Flammable liquids such as petrol, kerosene, alcohol, oil and paint thinners. | | **Class C** | **-**Flammable Gasses such as LPG, Butane, Acetylene, Hydrogen, natural gas and methane. | | **Class D** | **-**Combustible Metals: potassium, sodium, lithium, aluminium, magnesium and metal swarf. Fires of this class may occur in laboratories or industries that use these materials. Metal swarf fires may occur in machine shops where metal turning or milling is carried out. These fires burn at high temperatures and give off sufficient oxygen to support combustion. They may also react violently with water or other chemicals. | | **Class E** | **-** Electrical Hazards. Fires involving live electrical equipment (e.g. computers, switchboards and power tools). As long as it's "plugged in," it would be considered a class (E) fire. If the electricity supply to the equipment is disconnected (plug pulled out), then the fire is not class (E). It takes the class of the fuel that is burning. | | **Class F** | **-**Cooking Oil or Fat. |     **Building Fires & FR's**  **1. Two stages in building fires**  The two stages to be considered in the fire safety design of buildings in relation to building materials and structures are the **initial** and the **fully** developed fire.  In the initial fire, the building contents such as furniture etc, are of major importance both for the initiation of the fire and its development, but this is not regulated in building codes. Surface linings may also play an important role in the initial fire, especially in escape routes and limitations of their reaction to fire is required in most building codes. In the fully developed fire, the performance of load bearing and separating structures is important in order to limit the fire to the room or fire compartment of origin. This is called the fire **resistance of the building structure**.    ***Figure 1. Two main stages relevant for the fire safety in buildings in relation to building materials and structures.***  **2. Reaction to fire - Material properties**  Reaction to fire means the response from materials to an initial fire attack and includes properties like time to ignition, flame spread, heat release and smoke production, see [Figure 2](http://www.fireretard.com/building.html#figure2#figure2). These properties are relevant in the early fire development, which is the stage when products such as wood may contribute to fires.  The use of combustible linings in escape routes and public areas in buildings is restricted in order to limit the rate of fire growth, but the contribution from linings is often overemphasised in relation to the total fire potential of building content.  Four areas of concern in a materials reaction to the development of a fire are:  ***Figure 2. Reaction to fire properties of surface products.***  **3. Fire resistance - Structural fire performance**  Fire resistance means that structural elements, e g wall or flooring elements, shall withstand a fully developed fire and fulfil requirements of insulation, integrity and/or load bearing capacity, see Figures 2 & 3  **Fire Resistance Level (FRL):**  The fire-resistance grading period in minutes for an element of construction, component or structure, determined in accordance with the BCA and AS 1530, for;   1. insulation 2. integrity 3. structural adequacy   and expressed in that order   eg **60 / 60 / 30**  **60 minutes**structural adequacy  **60 minutes**intety  **60 minutes**insulation  **Figure 3. Performance criteria for fire resistance.**  These tests specify a fire exposure with ever increasing temperatures, which building elements are expected to withstand for a specified period of time, e.g. 60 minutes. Although considered highly combustible wood structures can obtain high fire resistance, e g 60 minutes, 90 minutes or even higher.  **5. Fire tests**  The fire hazard of building products is evaluated by the use of standard fire tests in order to satisfy requirements in national building codes. The fire tests used must be relevant to the end use of a product, e g a wall or ceiling lining or a structural element.  **Australian Fire Standards (Parts of AS 1530)**  **AS 1530.1-1994 :  Methods for fire tests on building materials, components and structures - Combustibility test for materials**  **AS 1530.2-1993 :  Methods for fire tests on building materials, components and structures - Test for flammability of materials**  **AS/NZS 1530.3:1999 :  Methods for fire tests on building materials, components and structures - Simultaneous determination of ignitability, flame propagation, heat release and smoke release**  **AS 1530.4-2005 :  Methods for fire tests on building materials, components and structures - Fire-resistance test of elements of construction**  **AS 1530.7-2007 :  Methods for fire tests on building materials, components and structures - Smoke control assemblies - Ambient and medium temperature leakage test procedure**    **6. Building Codes**  The safety level is of national responsibility and the BCA requirements are designed as ‘performance codes’, executed in a way to ensure the safety of persons, domestic animals and property. Essential requirements for fire safety include:  ·         the load-bearing capacity of the construction can be assumed for a specific period of time;  ·         the generation and spread of fire and smoke within the works are limited;  ·         the spread of fire to neighbouring construction works is limited;  ·         occupants are able to leave the building in case of fire or it is possible to rescue them by other means;  ·         the safety of rescue teams is taken into consideration.  **Building Code of Australia (BCA)**  **Volume 1** [SECTION C FIRE RESISTANCE](http://www.abcb.gov.au/abcbonline/LeftMenu.asp?pid=119&sid=544&cid=)  [Part C1 Fire Resistance and Stability](http://www.abcb.gov.au/abcbonline/LeftMenu.asp?pid=119&sid=2086&cid=)  [Part C2 Compartmentation and Separation](http://www.abcb.gov.au/abcbonline/LeftMenu.asp?pid=119&sid=2087&cid=)  [Part C3 Protection of Openings](http://www.abcb.gov.au/abcbonline/LeftMenu.asp?pid=119&sid=1758&cid=)  [Specifications](http://www.abcb.gov.au/abcbonline/LeftMenu.asp?pid=119&sid=2088&cid=)  **BCA Fire Terms refer to Part A1,  A1.1  Definitions**    **FIRE FIGHTING SYSTEMS AND EQUIPMENT IN BUILDINGS**  **General Fire Fighting Equipment**  Fire fighting systems and equipment vary depending on the age, size, use and type of building construction. A building may contain some or all of the following features:   * Fire extinguishers * Fire hose reels * Fire hydrant systems * Automatic sprinkler systems   **Fire Extinguishers**  Fire extinguishers are provided for a 'first attack' fire fighting measure generally undertaken by the occupants of the building before the fire service arrive. It is important that occupants are familiar with which extinguisher type to use on which fire.  Most fires start as a small fire and may be extinguished if the correct type and amount of extinguishing agent is applied whilst the fire is small and controllable.  The principle fire extinguisher types currently available include:   |  |  | | --- | --- | | **Extinguishing Agent** | **Principle Use** | | Water | wood and paper fires - not electrical | | Foam | flammable liquid fires - not electrical | | Carbon dioxide | electrical fires | | Dry Chemical | flammable liquids and electrical fires | | Wet chemical | fat fires - not electrical | | Special Purpose | various (eg. metal fires) |     Fire extinguisher locations must be clearly identified. Extinguishers are colour coded according to the extinguishing agent.  It is the policy of The Fire Safety Department that fire extinguishers be logically grouped at exits from the building, so that occupants first go to the exit and then return to fight the fire, knowing that a safe exit lies behind them, away from the fire. In some instances this will be at odds with the prescriptive requirements of Australian Standard AS2444 Portable fire extinguishers and fire blankets - Selection and location which simply specifies a distance of travel to a fire extinguisher rather than their location in relation to escape paths. Blind compliance with the standard has the potential to place the fire between the occupant and the safe escape path.    **Fire Hose Reels**  Fire hose reels are provided for use by occupants as a 'first attack' firefighting measure but may, in some instances, also be used by firefighters.  When stowing a fire hose reel, it is important to first attach the nozzle end to the hose reel valve, then close the hose reel valve, then open the nozzle to relieve any pressure in the wound hose, then close the nozzle. This achieves two principle objectives:   * A depressurised hose and hose reel seal will last longer than if permanently pressurised. * When the hose reel is next used, the operator will be forced to turn on the isolating valve, thus charging the hose reel with pressurised water supply, before being able to drag the hose to the fire. A potential danger exists if the operator reaches the fire and finds no water is available because the hose reel valve is still closed.   Because hose reels are generally located next to an exit, in an emergency it is possible to reach a safe place simply by following the hose.  In South Australia, a unique floor mounted swivel hose guide is often employed which lays the hose at floor level, prior to being dragged by the operator. In practice for a single person, this makes withdrawal of the hose much easier than does the traditional high level swinging arm hose guide.    **Fire Hydrant systems**  Fire hydrant systems are installed in buildings to help fire fighters quickly attack the fire. Essentially, a hydrant system is a water reticulation system used to transport water in order to limit the amount of hose that fire fighters have to lay; thus speeding up the fire fighting process.  Fire hydrants are for the sole use of trained fire fighters (which includes factory fire fighting teams). Because of the high pressures available serious injury can occur if untrained persons attempt to operate the equipment connected to such installations.  Fire hydrant systems sometimes include ancillary parts essential to their effective operation such as pumps, tanks and fire service booster connections. These systems must be maintained and regularly tested if they are to be effective when needed.  The placement of such equipment needs to closely interface with fire service operational procedure; simply complying with deemed to satisfy code provisions is a potential recipe for disaster.  **Automatic Sprinkler Systems**  Time is essential in the control of fire. Automatic sprinkler systems are one of the most reliable methods available for controlling fires. Today's automatic fire sprinkler systems offer state of the art protection of life and property from the effects of fire. Sprinkler heads are now available which are twenty times more sensitive to fire than they were ten years ago.  A sprinkler head is really an automatic (open once only) tap. The sprinkler head is connected to a pressurised water system. When the fire heats up the sprinkler head, it opens at a preset temperature, thus allowing pressurised water to be sprayed both down onto the fire and also up to cool the hot smoky layer and the building structure above the fire. This spray also wets combustible material in the vicinity of the fire, making it difficult to ignite, thereby slowing down or preventing fire spread and growth.  When a sprinkler head operates, the water pressure in the system drops, activating an alarm which often automatically calls the fire brigade via a telephone connection.  Some people say sprinklers cause a lot of water damage. As has been explained, only those sprinkler heads heated by the fire operate; all sprinklers in a building do not operate at once. Usually non-fire water damage only occurs if the occupants carelessly damage the system. Fire fighters use much more water than a sprinkler system. The combined damage from a fire and the water used by fire fighters dramatically exceeds that likely from a properly installed sprinkler system.  Because, historically, complete extinguishment of fires has not been achieved, it is traditional to consider that sprinklers only control fire growth until intervention occurs by the fire brigade. Today, some sprinkler systems are designed for early suppression and are considered to have failed if they do not extinguish the fire.  Sprinkler systems are usually installed in high or large buildings and high fire hazard occupancies. Statistics show that in a majority of cases where sprinklers are installed the fire has been controlled by one sprinkler head alone.  **FIRE DETECTION ALARM SYSTEMS AND EQUIPMENT IN BUILDINGS**  **Automatic Fire Detection and Alarm System**  Automatic fire detection and alarm systems are designed to warn building occupants of a fire situation, they do not generally intervene in the fire growth process except where interfaced with a fire suppression or other fire control system.  These systems generally use smoke, heat or flame detectors to detect the outbreak of fire and to alert building occupants and the fire brigade. Manual call points which allow an occupant who discovers fire to raise the alarm may also be included in the system..  Single station residential smoke alarms, as installed in most homes, are the simplest system for detecting a fire and warning the building occupants.  The time between the outbreak of fire and the commencement of firefighting is the single most important factor in fire control and can be effectively reduced by having the system monitored directly by the fire brigade.  Fire alarm systems must be heard by the building occupants in all parts of the building. To achieve this, they are often connected to occupant evacuation warning and intercommunication systems which sound a defined "beep - beep - beep" throughout the building when the detection system has been activated.  Sometimes these systems automatically close smoke and fire doors, operate flashing warning lights, stop air-conditioning systems or alert critical staff via personal pagers. Today these systems extensively rely upon computer systems and are changing at the same rapid pace as is computer technology. Today's systems can be "intelligent" defining exactly where the fire is, determining if the smoke is from a fire threat or just burnt toast and advising the maintenance manager when the detector needs cleaning or other routine maintenance work is required. |