Fire Basics

Overview of Presentation

- Fire triangle
- Adiabatic flame temperature
- Life cycle of a fire (4 stages)
- The four stages of combustion
- The chemistry of fire extinction
- Prevention of fire and flammability
- Storage guidelines
- Classes of fire
- Fire extinguisher
- Fires in buildings (flame test & temperature)
- Development of room fire
- Photos

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.

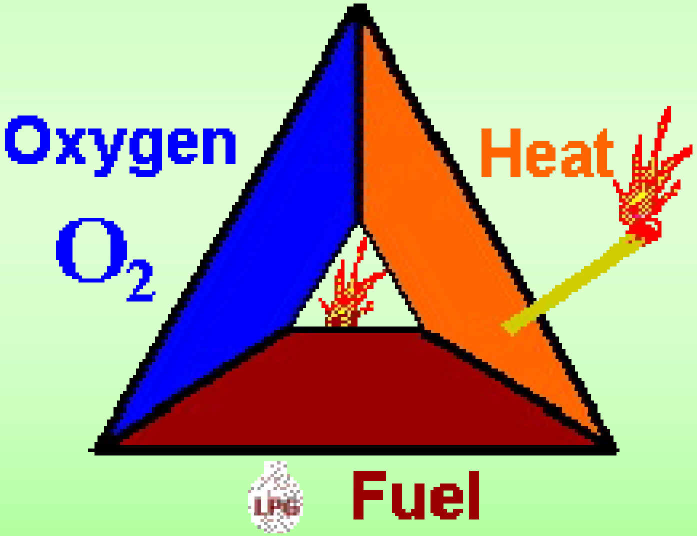
If complete combustion takes place, the elements carbon (C), hydrogen (H) and sulphur (S) react with the oxygen content of the air to form carbon dioxide CO_2, water vapour H_2O and sulphur dioxide SO_2 and, to a lesser degree, sulphur trioxide SO_3.

Fire Triangle

Fuel + Oxygen + Heat = Fire

The **FIRE TRIANGLE** represents the **three** elements needed for fire to occur: heat, fuel, and oxygen.

The air we breathe is about **21% oxygen**. Fire requires an atmosphere with at least **16% oxygen**.



Heat is the energy necessary to **increase the temperature of the fuel** to a point where sufficient vapors are given off for **ignition** to occur.

Fuel can be any **combustible material** in **any state of matter** - solid, liquid, or gas. Most solids and liquids become a **vapor or gas** before they will burn.

Fire Tetrahedron

1. There must be **Fuel** to burn.

   Any combustible material - solid, liquid or gas. Most solids and liquids must vaporise before they will burn.

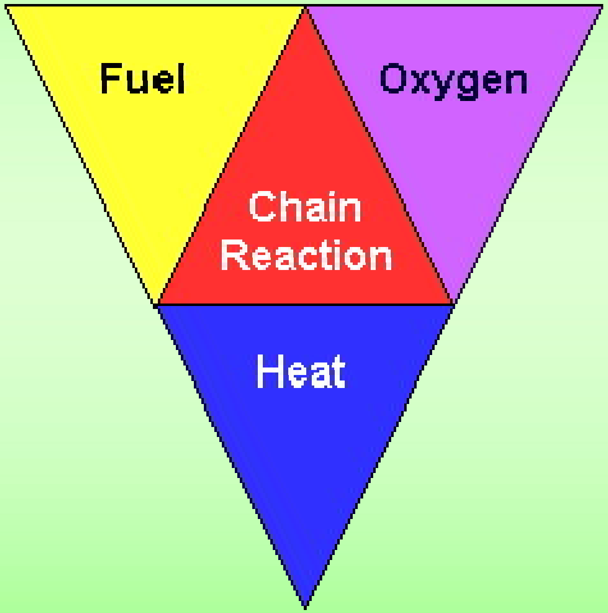
2. There must be Air to supply **Oxygen**.

   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.

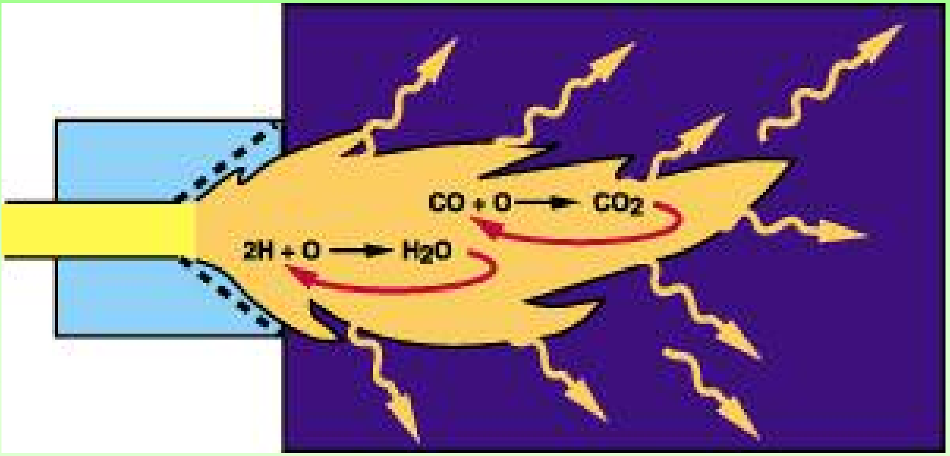
3. There must be **Heat** (ignition temperature) to start and continue the combustion process. Sufficient heat energy must be applied to raise the fuel to it's ignition temperature

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.



ADIABATIC FLAME TEMPERATURE



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 is transferred to the products of combustion.

This assumes that there is no heat loss to surroundings and no dissociation

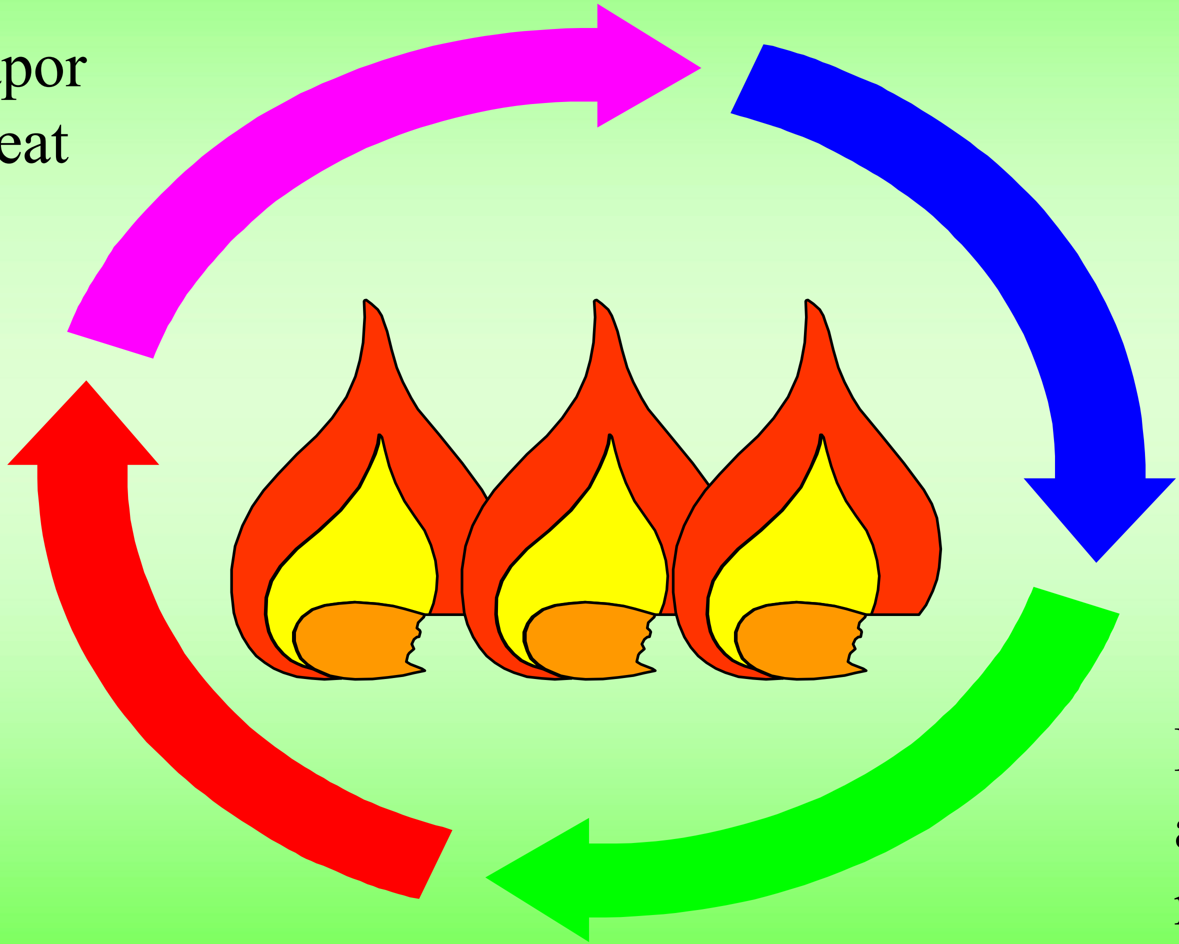
Dissociation is a reaction involving the breakdown of chemical compounds. In the case of combustion, these are water vapour and carbon dioxide.

LIFE CYCLE OF A FIRE

- 4 STAGES

Self sustaining reaction

Burning vapor
produces heat

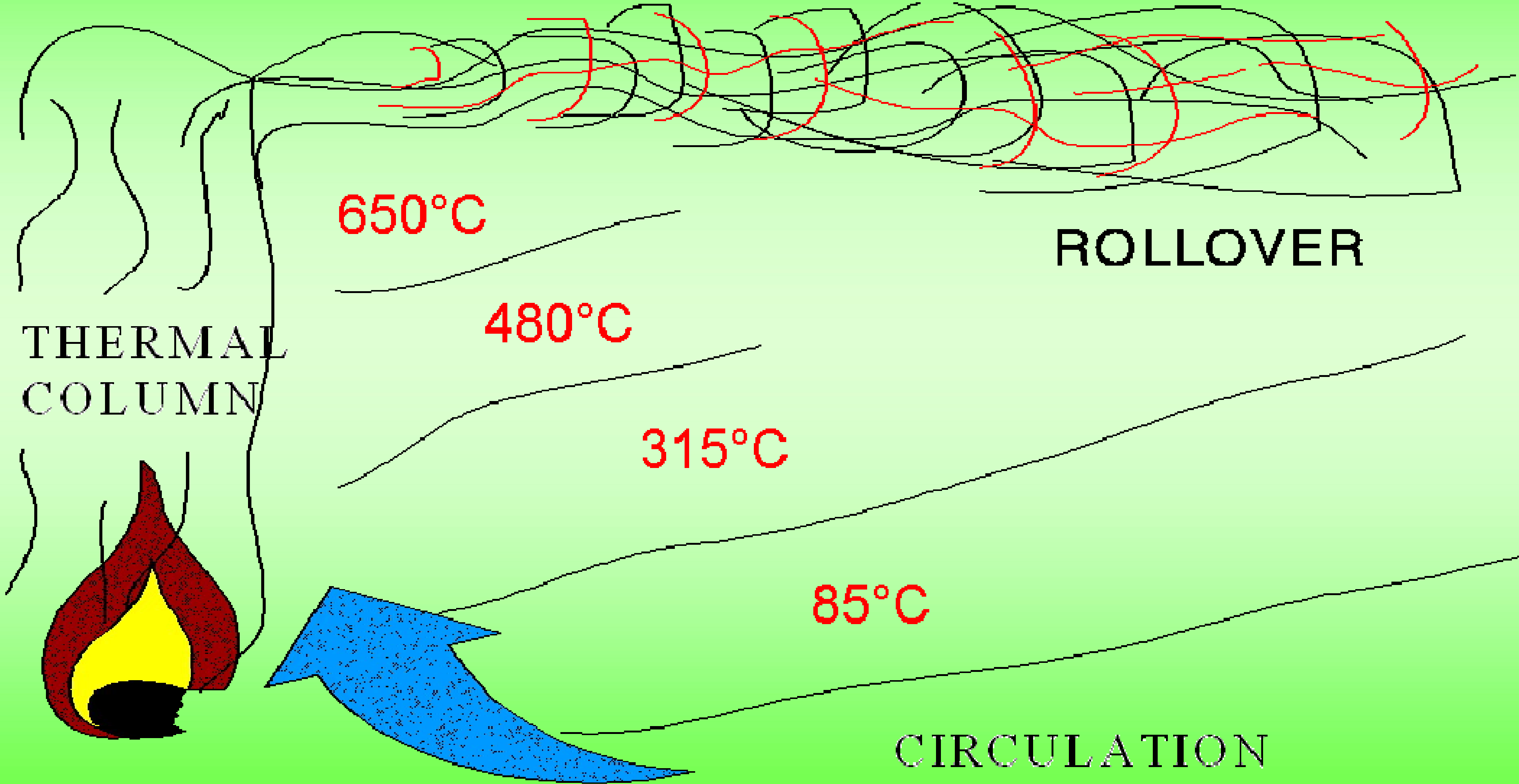


Heat releases
and ignites
more vapor

1.) GROWTH STAGE

- Earliest stage of a fire beginning with actual ignition.
- Fire limited to origin of ignition material.
- Flame temperature may be well above 540°C.
- Some heat being generated. Amount of heat will increase with the progress of the fire.
- Sufficient oxygen and fuel are available for fire growth to a point where total involvement is possible.
- Heat carried to uppermost region of confined area.
- Heated gases spread laterally from the top and then down.
- Cooler air forced to lower levels.
- Upper region can exceed 700°C.

THERMAL BALANCE / ROLLOVER



2.) FLASHOVER

- Simultaneous ignition of all contents of the compartment.
- Normally occurs when the upper gas layer reaches 600°C.
- Flashover can also occur in the space above the fire.
- Can usually be prevented by proper fog application or venting.

3.) FULLY DEVELOPED STAGE

- All combustibles in the space have reached their ignition temperature.
- Burning rate limited by the amount of oxygen available in the air for combustion.
- Unburned fuel in the smoke may burn as it meets fresh air in adjacent compartments.
- Structural damage to exposed steel normally occurs.
- Normally inaccessible by hose teams.
- Best fought using indirect attack.

4.) DECAY STAGE

– Available oxygen is consumed or reduced to a point where there is insufficient oxygen to react with fuel.
– Flame may cease to exist if the area is sufficiently airtight.
– Burning reduced to glowing embers
– If fire continues to smolder, compartment will fill with dense smoke and gases and temperatures could reach well over 1000^0C.
– Intense heat and high concentration of fire gases could produce suitable conditions for a backdraft explosion.

THE FOUR STAGES OF COMBUSTION

Most fires have quite humble beginnings and grow through four stages:

1. **Incipient Stage** - At this stage, decomposition is occurring at the surface of the fuel due to the influence of some form of heat. Products of combustion given off at this stage are invisible to the eye.

2. **Smoldering Stage** - At this stage, up to 10% of the decomposing products released at the surface of the fuel are visible.

THE FOUR STAGES OF COMBUSTION

3. **Flaming Stage** - Vapors from the decomposing fuel have ignited and are at the stage where flames are self propagating.

4. **Heat Stage** - At this stage the burning has progressed to the point where the fire is still small but generating sufficient heat to warm the air immediately around the fire, sending warm products of combustion upwards by convection.

THE FOUR STAGES OF COMBUSTION (cont.)

- The time required for a fire to develop through the first two stages is usually quite long when compared to the last two.

- Depending on conditions, the time involved going through all stages may be anything from seconds to days.

THE CHEMISTRY OF FIRE EXTINCTION

The principles of fire extinction consist of the elimination or removal of one or more of the four elements. These principles are:

1. **COOLING**

   The most commonly used fire fighting medium is water. Water absorbs heat from the fire and cools the fuel to a temperature where it no longer produces flammable vapors.

2. **SMOTHERING**

   By excluding the oxygen in the surrounding atmosphere, the fire will be extinguished.

THE CHEMISTRY OF FIRE EXTINCTION

3. STARVATION

Starvation is achieved by removal of the fuel burning in the fire. Sometimes combustible material can be removed such as by shutting off gas valves or fuel flows.

4. STOP CHAIN REACTION

Stop or interrupt the chain reaction between the fuel, heat and oxygen the fire will be extinguished.

Specific methods of extinguishing fires often involve a combination of more than one of the four principles

The Strategy of Preventing a Fire

- A fire must have three things to ignite and maintain combustion:
  - Fuel
  - Heat
  - Oxygen
- The basic strategy of fire prevention is to control or isolate sources of fuel and heat in order to prevent combustion.

If all three are not present in sufficient quantities a fire will not ignite or a fire will not be able to sustain combustion

Causes of Ignition

Flammable materials may ignite in many ways, some familiar, some less so.

The most common ignition source is flame.

Hot surfaces can also cause fire

Sparks generate very high temperatures in a very small space, but it is rare that a spark will cause ignition in the absence of other factors.

Flammable and combustible liquids

- Flammable and combustible liquids are potential fuel sources for fires and are present in almost every workplace.
- It is actually the vapor created by flammable and combustible liquids that ignites and burns.
- It is important to understand what materials in your work area are flammable and combustible so that you may properly store and isolate them from ignition sources.

How do I tell what's flammable?

NFPA classification system

The NFPA diamond is an easy way to determine the safety risks associated with hazardous materials. To determine a materials flammability refer to the red section of the diamond. A number in this section will indicate the flammability rating of the material.

For example, An NFPA diamond on a can of gasoline would have a 3 in the red section indicating that gasoline could ignite at normal working temperatures.

The following numbering system is used to indicate flammability

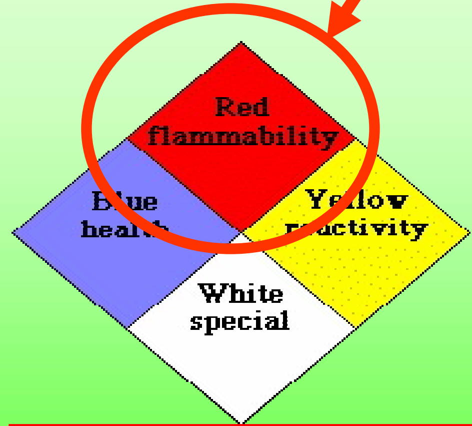
0- will not burn

1- must be preheated to burn

2-ignites when moderately heated

3-ignites at normal temperature

4-extremely flammable



NFPA Diamond

Here are some Australian signs

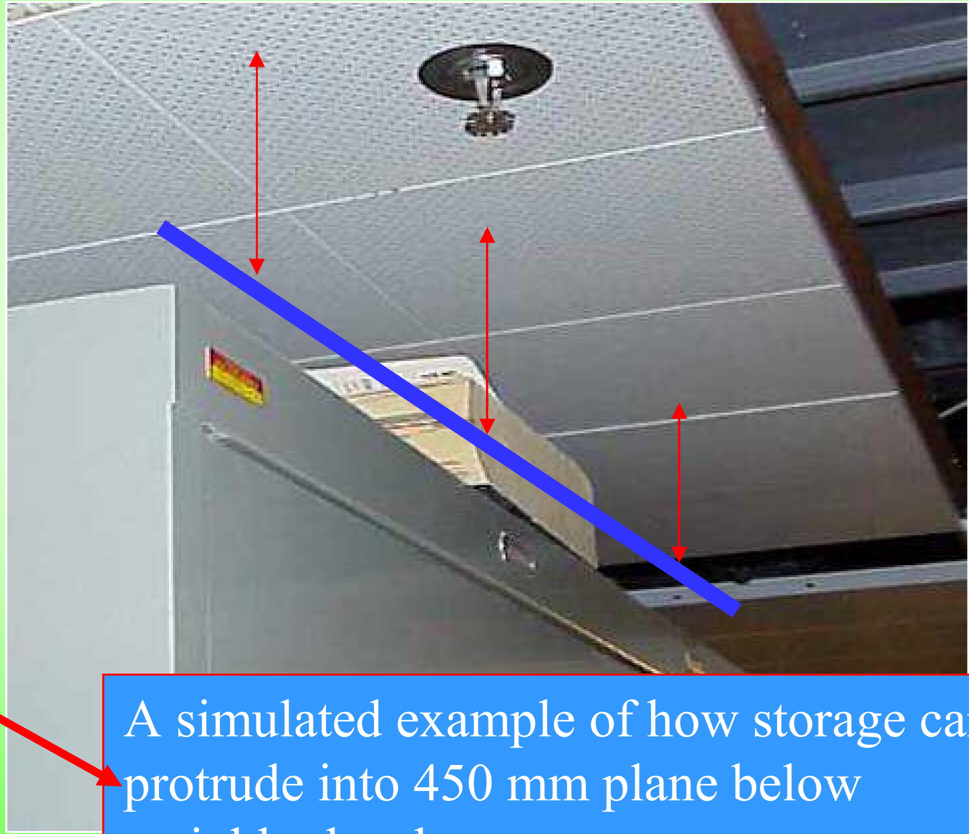
Storage Guidelines

- No storage is allowed in corridors and stairwells. A cluttered hallway could slow down emergency evacuation.

- Storage must not exceed a plane of 450 mm below sprinkler heads or smoke detectors. Storage that breaks this plane may prevent sprinkler heads from fully covering room during a fire.

NOTICE

Storage guidelines are applicable to all locations within buildings and are not limited to storage rooms. This includes stored materials in offices, labs, etc.



A simulated example of how storage can protrude into 450 mm plane below sprinkler heads.

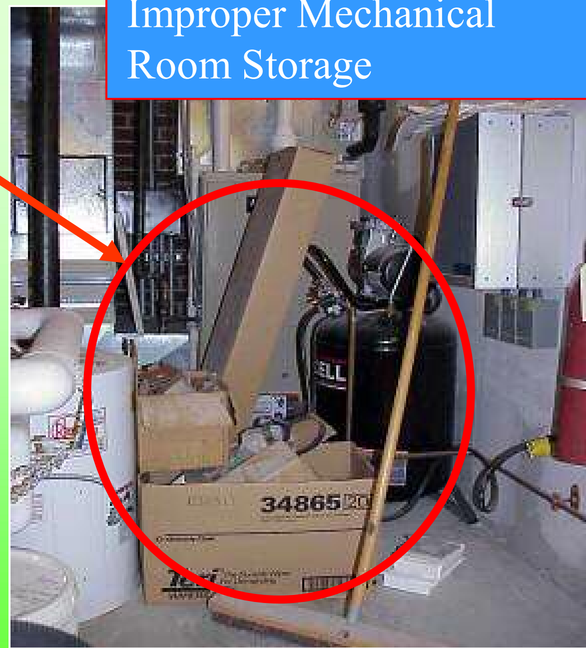
Storage Guidelines

- All storage must be at least 1 m from electrical panels. In some emergency situations it will be necessary to access these panels quickly.

- Maintain at least a 1 m clearance from heating surfaces, air ducts, heaters, and lighting fixtures.
- Storage of combustible materials in mechanical rooms is prohibited.

Improper Storage in front of Electrical Panel

Improper Mechanical Room Storage



Classes of Fire

- Not all fires are the same and not all extinguishing agents are compatible with all types of fuel.
- Fires are normally classified according to the fuel involved (Band on fire extinguisher)
- Most fire extinguishers will have a pictograph label telling you which fuels the extinguisher is designed to fight.

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.

EXTINGUISHER

- Understand the combustion process and different fire classes.
- Understand fire extinguisher types, operating procedures, capabilities, and limitations.
- Understand basic firefighting concepts:

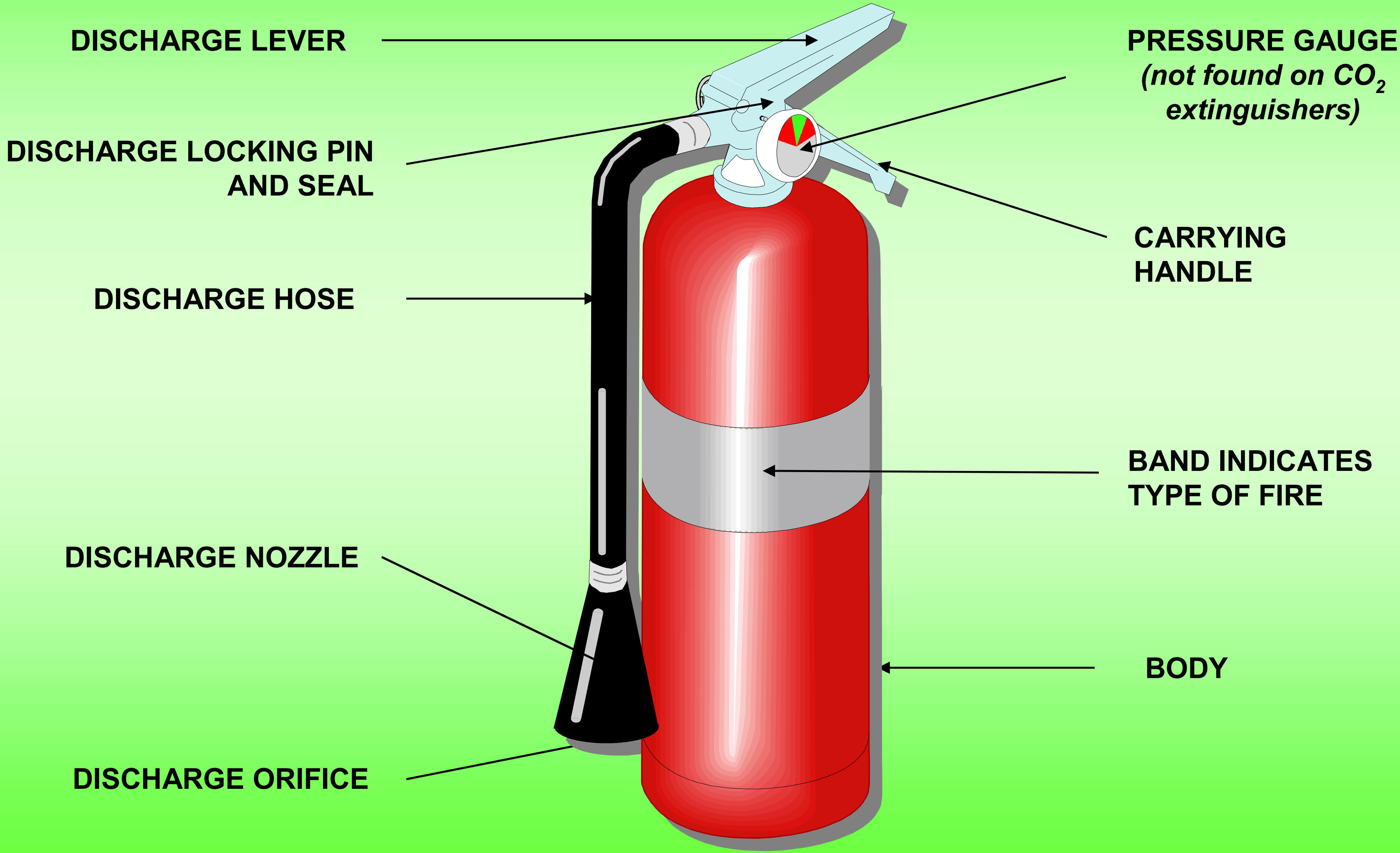
► R.A.C.E.

***R**escue*
***A**larm*
***C**ontain*
***E**xtinguish*

► P.A.S.S.

***P**ull the pin*
***A**im low at the base of flames*
***S**queeze the Handle*
***S**weep side to side*

Fire Extinguisher Anatomy



The Australian markings are:

Type	pre-1997	current
Water	Solid red	
Foam	Solid blue	Red with a blue band
Powder	Red with a white band	
Carbon dioxide	Red with a black band	
Vapourising liquid (not halon)	Red with a yellow band	
Halon	Solid yellow	—
Wet chemical	Solid oatmeal	Red with an oatmeal band

•

Types of Fire Extinguisher

Water
Class A - Carbonaceous solids, eg. wood, paper and plastics

Wet Chemical
Class A - Carbonaceous solids, eg. Wood, paper and plastics
Class F - Fire involving cooking oils and fats

Foam
Class A - Carbonaceous solids, eg. Wood, paper and plastics

Dry Chemical Powder
The idea behind a dry chemical fire extinguisher is to blanket the fuel with an **inert solid**

AB(E) POWDER
Class A - Carbonaceous solids, eg. Wood, paper & plastics
Class B - Flammable & combustible liquids
Class (E) - Fire involving energized electrical equipment

B(E) POWDER
Class B - Flammable & combustible liquids
Class (E) - Fire involving energized electrical equipment

Australian Standards for Portable Fire Extinguishers

AS/NZS 1841.1:1997 :
Portable fire extinguishers - General requirements

AS/NZS 1841.2:1997
Portable fire extinguishers - Specific requirements for water type extinguishers

AS/NZS 1841.3:1997
Portable fire extinguishers - Specific requirements for wet-chemical type extinguishers

AS/NZS 1841.4:1997
Portable fire extinguishers - Specific requirements for foam type extinguishers

AS/NZS 1841.5:1997
Portable fire extinguishers - Specific requirements for powder type extinguishers

AS/NZS 1841.6:1997
Portable fire extinguishers - Specific requirements for carbon dioxide type extinguishers

AS/NZS 1841.7:1997
Portable fire extinguishers - Specific requirements for vaporizing-liquid type extinguishers

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

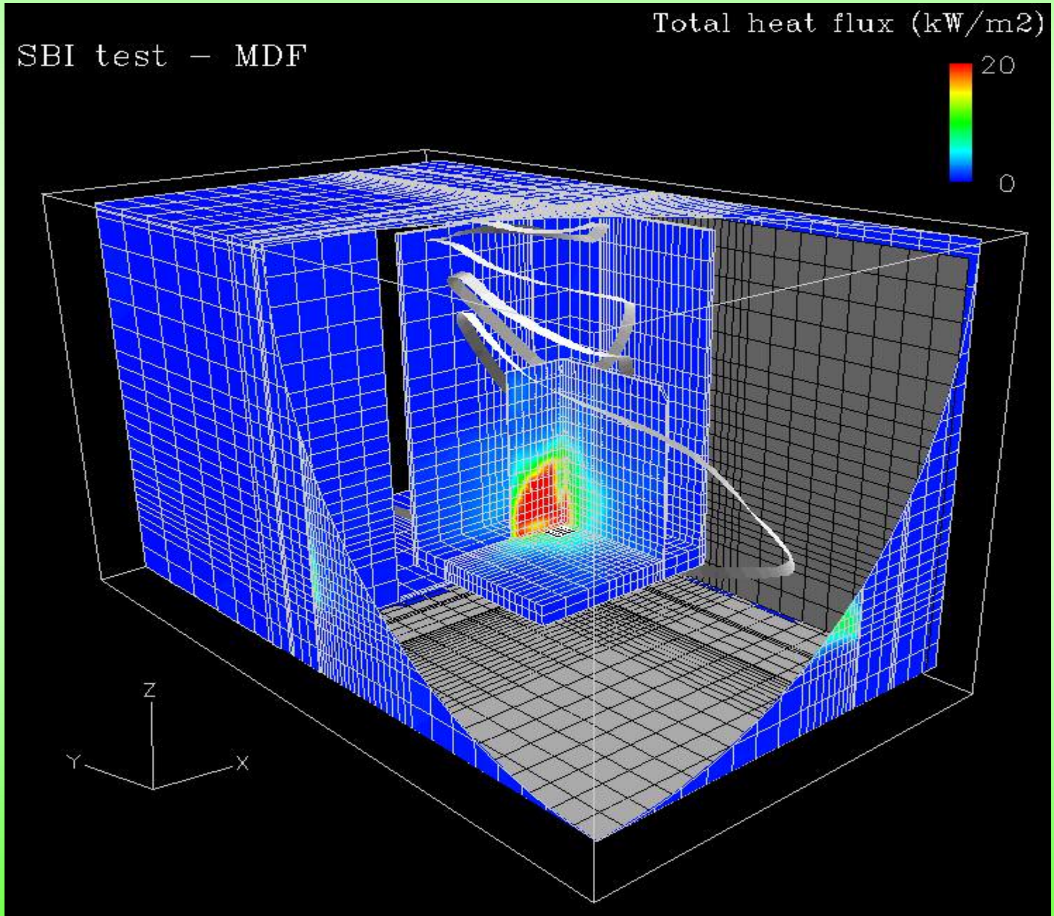
1. **Initial stage** and the
2. **Fully stage**.

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.

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.

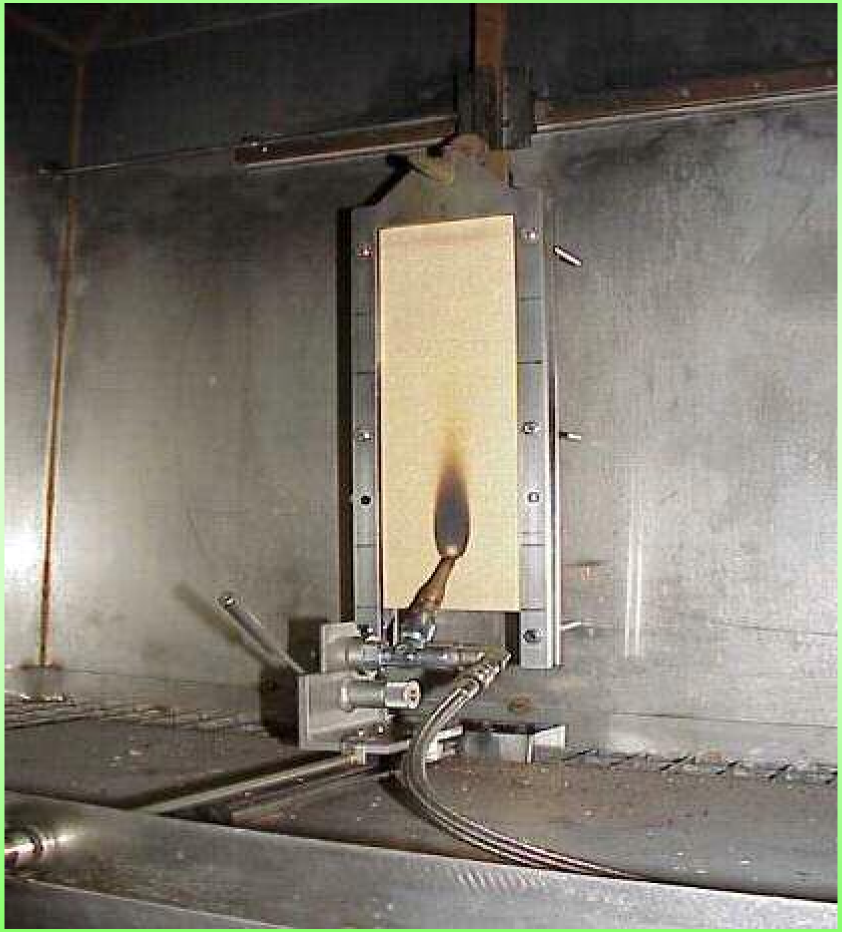
In the fully developed fire, the performance of load bearing and separating structures is important in order to limit the fire to the room or fire compartment of origin. This is called the fire **resistance of the building structure**.

Fires in Buildings



Flame test

- AS 1530.2-1993 :
  Test for flammability of materials
- This test evaluates the ignitability of a product when exposed to a flame.
- The test is relevant for the classes B, C, D, and E



FLAME TEMPERATURE

Fuel	Adiabatic Flame Temperature (K)	
	Oxygen as Oxidizer	Air as Oxidizer
Hydrogen - H_2	3079	2384
Methane - CH_4	3054	2227
Propane - C_3H_8	3095	2268
Octane - C_8H_{18}	3108	2277

A combustion process without heat loss or gain is adiabatic.

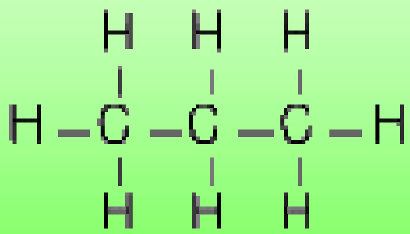
The adiabatic flame temperature of some common fuel gases like hydrogen, methane, propane and octane with oxygen or air as oxidizers is shown in the opposite Table

Hydro Carbons

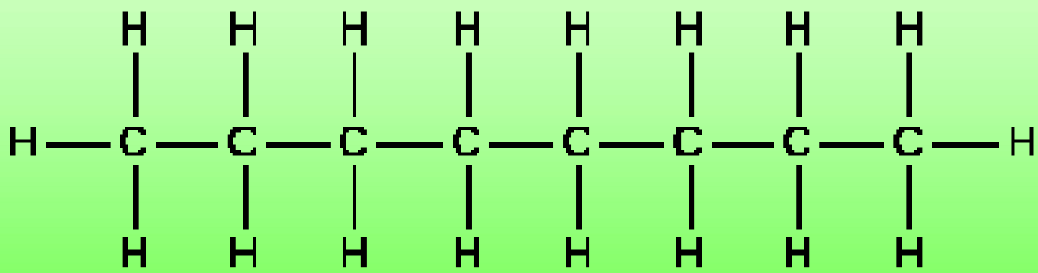
Structure	Name
1. CH_4	Methane
2. CH_3 - CH_3	Ethane
3. CH_2-CH_2-CH_3	Propane
4. CH_3-$CH_2CH_2CH_3$	Butane
5. CH_3-$(CH_2)_3$-CH_3	Pentane
6. CH_3-$(CH_2)_4$-CH_3	– Hexane
7. $CH_3(CH_2)_5CH_3$	– Heptane
8. CH_3 $(CH_2)_6$ CH_3	– Octane

One of the important families of organic compounds is the **Hydrocarbon** family**.** Hydrocarbons as the name implies, are compounds whose molecules contain only carbon and hydrogen.

Homologous series :
A series of compounds which have a common general formula and in which each member differs from the next member by a constant unit, which is the methylene group (- CH_2-) is called the homologous series.

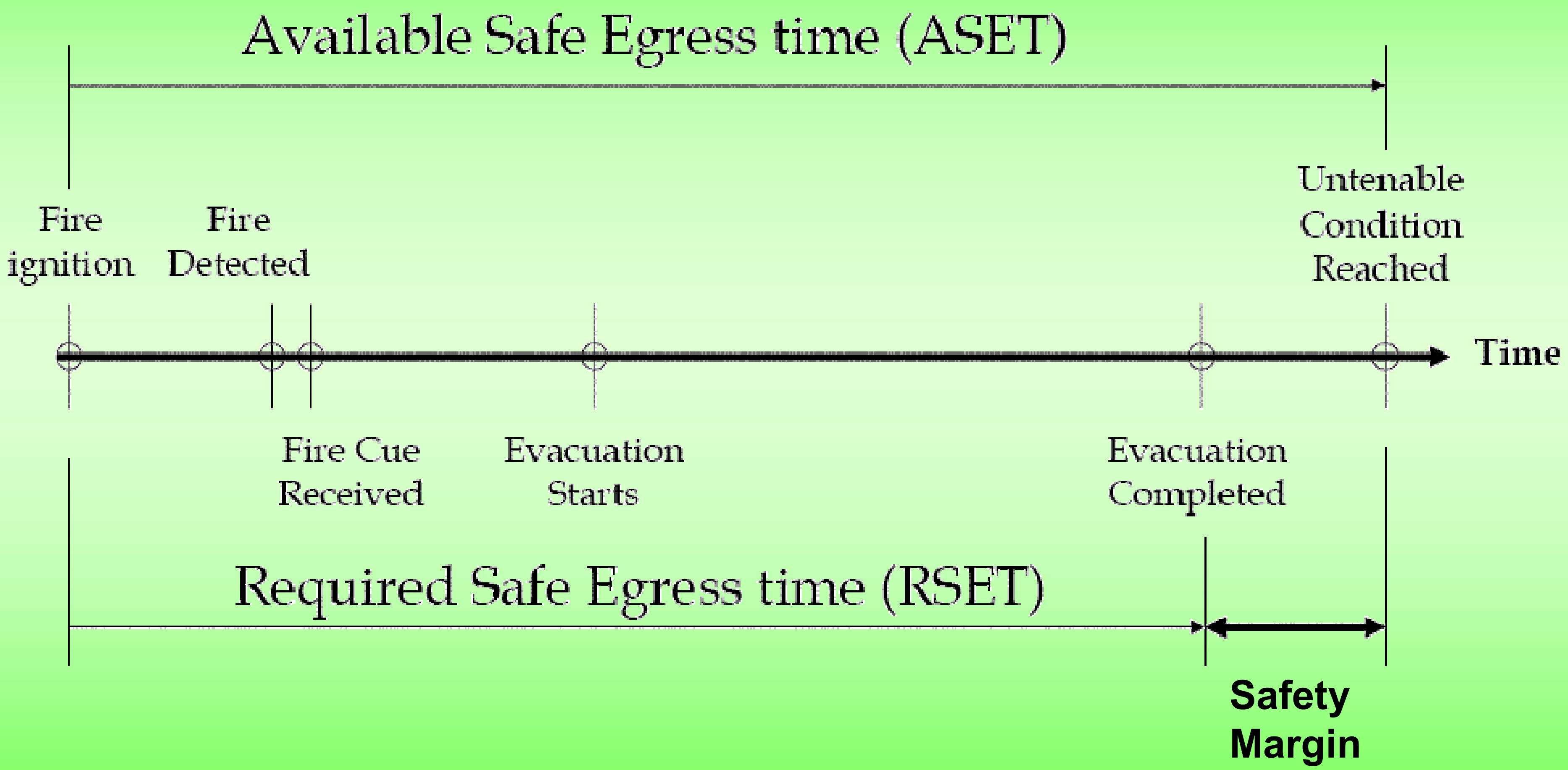


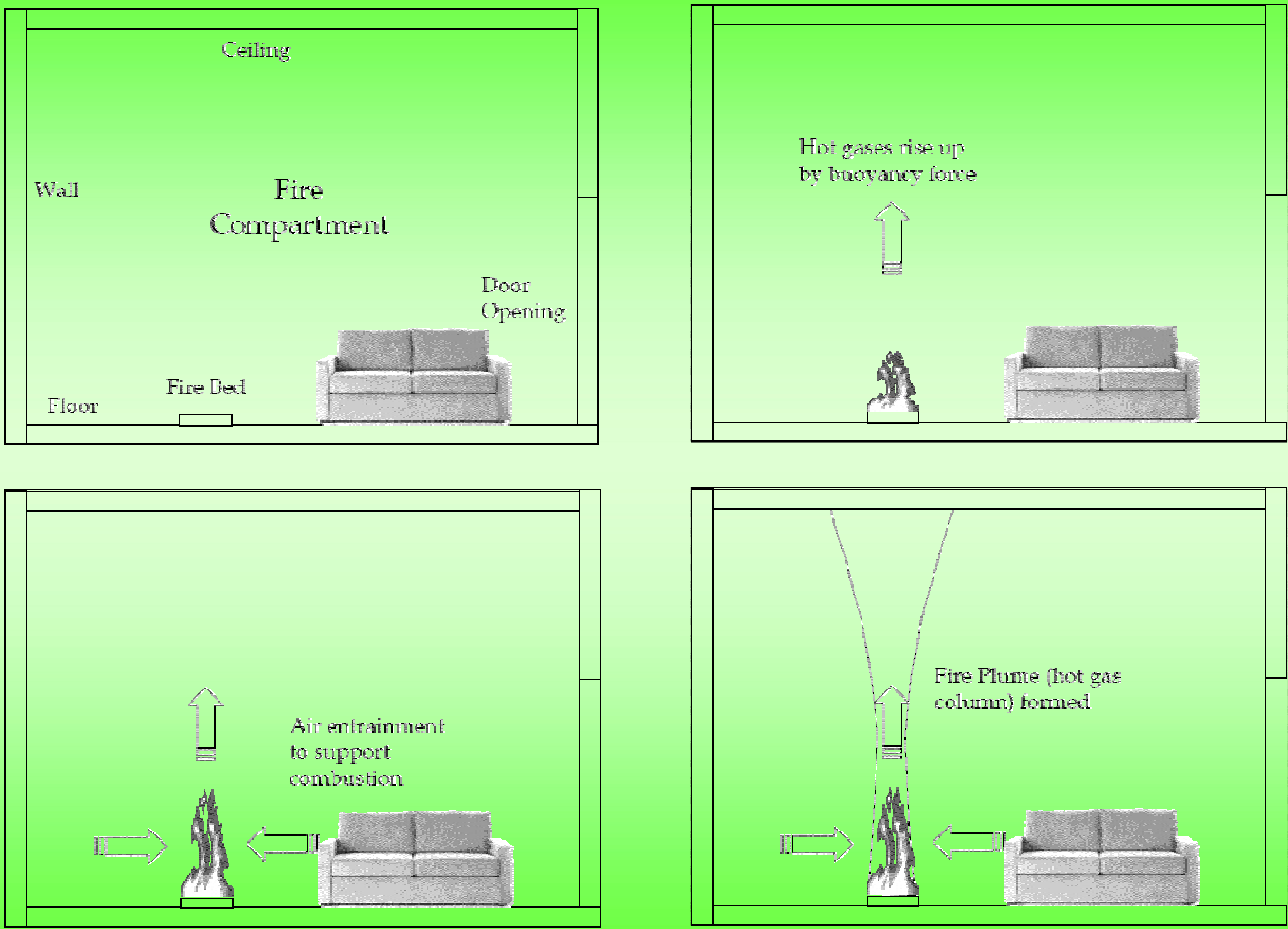
Propane

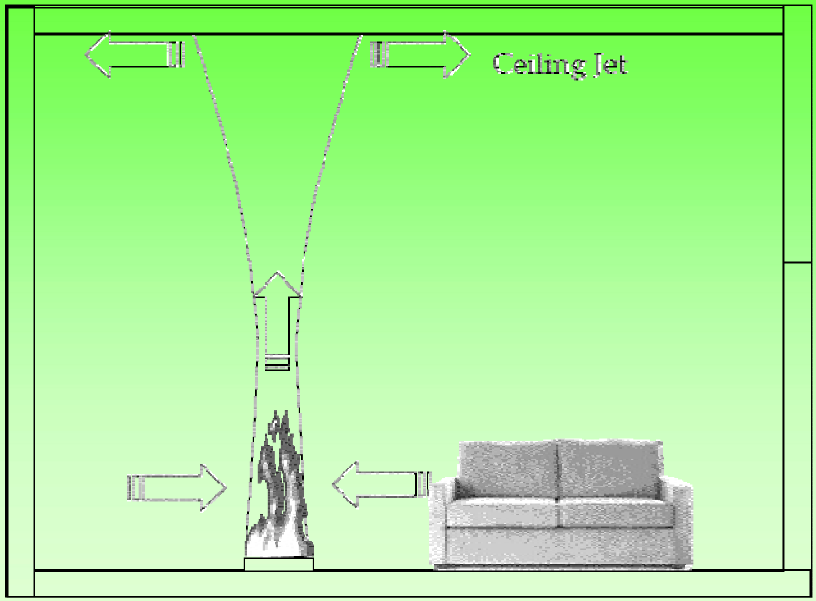


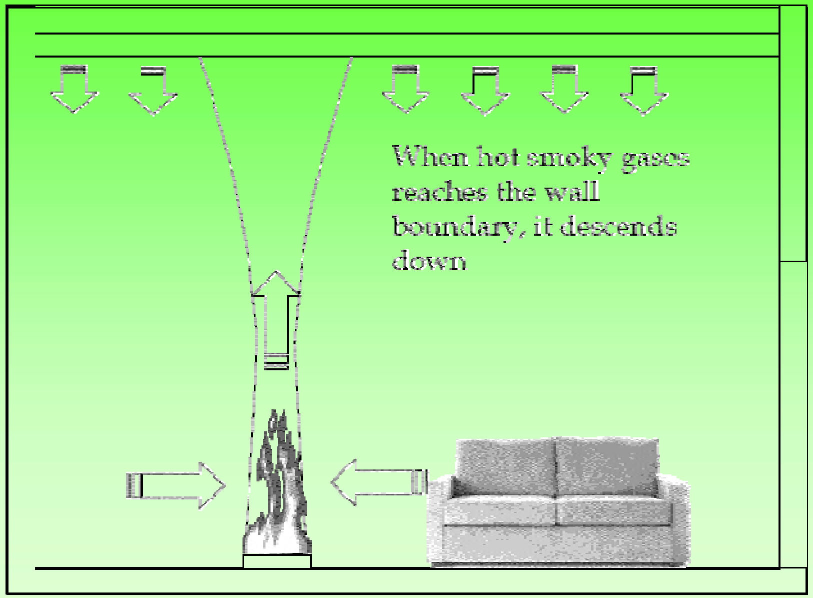
Octane a major constituent of gasoline

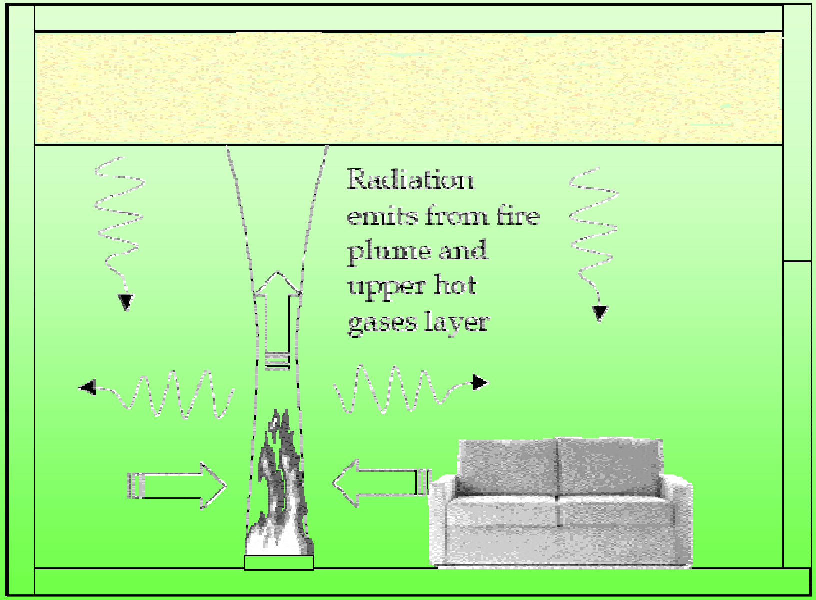
Timeline Approach

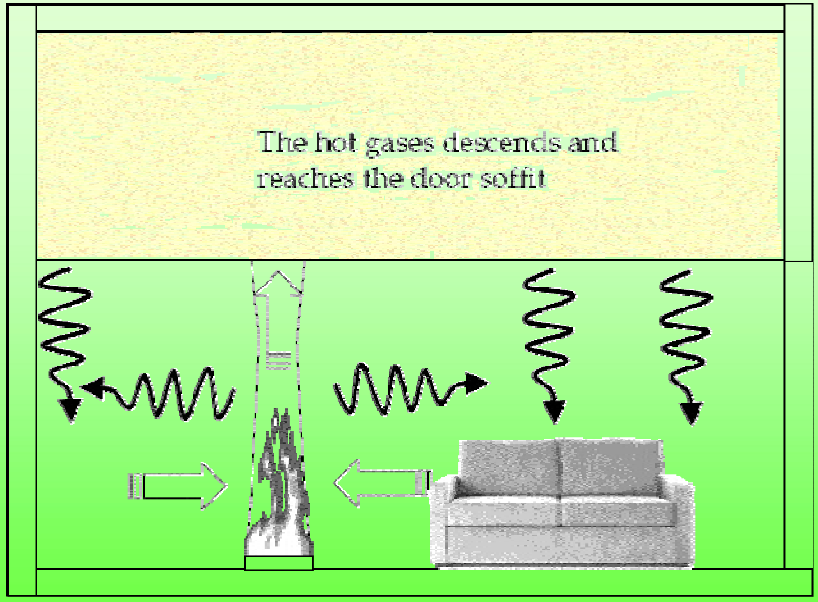


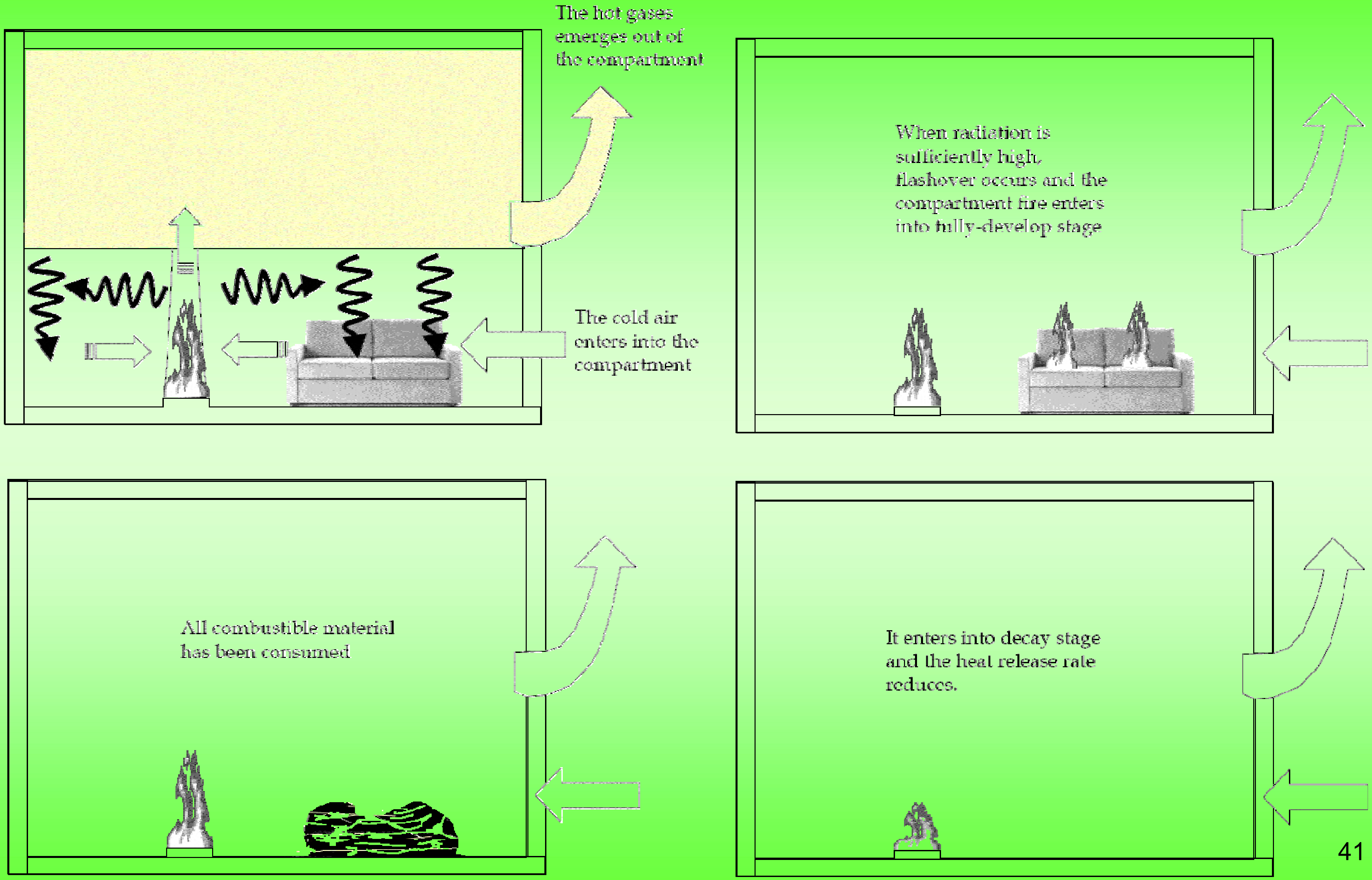

Ceiling
Wall
Fire
Compartment
Door
Opening
Fire Bed
Floor
Hot gases rise up
by buoyancy force
Air entrainment
to support
combustion
Fire Plume (hot gas
column) formed


Ceiling Jet


When hot smoky gases
reaches the wall
boundary, it descends
down

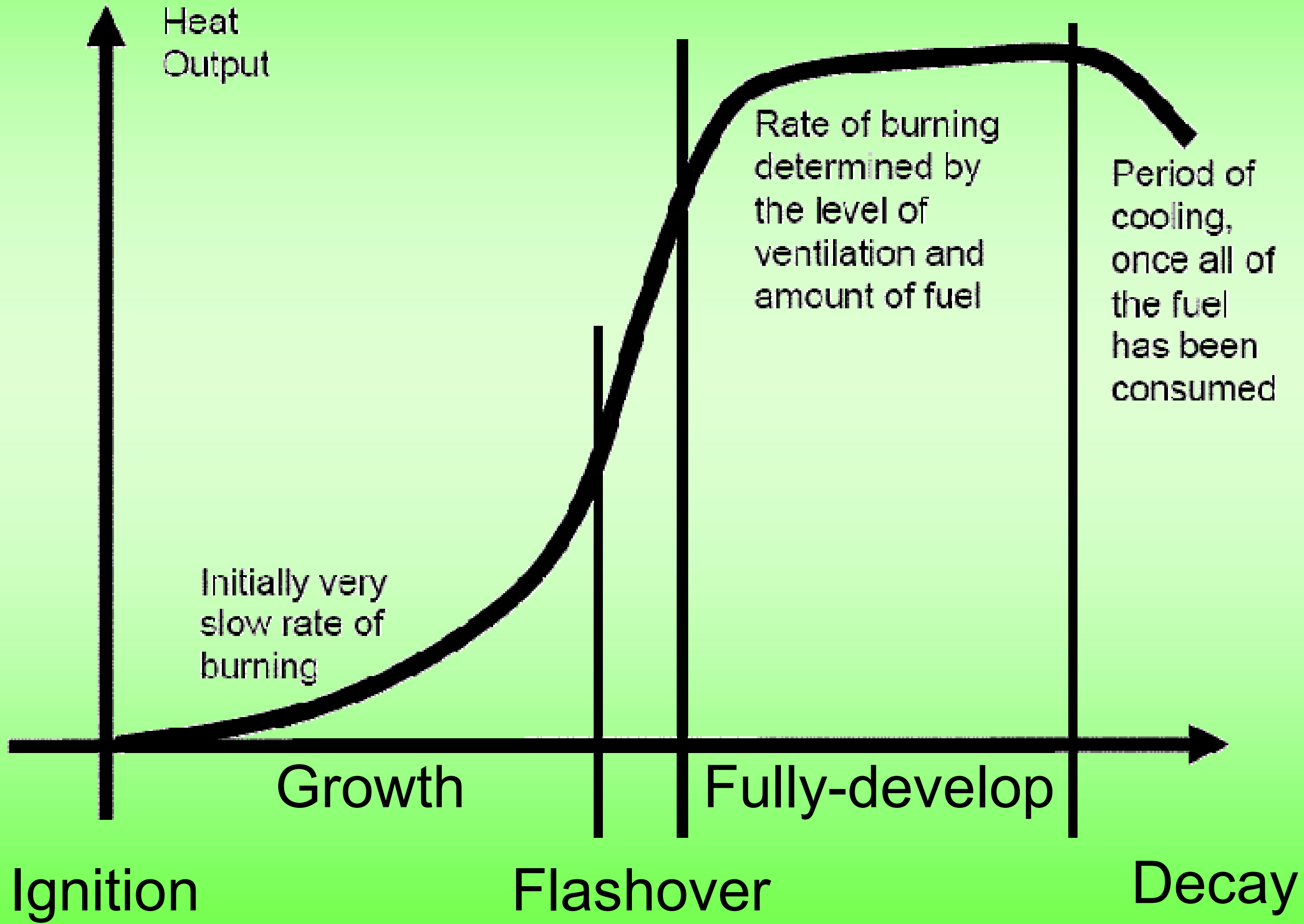

Radiation
emits from fire
plume and
upper hot
gases layer


The hot gases descends and
reaches the door soffit


The hot gases emerges out of the compartment
The cold air enters into the compartment
When radiation is sufficiently high, flashover occurs and the compartment fire enters into fully-develop stage
All combustible material has been consumed
It enters into decay stage and the heat release rate reduces.

Compartment Fire Development

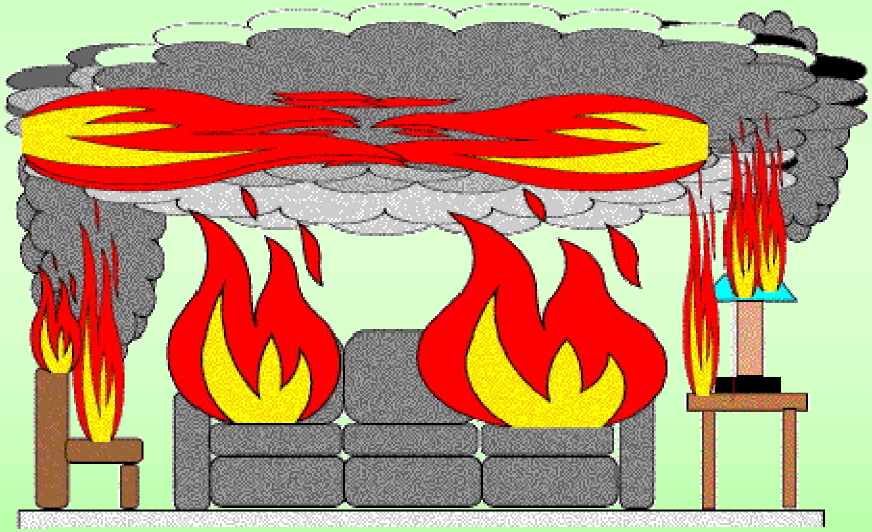
Stages
- Ignition
- Growth
- Flashover
- Fully-develop
- Decay

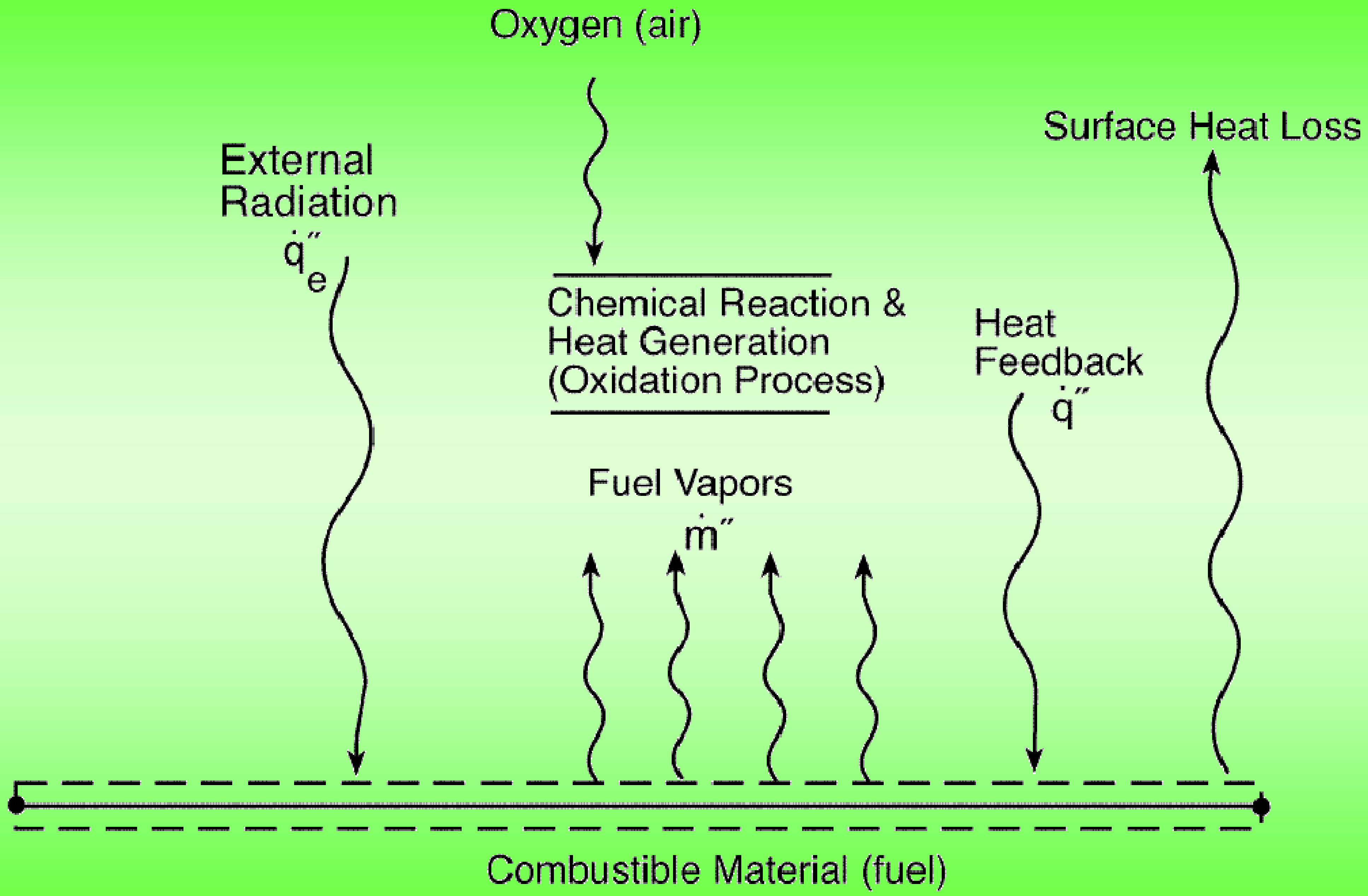


Flashover

- Radiant heat from fire plume and hot gases at upper layer is sufficiently high to ignite any combustible material inside the fire compartment at simultaneously

- Some Criteria
  - Hot gas temperature at 10mm below ceiling soffit reaches 500 ~ 600oC above ambient
  - Radiation on floor reaches approx. 20kW/m2





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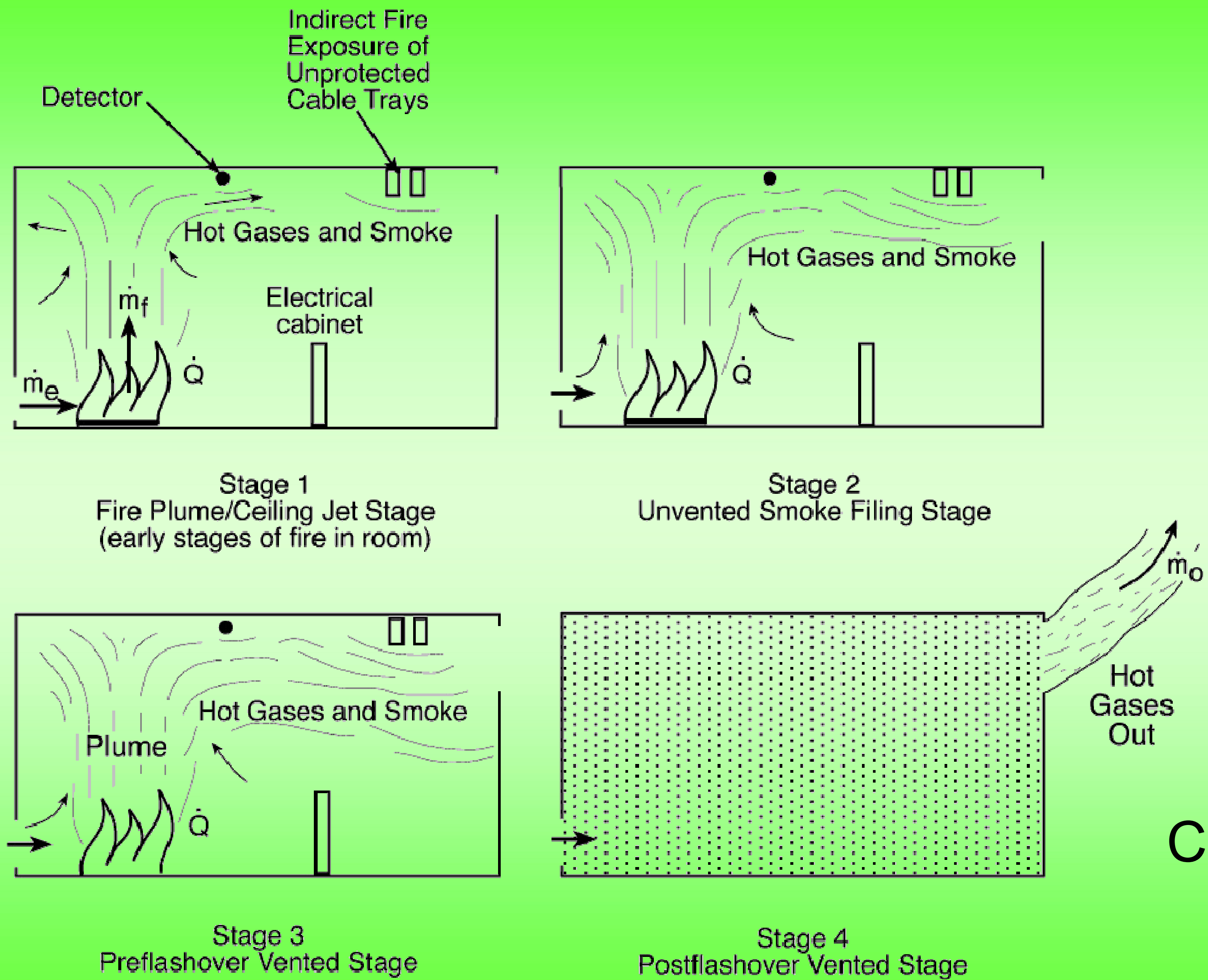

The course of compartment fires, and the conditions that result, depend on the following variables (among others):

- fire heat release rate (HRR) of the combustible
- enclosure size
- enclosure construction
- enclosure ventilation

Stages of Compartment Fire

Compartmentalization

- Buildings are designed to prevent fire, heat, and smoke from spreading beyond locations of origination. Building elements such as fire walls, fire dampers, and fire doors, are designed to seal off one location from the next. This system is called compartmentalization.
- Compartmentalization increases the safety of evacuating building occupants because smoke and fire are not able to escape into exit passageways.
- Containment of fire and smoke reduces property damage and prevents small fires from growing into large fires.
- In order for compartmentalization efforts to be effective fire barriers must be maintained.

What's A Fire Door?

- Fire doors are designed to withstand fire, heat and smoke for a period of 20-minutes to 3 hours.
- Did you know that corridor office doors are fire doors and should have a fire rating?
- Corridor laboratory doors should have a 60 minute rating.
- Fire Doors are required to:
  - Be Self Closing: fire doors should have a door closure that pulls doors completely shut after the door has been opened
  - Have Positive latching: a positive latch locks a door in place so can open swing open freely.

4 Reasons Not to Wedge Open Fire Doors

1 For the safety of your buildings occupants.
   – If a fire occurs in a location where the fire door has been wedged, smoke and heat will travel freely into exit corridors hindering or preventing occupant evacuation.

2 It's important to:
   – Periodically check and inspect buildings for fire access and egress

3 To reduce or prevent damage to property, research, personal belongings, etc.
   - Keeping your door shut will keep out smoke or fire originating in other locations.

4 To hold open your door you may have an electro-magnetic device installed.
   - This device releases a fire door upon activation of the fire alarm allowing it to close and latch.

Maintaining Fire Barriers

- Fire doors need occasional maintenance and repairs to function properly and should be periodically checked. To test a fire door:
  - Open the door fully and allow it to swing shut.
  - The door should close and latch completely by itself. Give the door a push after it closes to ensure that the latch has engaged.
  - If the door is not operating properly contact manufacturer for repairs.
- Ceiling, Floor, Wall Penetrations
  - All areas should be properly sealed to prevent the escape of fire, heat and smoke.
  - Common penetrations include holes in walls, around ducts, pipes, etc. These types of penetrations should be sealed with appropriate fire-stopping material.

Practice Burn Photographs

What clues might a fire investigator gain from this photograph?

Photos provided by Brock Brooks & the Havana Fire Department

Practice Burn Photographs

Photos provided by Brock Brooks & the Havana Fire Department

Practice Burn Photographs

A fire started in the kitchen area does not take long before it is a ball of flame reaching quickly to the ceiling.

Fires can easily double in size every 60 seconds, meaning there is little time to extinguish a fire before escape should be your primary goal if trapped.

Fire fighters look on as the fire spreads across a room.

The house is nearly completely consumed.

Source: http://www.ci.east-grand-forks.mn.us/fire/gallery/burn/burn.htm


BUSH


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End of Presentation - Thanks for your attention


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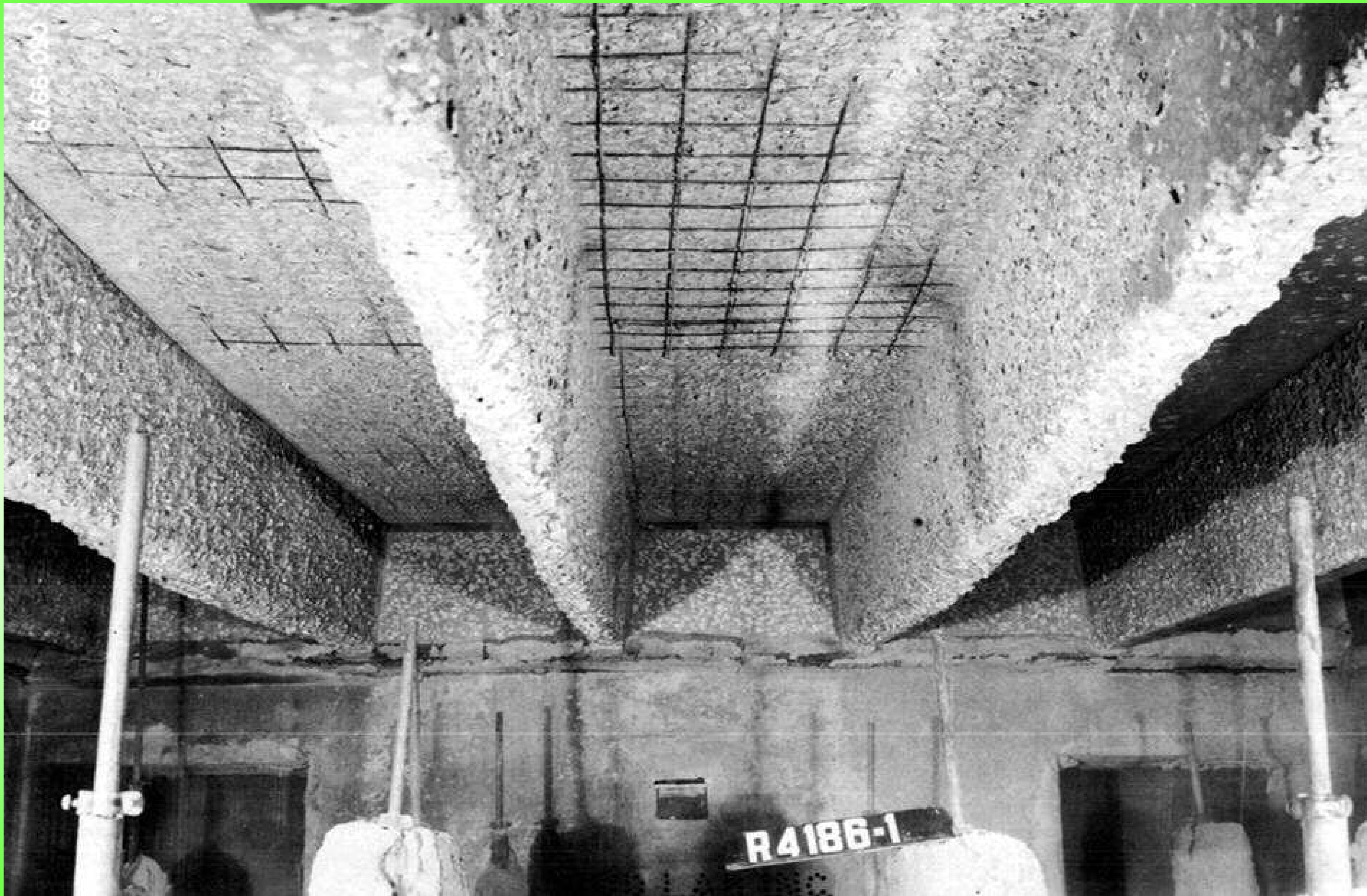
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