Summary

The following summary checklist sums up the main points of the section.

Many fires follow a pattern of four development phases:

- Incipient phase
- Growth phase
- Fully-developed fire ('flaming' or 'burning') phase
- Decay phase.

Incipient phase:

- The ingredients of combustion come together (fuel, oxygen and heat) and ignition occurs
- Smoke detectors may sound, as smoke is often generated before ignition
- Duration can be a few milliseconds or several days, depending on the conditions and ub tances involved
- Fire may go out if the fire triangle is split (e.g. fuel runs out).

Growth phase:

- Begins with self-sustaining combustion, which continues to burn when the ignition source is removed
- Growth rate depends on ventilation, fuel properties and compartment size
- Fuel must be converted to a vapour before combustion can occur.

Fully developed fire phase:

- Most damage occurs in this phase, as all fuel is consumed
- Fire continues to burn with high heat release and high temperatures
- Heat is transferred by convection, conduction, radiation and direct burning
- Duration depends on the amount of fuel and ventilation available.

Decay phase:

- Starts once 80% of the fuel has been consumed
- Rate of heat declines until all fuel has been consumed, and the fire goes out
- Duration depends on the characteristics of the available fuel.

If you are unsure about part of this section, go back and review it. Then if you still want to know more or want to make your own notes, write them in the space marked **Notes and questions** below, and discuss with your officer.

Notes and questions

Workbook Activity

You are now required to complete any appropriate questions in your Workbook.

Methods of fire transfer

Introduction

Heat is the by-product of combustion. It is the transfer of heat that causes fire to spread (transfer) from one place (fuel) to another, and beyond.

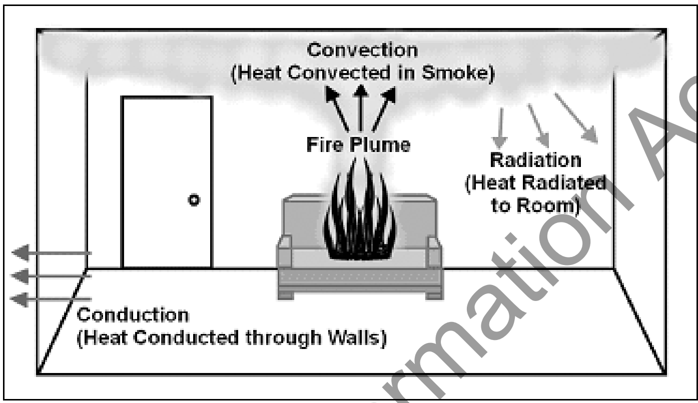


Figure 2.3: Three methods of fire / heat transfer

You need to use this fire transfer information to control fires, and the possible extension / transfer of the fire

The five methods of fire spread or heat transfer discussed in this section are:

1. Conduction
2. Convention
3. Radiation
4. Direct burning
5. Ember transfer.

How heat moves: convection, radiation, conduction

When a fire starts in a room, the hot smoke is contained and cannot easily escape. Heat is trapped, resulting in:

- Heat transfer from the fire to the smoke by *convection*
- Heat transfer from the smoke to the ceiling and the walls by *radiation*
- Fire *radiating* heat outwards to the rest of the room
- Hot smoke *radiating* heat downwards to the floor and the rest of the material in the room
- Heat *conducted* through walls.

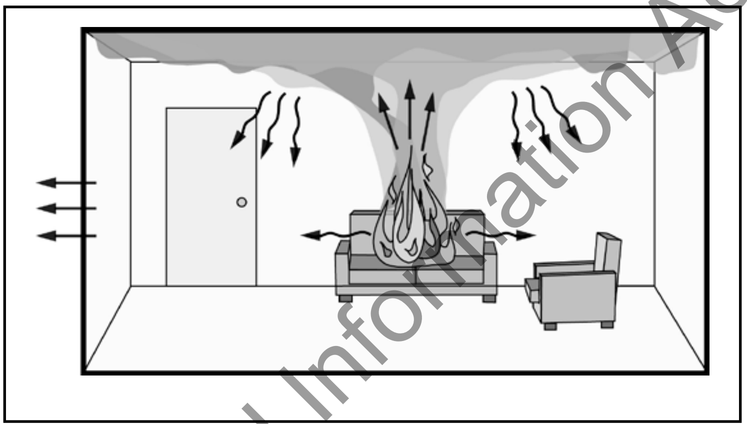


Figure 2.4: Heat transfer by convection, radiation, and conduction

Conduction

Heat energy will always flow from an area of higher temperature to an area of lower temperature

Substances that are good thermal conductors (e.g. most metals) will allow heat to flow through them (either vertically or horizontally) away from the fire.

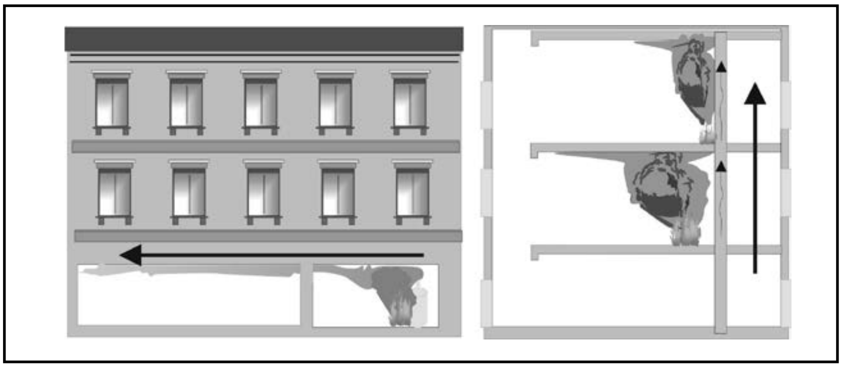


Figure 2.5: Vertical and horizontal heat / fire transfer

Good conductors of heat

The denser and heavier a material is, the better it conducts heat.

Examples:

- Metals are dense materials. A steel girder through an otherwise fireproof wall can cause fire spread because it conducts heat
- Concrete is a dense material made of rock, sand, and cement. It will also conduct heat, with enough transfer ability to ignite combustibles (although this process takes some time, compared to steel).

Figure 2 6: Fire transfer by conduction of heat along a steel girder

Poor conductors (good insulators) of heat

The lighter and less dense a material is, the better it *insulates* from heat. Air spaces within make it a *poor conductor*. Air is an excellent insulator.

Lighter materials with high ignition temperatures are the best insulators / poor conductors.

Example: Commercial insulators used in building construction are made of fine particles or fibres, with void spaces between them filled with a gas (e.g. air). (*IFSTA, 2001, p.36-37.*)

Note: Combustible insulating materials tend to ignite faster than combustible conductors, as they can't dissipate the incipient heat as quickly.

Convection

Convection is the transfer of heat through liquid or gas. It doesn't happen in solid materials.

When heat is applied to the bottom of a container containing a liquid or gas (e.g. boiling a pot of water), the liquid / gas in contact with the bottom of the container heats, becomes less dense, and rises. The cooler parts of the liquid / gas are displaced and sink to the bottom. This is a circulation system – the heated parts of the liquid (or gas) carry heat to all areas of the container.

Fluids (including gases) expand when heated. They become less dense and more buoyant, and tend to rise. Superheated fire gases can travel a substantial vertical distance and remain hot enough to cause further ignition.

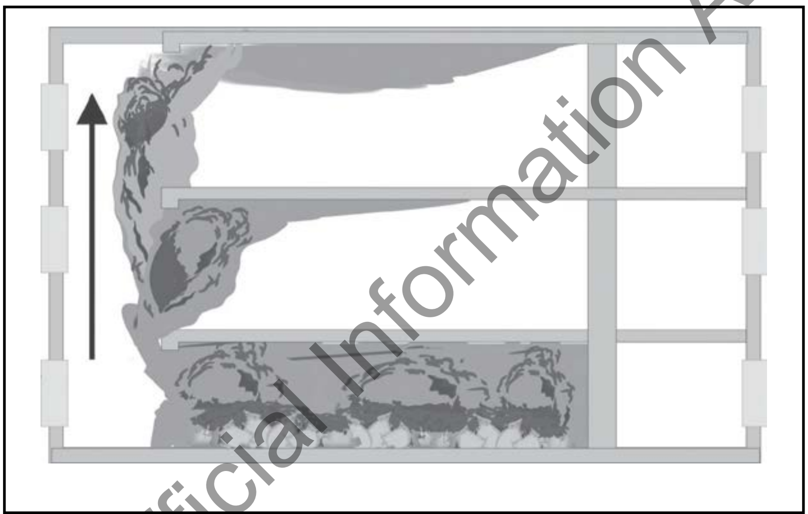


Figure 2.7: Fire transfer by convection

In a structure fire, convection currents convey hot gases (produced by combustion) upwards (e.g. through stairwells and open lift shafts). This spreads the fire to upper parts of the structure.

What does convection mean for you?

To determine fire spread, you must open wall cavities – this is essential to Fire Service operations.

Ventilation (in co-ordination with fire attack methods) reduces fire spread within a building.

This prevents fire spreading up lift shafts (by convection), or through lift doors that open into a smoke-protected area.

Radiation

Radiation is the transfer of heat energy (in all directions from a fire or heat source) to nearby objects or surroundings. Radiation is also the heat we feel without touching the source (e.g. when sitting beside a heater or in the sun).

Soot particles in a flame emit electromagnetic radiation (visible as a red or orange glow). These move through the air in a straight line

The temperature of combustible materials (both near and away from the fire) can be raised to their ignition temperature by receiving this radiation.

Examples:

- An electric heater can radiate sufficient heat to cause a piece of clothing to ignite, if it is placed too close to the source of radiant heat
- Large structural fires release a great deal of radiant heat – enough to blister paint on exposed surfaces, or even ignite an adjacent building
- Vegetation fires also release a great deal of radiant heat.

Radiant energy is transmitted *through* clear materials such as glass. (The glass does not heat up immediately.) Radiant energy from the sun can be concentrated through a magnifying glass, sufficient to ignite flammable material.

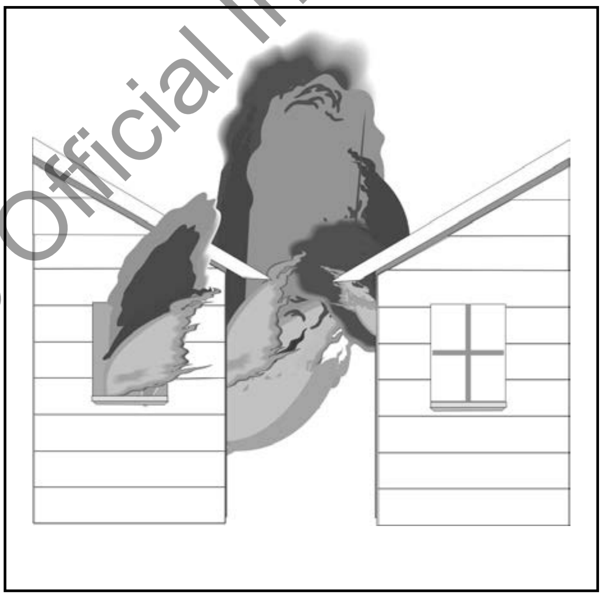


Figure 2.8: Transfer of fire / heat by radiation

What does radiation mean for you?

Water curtains help preventing radiation spread, by cooling the surface of the exposed buildings. This can be achieved through fixed fire systems, or Fire Service deliveries.

Direct burning (direct flame contact)

This fire transfer method is really not a separate method of heat / fire transfer. It is a combination of the three methods (conduction, convection, and radiation).

Direct burning is most influenced by *convective* heat transfer. A direct flame contact tends to spread in an upward direction, or transfer across any areas with a line of fuel for the fire to follow.

Examples:

- Fire spreads along a piece of wood and sets fire to other combustibles or pieces of wood it comes into contact with
- A candle is placed too close to a curtain. The flames touch it and the fire is transferred.

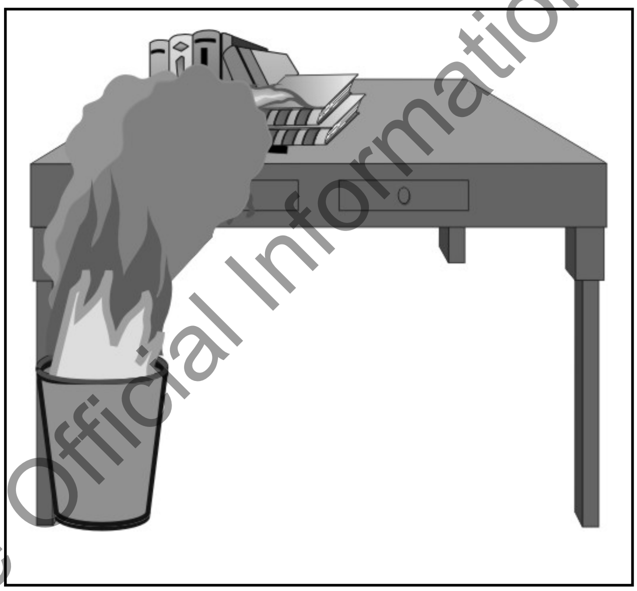


Figure 2.9: Transfer of fire / heat by direct burning or direct flame contact

Ember transfer (convection)

Ember transfer occurs where an ember is *transferred* to (or moves into contact with) a combustible material via the fire's rising heat. Like direct burning, ember transfer is not really a separate method of heat transfer, but a category of convection transfer.

Ember transfer plays a significant role in the spread of vegetation fires. Large-scale convection currents generated by a fire can alter local or general wind conditions (especially if these are less than 15 kph).

Convection currents carry burning embers into the air, depositing them away from the original fire into unburnt fuel. These embers create spot fires. Embers can travel more than a kilometre from the fire front, depending upon winds and fire up-draughts.

What does ember transfer mean for the Firefighter?

Wind can spread fires across firebreaks through ember transfer. Even within the urban area, fires can start well away from the affected building during high winds, due to ember transfer.

Summary

The following summary checklist sums up the main points of the section.

Fire and heat transfer

The transfer of heat causes fire to spread from one place to another. Fire is spread through:

- Conduction
- Convection
- Radiation
- Direct burning
- Ember transfer.

Conduction:

- Heat always conducts from high temperature zones to low temperature zones
- Dense, heavy materials (e.g. metal and concrete) are good conductors
- Light materials (e.g. wood and fibrous building materials) are poor conductors

Convection:

- Convection is the transfer of heat through liquids or gases
- During a fire, hot combustion gases rise upward, transferring heat through wall cavities, roof spaces, stairwells and lift shafts.

Radiation:

- Radiation is the transfer of heat in all directions from a fire
- Combustible materials can be heated until they reach their ignition temperature
- Structure fires and vegetation fires generate a great deal of radiant heat.

Direct burning:

- A combination of conduction, convection and radiation
- Physical contact of flame on a combustible material causes fire transfer.

Ember transfer

Ember transfer occurs when an ember is transferred to a combustible material via the rising heat of the fire (convection).

If you are unsure about part of this section, go back and review it. Then if you still want to know more or want to make your own notes, write them in the space marked **Notes and questions** below, and discuss with your officer.

Notes and questions

Workbook Activity

You are now required to complete any appropriate questions in your Workbook.

Compartment fire development – flashover

Overview

To understand how *flashover* and *backdraught* happen, you need to know how a compartment fire develops.

Flashover	**Backdraught**
Happens often Causes rapid fire development Triggered by heat build-up Occurs in the growth phase of fire Must be a ventilated fire.	Rare (may or may not ever experience it) Violent reaction Triggered by sudden introduction of fresh air to an under-ventilated fire May not be significant heat build-up May occur in the growth or decay phases of fire.

Figure 2.10: Comparison of flashover and backdraught

A flashover (and a backdraught) can occur in a room or compartment adjacent to or above the fire area. Basements and roof voids are common places for backdraught.

Ventilated compartment fire development

As covered earlier in this section, a characteristic compartment fire can be divided into four phases:

1. Incipient, beginning when the ingredients of the fire tetrahedron are present
2. Growth, beginning with ignition
3. Fully developed, often beginning with flashover
4. Decay, beginning when 80% of the fuel has been consumed, and ending when the fire has gone completely out.

Note: Flashover occurs rapidly when conditions are right. It is not just a phase of gradual fire development.

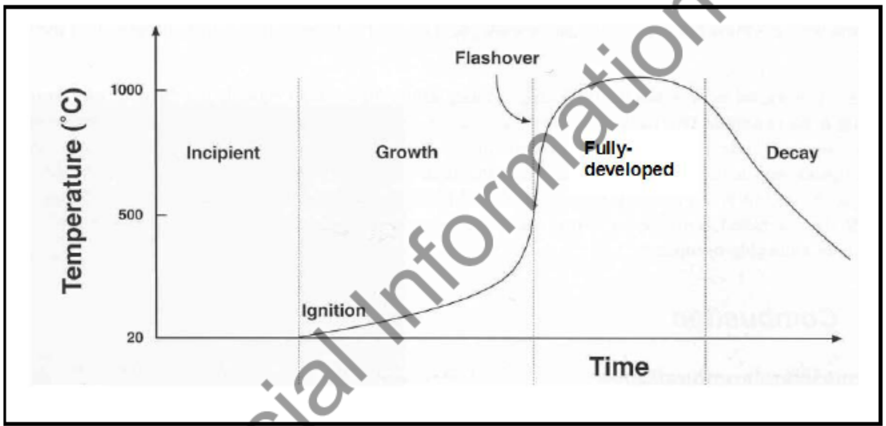


Figure 2.11: Typical compartment fire development curve
(Source: Fire Engineering Design Guide – Buchanan)

Non-ventilated fire development

In comparison, the diagram below shows a typical non-ventilated fire development curve.

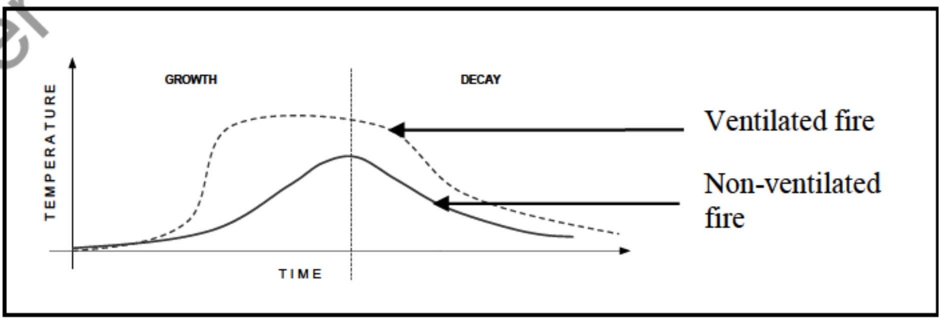


Figure 2.12: Typical non-ventilated compartment fire development curve

Incipient phase

Typical residential fire compartment

A typical residential fire compartment consists of a *fuel load* (e.g. furnishings and appliances) inside an enclosure with an opening (e.g. doors, windows or gaps).

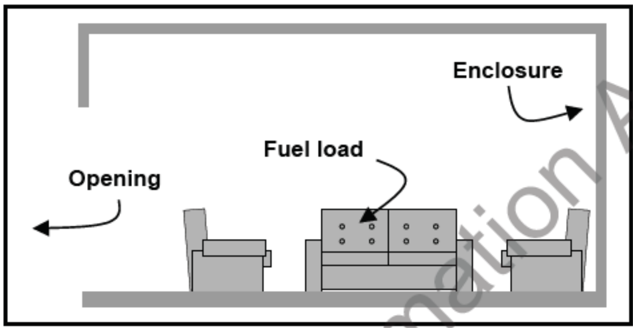


Figure 2.14: Typical residential fire compartment

Incipient phase

The incipient phase occurs after ignition, but before the fire becomes well established and increases significantly in size.

In this phase, fire is small and has not taken hold of the fuel yet – growth rate is slow. The fire generally gives off smoke and other combustion products, but little heat (energy) during this phase.

A smoke alarm on the compartment ceiling may activate during this phase.

Growth phase

Introduction

In the growth phase, the fire has taken hold of the fuel and starts to quickly grow.

Smoke and other combustion products are hotter than the surrounding air, and rise towards the ceiling (due to convection) in a *fire plume.*

The buoyant smoke in the fire plume begins to collect at the ceiling level.

If a smoke alarm is present in the compartment, it should activate by this stage.

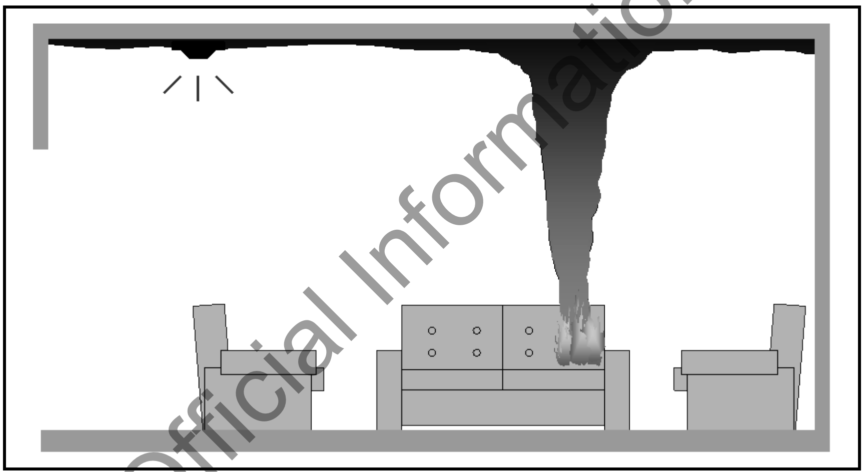


Figure 2.14: Smoke collects at the ceiling

Entrainment of fresh air

As the fire grows in size, so does the amount of smoke and hot gases rising in the plume.

The upward movement of the plume entrains fresh air, increasing its volume and reducing its temperature slightly.

The hot buoyant smoke collecting at the ceiling begins to descend as a layer.

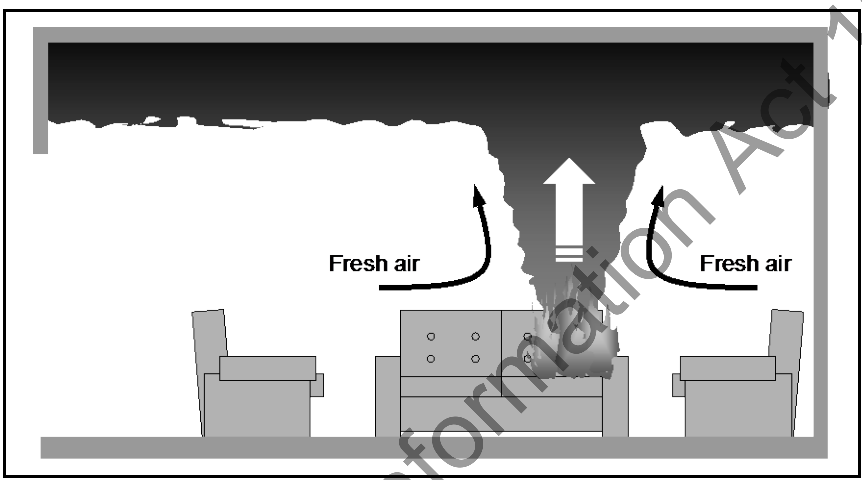


Figure 2.15: Fresh air is entrained in the fire plume

Layers: the two-zone model

The space inside the compartment is now divided into two distinct layers:

1. The upper, hot, buoyant smoke and fire gases form the *over-pressure zone* (or *positive-pressure zone*)
2. The lower layer, containing cooler, denser, fresh air is the *under-pressure zone* (or *negative-pressure zone*).

The boundary between the two layers is the *neutral plane.*

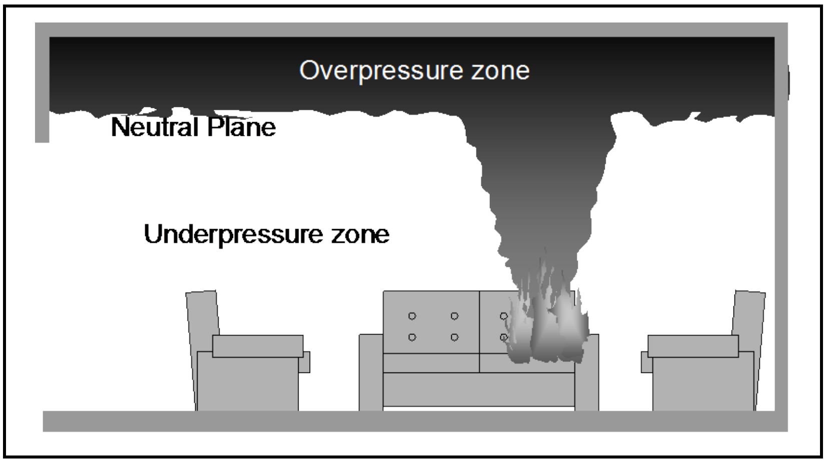


Figure 2.16: Two zone model

Contents of upper layer and plume

The fire plume and hot upper layer consists mainly of the following products of combustion:

- Carbon particles (soot)
- Carbon monoxide
- Carbon dioxide
- Hydrogen cyanide
- Water vapour
- Unburnt flammable fuel vapours
- Entrained air.

Growth phase development

As air within the compartment is used up by the fire – or entrained into the plume – fresh air must be drawn into the compartment through openings (e.g. windows and doors).

If there are not enough openings to allow sufficient oxygen into the compartment to feed the fire, it will not continue to grow. You need to watch for a potential backdraught in this situation.

If sufficient oxygen enters the compartment, the fire will continue to grow. The over-pressure zone will increase in temperature and descend towards the floor.

If the neutral plane descends below the top of an opening (e.g. a door or window), then smoke from the hot layer will flow out through the top part of the opening (either outside, or to other spaces in the building). At the same time, fresh air will continue to enter the compartment through the lower part of the opening to feed the fire, as shown in Figure 2.17.

As the temperature of the *over-pressure zone* increases, it will radiate heat down into the *under-pressure zone.*

This radiation from the *over-pressure zone* will increase the growth rate of the fire, and will start to heat other objects within the compartment.

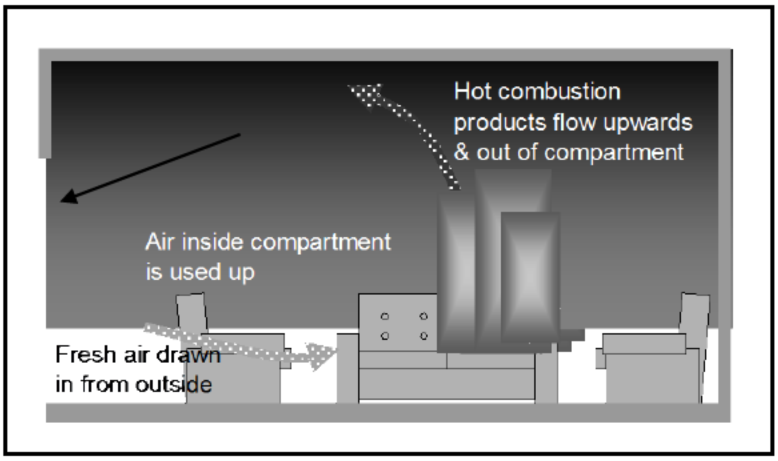


Figure 2.17: Two zone model, showing flow of gases

Flow of gases causing rollover

As the fire size increases, fuel vapour is released at a rate greater than it can be burnt. This unburnt fuel vapour collects in the over-pressure zone.

As the temperature of the over-pressure zone increases, this unburnt fuel may ignite as it reaches *auto-ignition temperature.* (Remember – air has also been entrained into the over-pressure zone.)

This ignition of fuel vapours within the over-pressure zone is called *rollover*, and appears as 'tongues of flame' within the smoke. (This is known as 'dancing angels' in the USA.) Rollover is a clear indicator that *flashover* is about to happen.

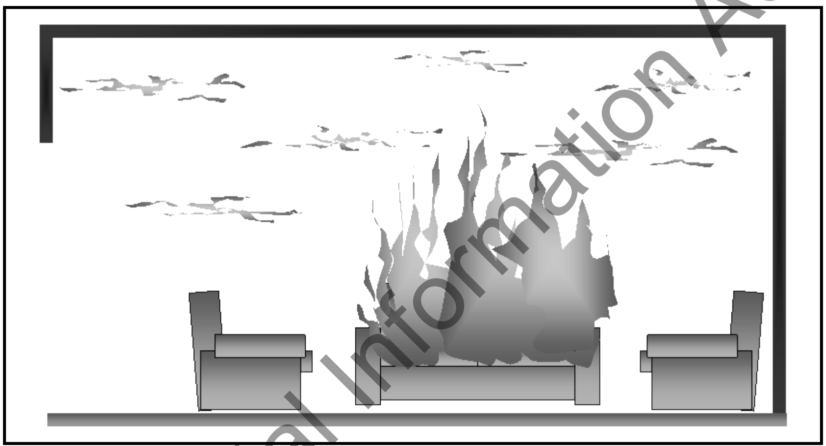


Figure 2.19: Rollover indicates that flashover is about to happen

Imminent flashover stage

By now the fire will be growing very quickly.

As the over-pressure zone temperature increases, the neutral plane descends. The amount of radiation emitted also increases, causing all fuel items within the compartment (e.g. curtains, furnishings and carpet) to be quickly raised to their respective ignition temperatures.

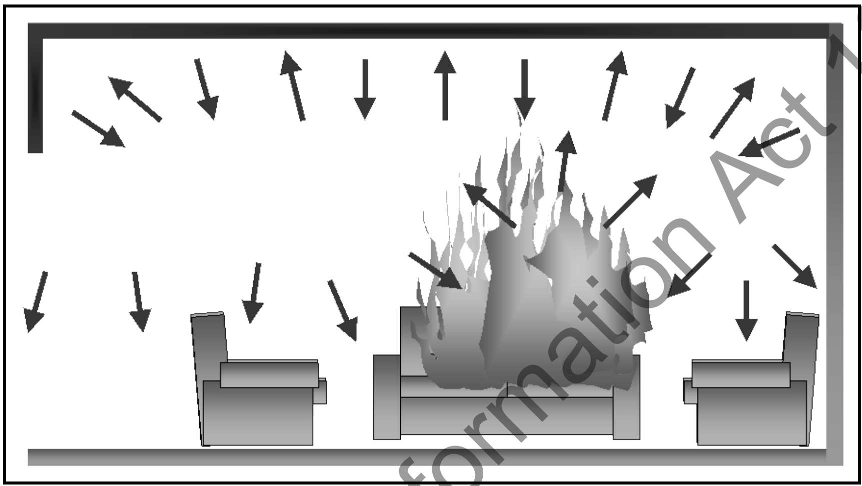


Figure 2.19: Radiated heat raises all fuel items to ignition temperature

This radiant feedback from the hot upper layer and compartment boundaries causes extreme heat increase, leading to flashover. This sudden and dramatic rise in temperature is another indicator of the onset of flashover.

At this point, fuel items can be seen to be pyrolysing, giving off a whitish vapour prior to ignition. This is a final sign that flashover is about to occur.

Flashover warning signs

The following signs indicate flashover is about to happen:

- Roll-over ('tongues of fire') visible in the smoke layer above your head
- Dramatic and rapid rise in compartment temperature, and heat from gases at ceiling level (forcing you to crouch low)
- Fuel surfaces giving off fumes (pyrolysis)
- Smoke rapidly backing down to the floor.

Preventing or delaying flashover

To prevent or delay flashover, you must direct a hose stream into the over-pressure zone. The hose stream is converted to steam in the over-pressure zone, and expands up to 3400 times.

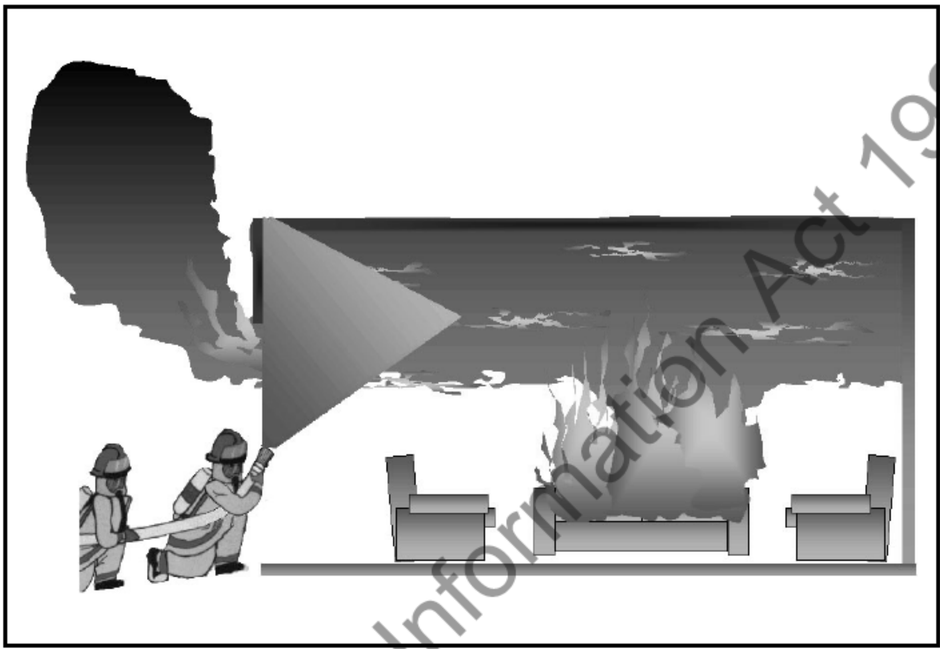


Figure 2.21: Cooling the over-pressure zone

Safety Note

Directing a hose stream into the over-pressure zone can disrupt the neutral plane, forcing superheated steam, smoke, and flame into the lower part of the room. If this occurs, Firefighters will experience significant discomfort, reduced visibility, possible injury – and the survival chances of victims are significantly reduced. See Figure 2.22 below.

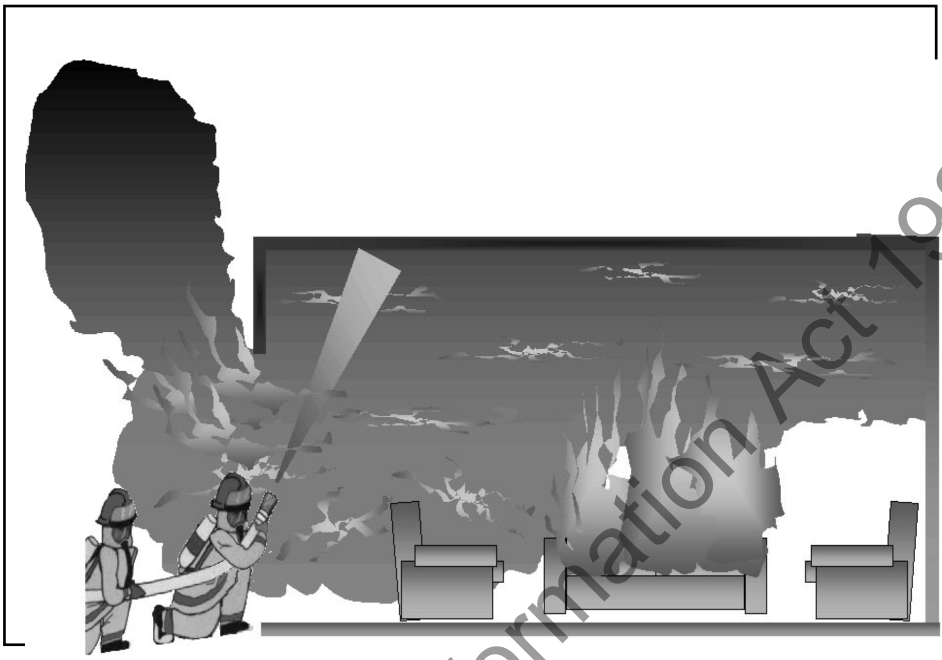


Figure 2.22: Applying a 'controlled burst'

Maintaining the thermal balance

In order to maintain the thermal balance, the hose steam should be applied in controlled bursts.

Controlled burst: Application of water in a spray pattern. Short controlled burst at a 45° angle towards the ceiling.

As the over pressure zone temperature reduces, flammable gases drop below self-ignition temperature. Radiant heat from the smoke layer, descending into the lower part of the compartment, is also reduced.

Thermal balance is maintained by balancing the steam expansion with the contracting fire gases as they cool.

Controlled bursts allow precise control, and effective use of available water.

Flashover

Introduction

Flashover can be considered the transition point between the growth phase and the fully-developed phase of fire.

Flashover occurs when all fuel items within the compartment ignite, virtually at the same time. It results during full compartment involvement in a fire, and is accompanied by extreme heat levels and large quantities of smoke.

If the windows in the compartment have not yet broken, they will generally break during a flashover. This noise often alerts people to the presence of the fire.

Even in full PPE, Firefighters cannot survive a flashover for more than a few seconds without sustaining serious or fatal injuries.

Temperature extremes

During flashover, the temperature range within a fire compartment varies. This variation depends on a number of factors, including size and fuel type. However, the following temperatures are a general guide:

- A smouldering fire is around 260°C
- In the minute prior to flashover, temperatures reach 500–600°C
- Immediately on flashover, temperatures climb to 800–1000°C. It is now a fully developed compartment fire. (*Quintiere, 1998, p. 170.*)

Flashover safety precautions

Take the following steps when dealing with the possibility of flashover:

1. Be aware of the potential for flashover (and backdraught). Don't go into any room if a flashover is likely. Watch for flashover warning signs
2. Make sure you are properly protected, with full structural firefighting clothing, gloves and BA
3. Ensure an additional charged branch covers the entrance
4. Ensure the escape routes are protected
5. Check the outside of the door for signs of heat
6. Stay low
7. Use controlled bursts of water from the branch. Direct the bursts at hot gases at the ceiling level
8. Ventilate only when it is safe to do so, and only when directed by the Officer. (*Fire Service Manual, Volume 2, Compartment Fires and Tactical Ventilation, 1997, p. 15.*)

Controlling flashover as a hazard

The Fire Service must frequently enter structures where flashover is a hazard.

To reduce the risks:

- You must be briefed on the tactics chosen by the officer
- Cool the over-pressure zone
- Ventilate the compartment.

Sometimes it is not as simple as just extinguishing the fire, because:

- The seat of fire may not be visible
- Search and rescue operations may need to be carried out
- The water application rate may not be large enough to effectively extinguish the fire
- You need to plan your entry and approach.

Safety Note

You must be briefed on the tactics chosen by the Officer, so you are aware of other actions being carried out by other crews.

Post-flashover

Fully-developed 'steady state' phase

Once flashover has occurred, there are no longer two distinct zones within the compartment. Instead, the compartment is now a single turbulent burning region. The fire is now said to be *fully developed* or *steady-state*.

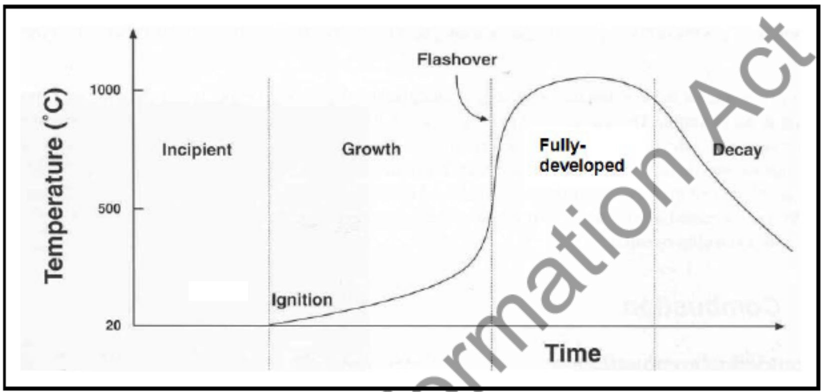


Figure 2.22: A fully-developed fire starts with flashover
(Source: Fire Engineering Design Guide – Buchanan)

The size of the fire is now limited by the amount of ventilation available. This is a function of the openings in the compartment. Because of this, the fire is referred to as being *ventilation-controlled.*

Ventilation-controlled fire

Often, during the fully developed phase, the size of the fire is limited by the amount of oxygen available. This amount depends on the size and location of any openings in the compartment.

Often there may be insufficient oxygen available for combustion to occur throughout the entire compartment – resulting in flames burning out from openings as the unburnt gases gain access to outside air.

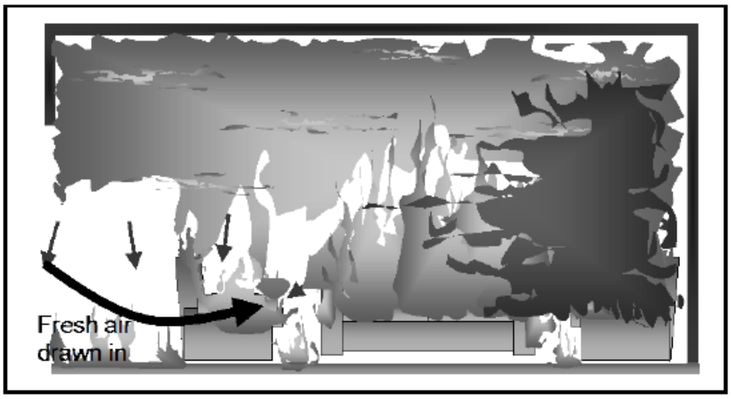


Figure 2.23 Ventilation-controlled fire

Ventilation-controlled fire: example

Figure 2.24: Flames from the window indicate a ventilation-controlled, post-flashover fire
(Source: Fire Engineering Design Guide – Buchanan)

Decay phase

Fuel-controlled fire

Once the fire has consumed most of the available fuel within the compartment, it starts to die down. This is the *decay phase* of fire development.

At some stage, the fire ceases to be ventilation-controlled, and reverts to a *fuel-controlled* state.

Usually the fire will decay at a steady rate until all the fuel is used up.

Summary

The following summary checklist sums up the main points of the section.

Flashover

In a compartment fire, flashover may occur between the incipient phase and fully developed phase:

- Extreme amounts of heat energy and combustion products are released from the compartment
- Occurs very rapidly and is *extremely* hot.

Warning signs:

- Rapid increases in compartment temperature (due to the radiation from hot gases at ceiling level)
- Tongues of fire visible in the smoke layer
- Other combustible surfaces giving off fumes / vapours
- Smoke rapidly backing down to the floor.

Controlling onset

Cooling the overpressure zone and / or venting the compartment can control the onset of flashover.

Safety precautions:

- Always be aware of possible flashover (and backdraught)
- Wear PPE, including gloves, and BA
- Ensure an additional charged branch covers the entrance
- Ensure escape routes are protected
- Check the outsides of doors for signs of heat before entering
- Stay low
- Use controlled bursts from the branch (not the pulse suppression technique) directed at the hot gases at the ceiling level
- Ventilate only when safe to do so, and only as directed by the officer.

Cooling the over-pressure zone:

- As the over-pressure temperature reduces, flammable gases drop below self-ignition temperature range
- Thermal balance is maintained by balancing steam expansion with contracting fire gases as they cool.

If you are unsure about part of this section, go back and review it. Then if you still want to know more or want to make your own notes, write them in the space marked **Notes and questions** below, and discuss with your officer.

Notes and questions

Workbook Activity

You are now required to complete any appropriate activities in your Workbook.

Compartment fire development – backdraught

Overview

Backdraught is the sudden eruption of fire in an under-ventilated compartment, due to the introduction of fresh air.

Backdraught (and flashover) can occur in the room or compartment above the fire area. Basements and roof void are also common places for backdraught.

You need to know a backdraught occurs in under-ventilated fire compartments (i.e. that are closed up or with few gaps, resulting in limited fresh air (oxygen) being able to enter).

Sequence of flashover and backdraught

It is possible for backdraught *and* flashover to occur in sequence.

Opening a door to an under-ventilated compartment fire that has been producing volatile gases for some time may result in a backdraught – followed rapidly by a flashover, caused by the sudden increase in temperature.

Unburnt products of combustion can accumulate into an explosive mixture on upper floors. Flashover in one compartment may trigger a backdraught in the ceiling voids, or on the floor above.

Important issues with under-ventilated compartments

Modern buildings are well sealed (to prevent draughts and air flow), and well insulated. This means they can keep heat trapped for long periods. Fire would continue to grow until oxygen in the compartment starts to run out.

If there are *no* openings, fire can die down to smouldering combustion, or extinguish completely.

Inefficient combustion produces large quantities of CO (carbon monoxide), a highly flammable gas. However – if there is insufficient oxygen in the compartment, the CO doesn't ignite but accumulates in the compartment.

Pyrolysis can continue for some time after flaming combustion has stopped (due to the limited supply of oxygen). This means other flammable vapours (along with carbon monoxide) are still being produced, and accumulate in the compartment providing the fuel source.

Temperatures can even be above the self-ignition temperature of the flammable vapours (rare, but possible) – however, smouldering combustion and embers may still be present, providing a heat source.

The only thing missing is ***oxygen!***

Typical ventilated compartment fire

As described in Section 3, flashover in a typical compartment fire (compared to an under-ventilated fire compartment) results in:

- Hot combustion products flowing upwards
- Air inside the compartment being used up
- Fresh air being drawn in from outside
- Hot combustion products flowing upwards and out of the compartment

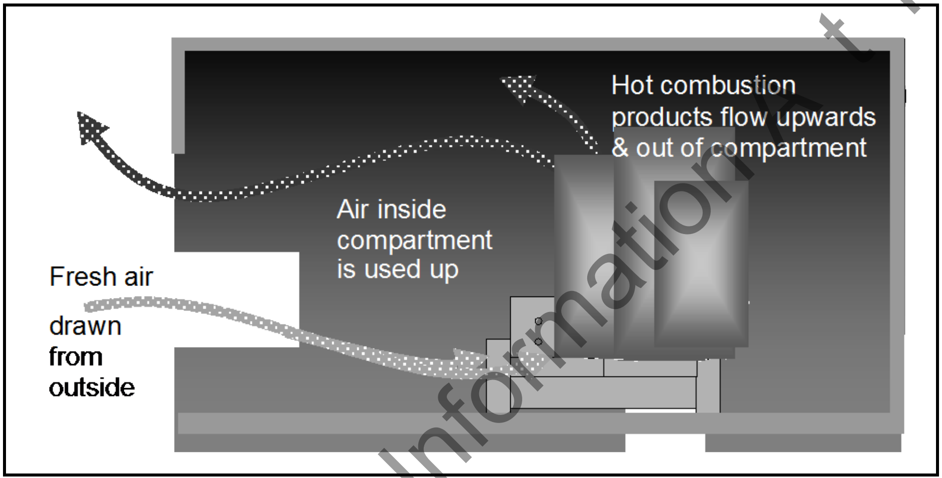


Figure 2.25: Typical ventilated compartment fire model

Under-ventilated compartment fire (lack of oxygen)

Compared to a typical ventilated compartment fire, in an under-ventilated compartment fire the openings are closed and intact. There is limited opportunity for replacing oxygen used in early fire development. As a result if there are:

- *Limited* openings, fire continues to burn at a steady rate, controlled by the amount of oxygen entering the compartment
- *No* openings, fire dies down to smouldering combustion, or extinguishes completely (if oxygen levels drop below 12%).

As in all fires, insufficient oxygen results in incomplete combustion. Two by-products of incomplete combustion are:

- Carbon particles (soot)
- Carbon monoxide.

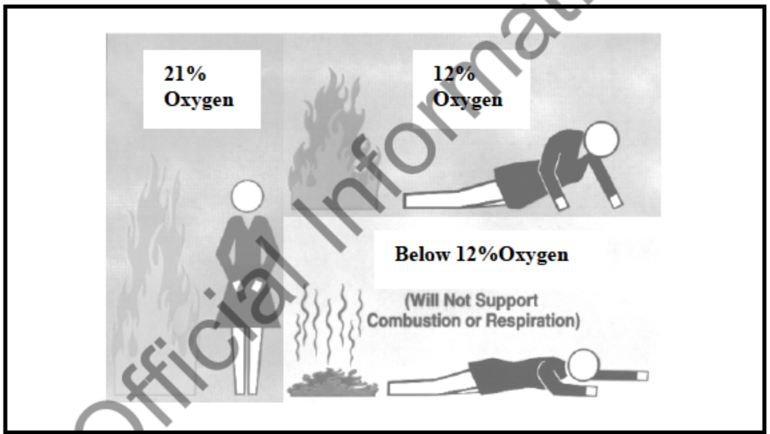


Figure 2.26: Effect of limited oxygen on fire development and human respiration

When fire starts in an under-ventilated compartment

If a fire starts in the lower part of a closed room (an under-ventilated compartment), the fire gives off combustible gases. Heat (thermal radiation) also causes the walls and ceiling to give off gases, which collect under the ceiling.

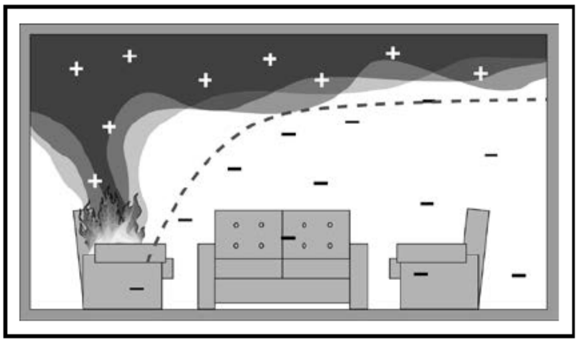


Figure 2.27: Fire starts in a under-ventilated compartment

Ignition

When these gases reach their LFL (lower flammable limit)**,** the original fire may ignite them. The flame travels over the ceiling, using up the available oxygen.

Fire dies down

As a result of ignition, there is now a rich mixture of materials above their UFL. However, the original fire dies down into a smouldering state due to lack of oxygen, causing an over-pressure zone – and the smoke level descends.

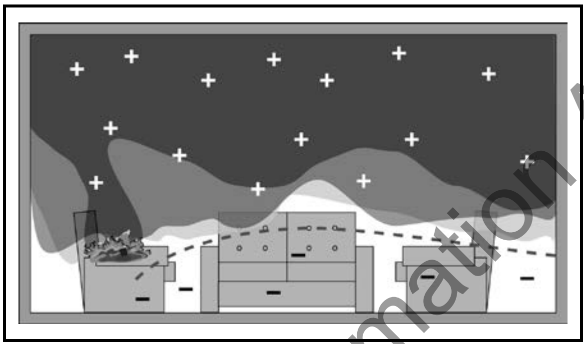


Figure 2.28: Large flames die down due to lack of oxygen

Smouldering and descending smoke level

At this stage, sufficient heat is trapped in the compartment, allowing pyrolysis to continue for some time after flaming combustion has stopped.

The resulting flammable vapours accumulate within the compartment, along with the CO already present.

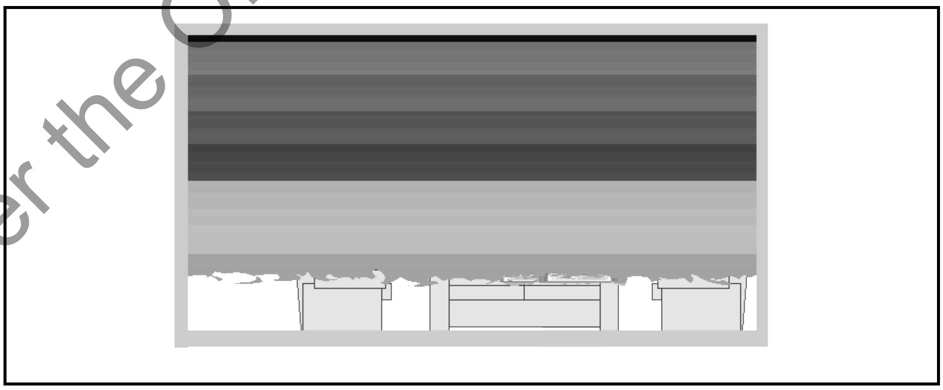


Figure 2.29: Smoke layer thickens and descends

Pulsation cycle

As a fire decreases, large flames die down, the room cools, and the gases contract. This results in the room changing from an over-pressure to an under-pressure state.

Although it is an under-ventilated room, the under-pressure tries to draw some air through openings / gaps, such as around doors or windows. When it succeeds, this causes some of the gases to mix, and the original fire flares up again as the gas layer re-ignites.

As before, flame growth occurs until the oxygen levels drop – the fire then dies down. This cycle is repeated, with the temperature in the room increasing each time. This is called the *pulsation cycle.*

Signs of the pulsation cycle include:

- Smoke-blackened windows
- Smoke pulsing from around doors and windows
- Windows rattling
- Signs of heat around / on the doors.

These are *also* all signs of possible backdraught.

Note: At certain times, the pulsing effect may or may not be visible.

The cycle continues

The pulsation cycle continues until either:

- The under-pressure in the room becomes enough to cause more damage (e.g. pulling a heat-weakened window inward)
- The door is opened (usually by you and your crew).

Note: If heat (not under-pressure) causes a window to fail, or is sufficient to force out anyone opening a door, then flashover is more likely to occur than backdraught.

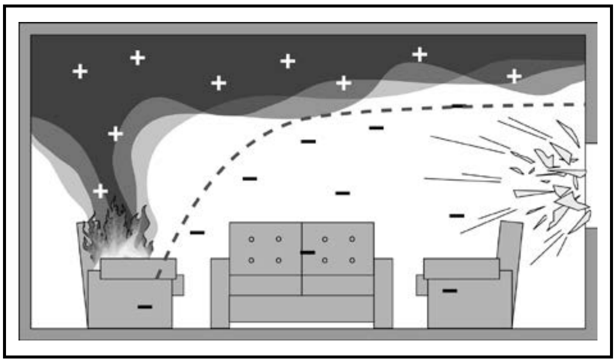


Figure 2.30: Under-pressure pulls a heat-weakened window inward

Trigger for backdraught: introduce oxygen

Any sufficient opening in a compartment (see Figure 2.31) allows air to be freely drawn in from outside – feeding the fire.

Oxygen flows into the compartment on what is sometimes called a *gravity current* or *air track*. This is created by the different densities between air and the compartment gases. The oxygen continues flowing into the compartment, mixing with flammable vapours, and disturbing the smouldering fire.

Flames flare up as the UFL is reached, and the surrounding combustible gas layer ignites – violently and explosively, causing a *backdraught*.

Heat output is substantial, and large amounts of combustible gases are emitted from combustible surfaces.

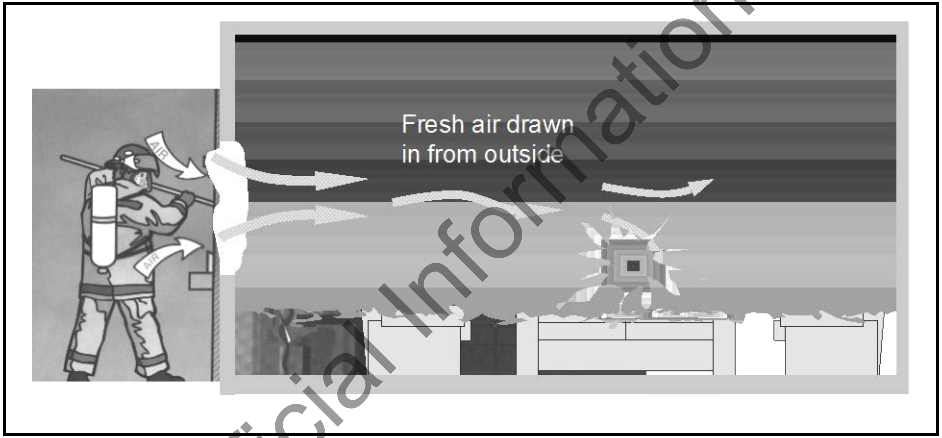


Figure 2.31 Oxygen travels inwards from an opening and ignites

How backdraught occurs

The explosive ignition described on the previous page is called *backdraught*. The explosion expands rapidly within the compartment, and will tend to follow the oxygen source.

The majority of gases generated now leave the room via the top half of the opening (over-pressure zone).

Air enters the bottom half of the room and circulates, mixing with flammable gases. This new supply of oxygen causes a full room of fire in very quick time: flammable vapours explode violently.

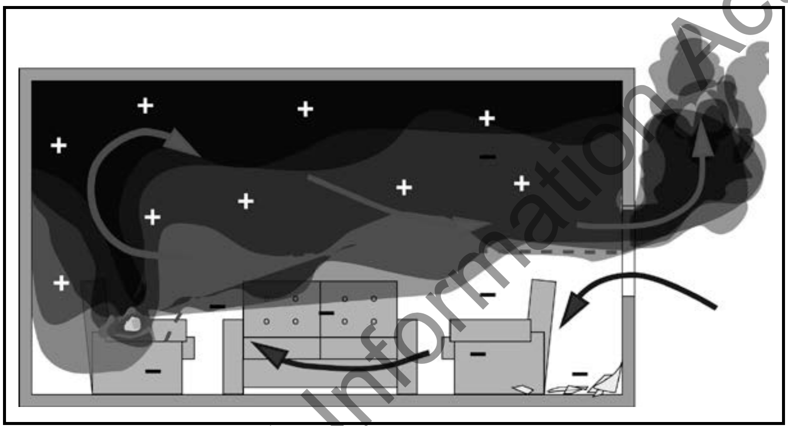


Figure 2.32: Backdraught – explosive ignition

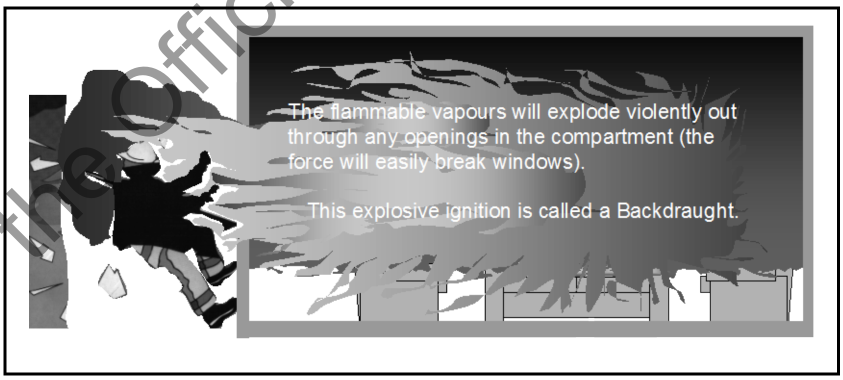


Figure 2.33: The danger of standing in front of a ventilation opening during a backdraught event

Post-backdraught

The possibility of a backdraught occurs in the cycle when the fire vents, or the compartment is opened.

If a backdraught occurs, you will likely suffer serious injury or death if you are in the compartment or within the path of the explosion.

A powerful backdraught can also cause structural damage, leading to partial or even complete structure collapse.

Backdraughts may be instantaneous, or could be delayed (see below) if:

- The size of openings, or of the compartment, or the distance from the opening to the compartment, delays oxygen levels reaching combustible levels
- Ignition sources are not immediately present (i.e. they may be exposed during overhaul or in another compartment).

Delayed backdraught

A delayed backdraught is particularly dangerous, as it may:

- Allow you to enter the compartment and expose yourself to greater danger
- Allow the fuel / air concentration to balance, resulting in a more forceful explosion
- Lull you into a false sense of security (especially if you're in another compartment, or performing overhaul).

Warning signs

The only safe way to deal with a potential backdraught is to identify the danger at an early stage, and avoid it.

Warning signs include:

- Smoke puffing out around windows, doors, and eaves, as the fire searches for more oxygen
- Pulsation at the windows and doors
- Black smoke and soot-stained windows
- Windows rattling, appearing 'oily', and being too hot to touch
- Excessive heat being apparent when feeling the back of a door / surface with the back of the hand, or when Firefighters are forced to crouch down
- Confinement of fire (no openings are visible in the compartment)
- Thick, heavy, black (carbon-rich) smoke filling up a room, or logging or banking down the inside of the compartment
- Little or no visible sign of flame / fire within the compartment
- Sudden inrush of air when an opening is made
- Black smoke becoming dense grey-yellow as it exits the building
- Muffled sounds within the compartment – heavy smoke dampens noise.

Backdraught safety precautions

The following precautions should be taken:

- Ensure you are properly protected.
- Keep doors closed and covered with charged delivery.
- If possible, keep out of the room and ventilate it from outside.
- Ensure escape routes are secure and protected.
- Cool and ventilate any outer compartment.
- Plan an escape route for gases before releasing them.
- Stay low, and to the side of the door / opening.
- Open the door slightly, and direct water spray into the upper layers.
- Cool as much of the compartment as possible.
- Keep out of the way of escaping steam and hot gases
- Only enter the room if you have to. There may still be flammable gases present. (*Fire Service Manual, Volume 2 Compartment Fires and Tactical Ventilation, 1997, p. 11.*)

Minimising the risk of backdraught

Introduction

A backdraught occurs when oxygen is introduced into a fuel-rich environment. Therefore, when there are warning signs of a backdraught situation, take the following precautions to reduce the risk of backdraught occurring:

- Prevent oxygen from entering, and wait until the compartment cools down
- Cool the environment
- Remove the flammable vapours.

Prevent oxygen from entering, and wait

It may be impractical in *most* situations to try preventing oxygen from entering while you wait for the compartment to cool – you will also need to perform search and rescue, assess property damage, and deal with time factors.

It may also be hard to control oxygen entry, as windows may break at any time from the heat.

You need to be aware that:

- Gases do not necessarily have to be super hot to ignite
- Smouldering combustion and embers can remain for a long time.

Cool the environment

In order to cool the environment you need to create an opening. This is a good option in situations where:

- A *small* opening can be made into the compartment
- A hose stream can be introduced.

Be aware – even if this tactic successfully cools the compartment, flammable vapours may still remain.

Remove flammable vapours (ventilate)

The best option for preventing backdraught is to remove the flammable vapours by ventilation. This tactic:

- Removes significant amount of heat
- Reduces smoke damage.

Ventilation should occur from the highest possible point. A hose stream should be in position for cover prior to attempting ventilation.

Ventilation can be *horizontal* or *vertical*.

Horizontal ventilation

Horizontal ventilation (e.g. through a window or wall) is more hazardous, because it is more likely to introduce oxygen to the compartment (which may trigger the backdraught you are aiming to prevent).

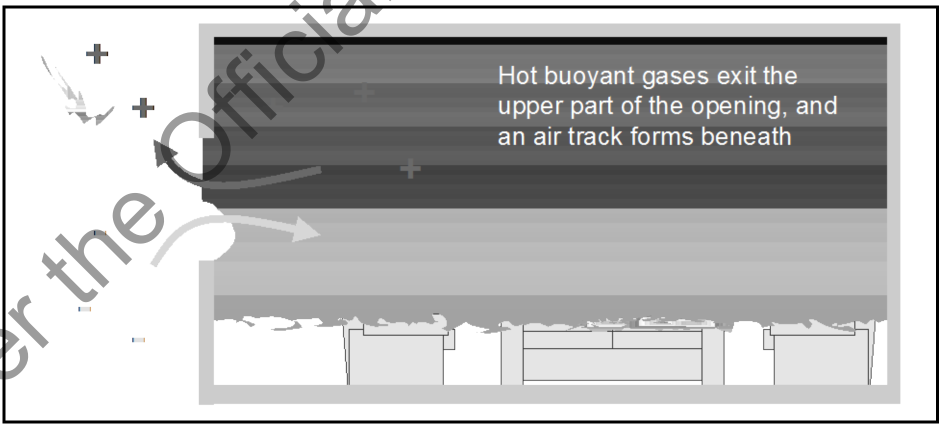


Figure 2.34: Horizontal ventilation through a door or window

Vertical ventilation

Vertical ventilation (e.g. through the roof) will allow hot gases to escape from a compartment, without providing an easy access for oxygen into the compartment.

For more information refer to the next section on ventilation.

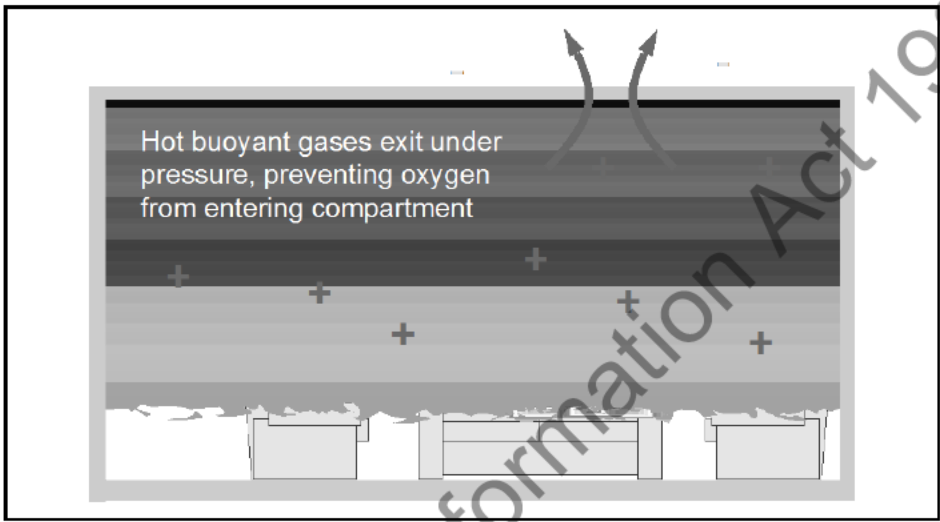


Figure 2.35: Vertical ventilation from a roof

Safety note

Ventilation should only be carried out with the approval of your officer.

Uncontrolled ventilation can lead to hazardous conditions.

Unusual situations

1. Flammable gases present in smoke can travel long distances from the seat of the fire.
2. Smoke can cool down considerably – but if exposed to an ignition source, a backdraught can still occur. This is known as a cold smoke explosion.
3. Flammable gases can accumulate in the ceiling void. If the ceiling structure is pulled down during overhaul, and an ignition source is still present in the room below, a backdraught could occur.
4. Firefighters shovelling debris, opening cupboards, or turning over mattresses and padded furniture could expose smouldering embers or flammable gases, resulting in a backdraught.

Fire Suppression Guide (F1)

For practical application and further information refer to the Fire Suppression Guide (F1) on the Bookshelf on FireNet.

Summary

The following summary checklist sums up the main points of the section.

Backdraught

The sudden eruption of fire in an under-ventilated compartment due to the introduction of fresh air.

Warning signs:

- Recognising warning signs is the best (only) defence
- Smoke puffing out around windows, eaves, and doors searching for oxygen
- Black smoke and soot-stained windows
- Excessive heat
- Windows rattling
- Muffled sounds within the compartment
- Confinement of fire (no visible openings)
- Thick black smoke logging inside compartment
- Sudden inrush of air when an opening is made.

Safety precautions:

- Ensure proper protection is worn
- Keep doors closed, cover with charged branch, and stay low
- Keep out of room if possible
- Cool as much of the compartment as possible: direct water spray upwards.

Minimising risk of backdraught:

- Prevent oxygen from entering and wait until the compartment cools
- Cool the environment
- Remove flammable vapours.

If you are unsure about part of this section, go back and review it. Then if you still want to know more or want to make your own notes, write them in the space marked **Notes and questions** below, and discuss with your officer.

Notes and questions

Workbook Activity

You are now required to complete any appropriate activities in your Workbook.

Section 3: Ventilation

What this section contains

This section contains the information you need to demonstrate the application of ventilation principles. It includes:

1. Ventilation
2. Ventilation operations
3. Tactical use PPV.

By the end of this section you will be able to:

1. Explain process of ventilation, how it can occur, its benefits to firefighting and its disadvantages
2. Explain the difference between natural and forced ventilation and the use, advantages and disadvantages of horizontal and vertical ventilation
3. Select and make appropriately sized and placed outlet vents for tactical ventilation
4. Explain how to ensure operator safety, the correct chain of command and when the PPV can be stopped
5. Explain fan placement, the methods of using multiple ventilators, used of positive ventilation techniques for stair wells and proper deployment of PPV fan.
6. Explain the impact of PPV on fire dynamics and what the crew action should be on fan failure
7. List and explain the five PPV tactical modes and when PPV use is appropriate or not appropriate and why
8. Explain the aim, outlet vent selection, application and procedure for PPV salvage and overhaul
9. Explain the aim, outlet vent selection, application and procedure for PPV fire control controlled
10. Explain the aim, outlet vent selection, application and procedure for PPV fire attack
11. Explain the aim, outlet vent selection, application and procedure for PPV fire isolated
12. As a team respond correctly and safely to a fire situation using PPV.

Why you need to know this

You will often work in situations where knowledge and application of ventilation principles may be used to reduce damage and danger. Therefore you need to have a sound knowledge of :

- Types of ventilation
- Ventilation principles
- Uses of ventilation

This section covers the theory you will use during the ‘Ventilation’ component of the QF practical course.

Ventilating the compartment

Why ventilate

Ventilation can occur in three ways

Self-ventilation

This happens when the structure is damaged by fire and increased ventilation occurs.

Automatic ventilation

This occurs when pre-installed vents are activated automatically, usually in the early stages of fire, by the fire detection system or fusible link devices.

Tactical ventilation

This requires the intervention of the fire service to open up the building releasing the products of combustion.

Benefits of ventilation

When ventilation techniques are properly applied they can provide significant benefits for the fire attack.

1. Ventilation can restrict the spread of smoke, thus improving visibility and extending available egress times. This will also make any search and rescue procedure more effective.
2. It can provide a clear exit route for persons still in the building where the escape route contains smoke.
3. Ventilation will help to improve visibility, and speed access if Firefighters are hampered in reaching the fire because their route is smoke logged. Ventilation can be useful whenever the removal of hot gases and smoke will make firefighting operations easier and safer.
4. It can improve the safety of Firefighters by reducing the risk of flashover and backdraught, and make it easier to control the effects of a backdraught. For example planning the route for the backdraught gases to take, and directing them away from Firefighters.
5. It can reduce property damage by making it possible to locate and attack the fire more quickly.
6. It can restrict fire spread by limiting the movement of smoke and hot gases.

Additional benefits of positive pressure ventilation

Many of the advantages of using positive pressure ventilation are the same as the advantages for natural ventilation. The points below are specific advantages of deploying positive pressure ventilation**:**

1. It provides a flow of cool, fresh air into the building at a point where Firefighters make their entry.
2. It achieves all the benefits of natural ventilation faster and, to a certain extent, independently of weather conditions.
3. PPV is a more controllable form of ventilation. The fan, unlike the wind, can always be turned off.
4. It improves conditions for casualties by supplying large amounts of cool fresh air and raising the smoke layer, therefore decreasing their exposure to toxic gases.
5. Steam created by firefighting is forced through the outlet vent, decreasing the humidity within the compartment
6. PPV will speed up the fire attack, and any search and rescue procedures due to the increase in visibility and the decrease in temperature within the structure.
7. PPV provides safer and more comfortable working conditions for crews during salvage / turning over.

Disadvantages of positive pressure ventilation

Just like any form of ventilation, PPV also has certain disadvantages:

1. Incorrect application can lead to increased fire growth, flashover or backdraught and increased smoke and fire spread.
2. The fan is noisy and can disrupt fireground communications.
3. PPV requires considerable training and experience to be used effectively.
4. Incorrect placement of outlet vents may lead to fire spread and could jeopardise the safety of Firefighters and / or casualties.

Ventilating choices

All methods of ventilation aim to release smoke and heat from the compartment.

There are three types of ventilation available to Firefighters:

1. Natural
2. Forced (mechanical)
3. Anti (or negative) pressure.

Both natural and forced ventilation can be delivered:

- Vertically (e.g. through an opening in a roof)
- Horizontally (e.g. through a window or door).

When to ventilate

Ventilation needs to be considered where any of the following situations occur:

- Heat, smoke, and gases rising from the fire create a life hazard for the occupants
- Firefighters are unable to gain entry
- Smoke has damaged th contents and structure
- The seat of fire cannot be found
- A backdraught or flashover situation exists.

What you need to know before ventilating

A good knowledge of a structure and its contents is required before deciding how to best ventilate the building, such as:

- The availability of natural openings (e.g. skylights, windows, doors, elevators and ventilator shafts, stairways, and chimneys)
- The location of the fire
- The direction the fire is likely to travel when ventilation occurs
- The structure's construction and condition
- The presence of wind and other weather conditions
- Any exposures, particularly of adjacent structures.

Ventilation options

Ventilation options include:

- *Natural ventilation* involves opening doors to take advantage of normal air currents
- *Negative-pressure ventilation* involves reducing the air pressure within a burning structure by drawing out the smoke, e.g. with smoke extractor equipment or the building's air-conditioning system, or by using a hose stream
- *Positive-pressure ventilation* involves increasing the atmospheric pressure in the structure so that smoke is forced out. (*AFAC Fire Suppression 2 (2.13), 2000, p.137*.)

Horizontal ventilation

Horizontal ventilation (e.g. through a window or door) involves creating openings in a wall, such as breaking a window as high up as possible.

Advantage: Horizontal ventilation is usually easy and accessible, and doesn't place you in danger from having to vent above the fire.

Disadvantage: It can cause a potential backdraught. Horizontal ventilation allows more oxygen in, so the fire size may increase.

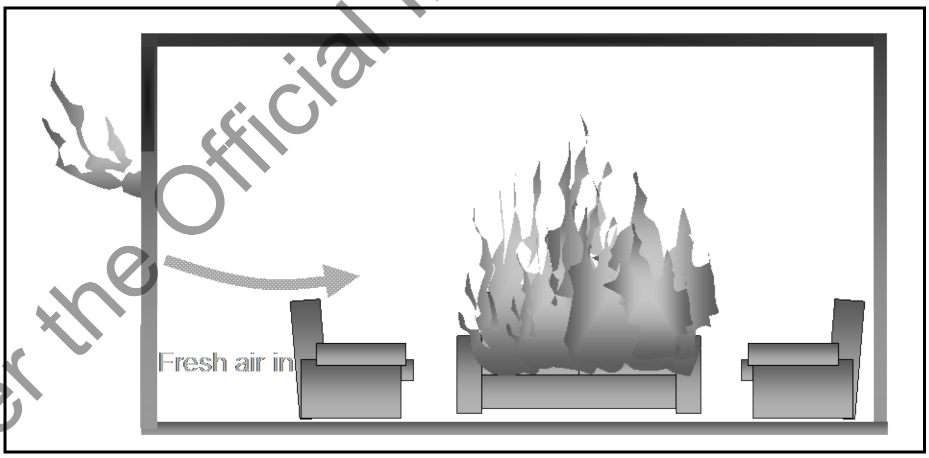


Figure 3.1: Horizontal ventilation (e.g. through a window)

Vertical ventilation

Vertical ventilation (e.g. through the roof) usually involves creating openings in the roof.

Risks include:

- Working on a roof almost above the fire (roof collapses)
- Cutting the roof requires close supervision, safety equipment and height awareness training
- Coordination is needed with hose crews waiting to directly attack the fire. (*AFAC Fire Suppression 2 (2.13), 2000, p.137*.)

Commonly misunderstood effects of PPV

Outlet vent size

A common misconception is that the outlet vent must be smaller than the inlet vent for positive pressure to build up. This myth has been proven scientifically to be wrong. Positive pressure will still build up within a structure due to the large flows of air that are pumped into the building by the fans, providing that the outlet vent is no larger than two times the inlet vent size.

PPV makes a fire grow abnormally fast or explosively

A fire which is burning in a fuel controlled manner already has a supply of oxygen in the region of 16–20%. Introducing more air using PPV will not significantly increase the burning rate of the fire.

A ventilation controlled fire may slightly increase in size when PPV is applied. This is due to the fact that the fire is burning in a smoky atmosphere and hence at lower oxygen concentrations. The opening of a vent and the initiation of PPV will lead to a rising of the smoke layer and an increase in the oxygen concentration, and this will cause the fire to begin to steadily grow. However, due to the increased visibility and decreased heat within the compartment the fire is located and extinguished far more quickly and the heat from the fire is forced out of the vent. Therefore it is unlikely that the fire growth will have any effect upon the compartment as a whole.

PPV forces fire throughout a building

When PPV is used correctly this will not occur.

Fire is spread principally by convection, which is the transfer of heat through fluid motion, the fluid in this instance is smoke. Smoke expands when it is heated. When this expansion is constricted by the confines of a compartment, the pressure of the smoke increases above atmospheric pressure.

The laws of physics state that areas of high pressure will always flow naturally to areas of lower pressure. Therefore the smoke will flow naturally towards a vent, as the pressure at the vent is lower than that of the smoke. PPV will accelerate this process.

If the vent is made in the wrong position, for example far away from the seat of the fire, the smoke will have to travel further to reach that vent. Therefore the risks of spreading the fire are increased as the heated smoke will come into contact with more of the surface area of the structure. This is not forcing the fire, it is merely increasing the heat transfer to the surfaces within the structure due to the prolonged contact between the smoke and the surfaces.

Poor outlet vent locations may lead to fire spread regardless of whether PPV is used or not.

PPV forces fire throughout a building: continued

Myths have surrounded PPV forcing the fire through a building for many years, but this has not been proven scientifically.

PPV works as a volume operation and not a velocity operation. This means that the flow of air through a building is determined by the pressure difference between the air in the structure and atmospheric pressure, not the velocity of the fan at the inlet vent. If a sufficiently large fan, in relation to the size of the structure, was used at the inlet it is possible for velocity to dominate the flow, however this is extremely unlikely as the NZFS uses relatively small fans.

In much the same way that smoke increases in pressure due to the confines of a compartment, the large volumes of air forced into the structure increases the air pressure as more air is forced in than can escape. In order to push a fire through a building a significant velocity would be required to overcome the natural buoyancy of the fire plume and change it from a vertical flow to a more horizontal flow.

During PPV operations, a significant velocity only exists at the inlet and outlet vents, and decreases rapidly from the inlet opening. The primary factor driving the airflow is pressure, due to the lower pressure at the outlet vent side of the fire and the higher pressure at the inlet side of the fire.

This pressure difference may create a slight movement of the fire plume from the vertical plane, but it is unlikely to contribute greatly to fire spread. This is because the gases produced at the low pressure side will be forced out of the compartment more quickly, and will have less time in contact with the structure to heat it to its ignition temperature.

Cool air will also be drawn in to the fire plume which will decrease the smoke temperature on the low pressure side, compared to natural ventilation. Therefore using PPV is less likely to force fire through a structure than if natural ventilation were used alone.

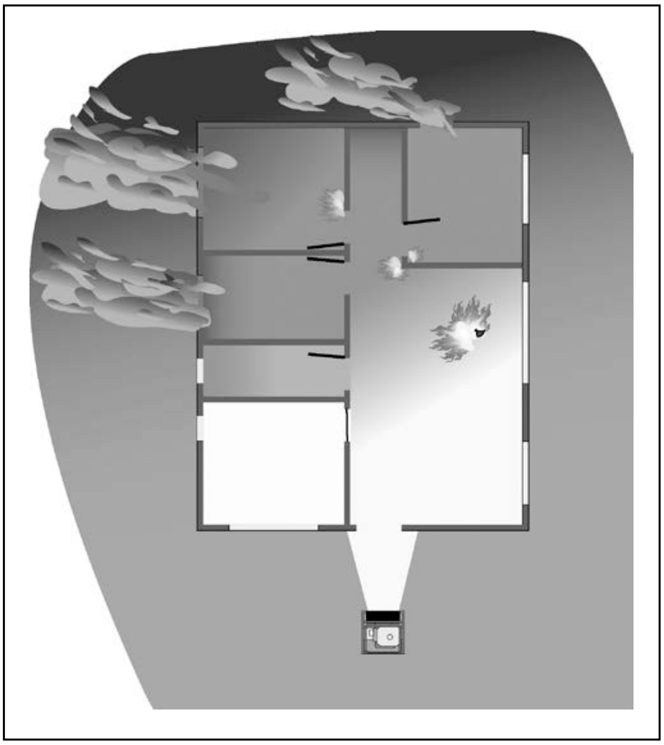


Figure 3.2: Incorrect vent: too far from seat of fire

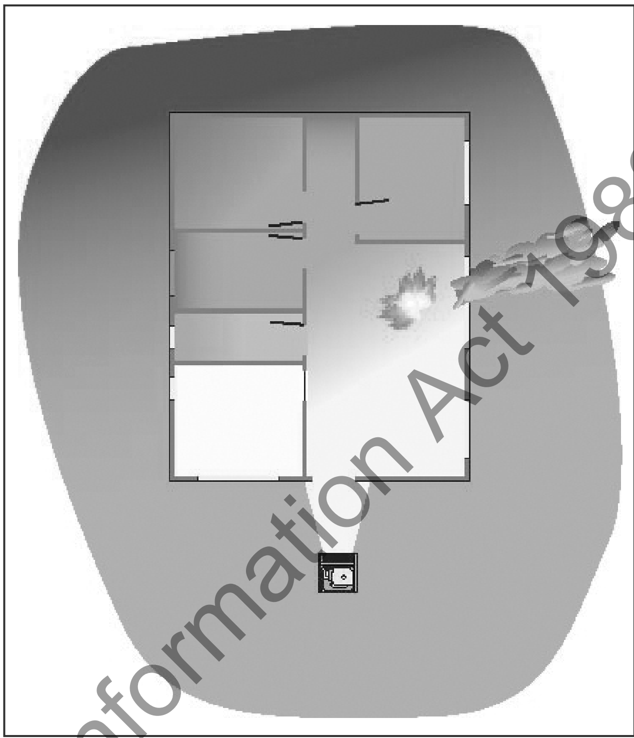


Figure 3.3: Correct vent: close to seat of fire

PPV forces fire throughout a building continued

The critical factor to prevent fire spread is the choice of a good vent location, as close to the fire as possible, which will minimise the travel of gasses through the structure before they reach the vent. PPV will not force the fire through the building, but a poor vent location may do so.

PPV pushes fire into voids

PPV will only push fire into voids when it is used incorrectly. For example when the PPV fan is used without a vent being created from the fire compartment. When no vent is made within the structure and PPV is used the pressure difference between the internal structure and any voids is greatly increased. Smoke will always move from areas of high pressure to areas of lower pressure. As the pressure within the voids is less than that in the remainder of the structure the smoke is forced into the void by the PPV fan.

This will be avoided if the PPV is deployed correctly and an outlet vent is made from the structure before the fan is directed into the inlet vent. Smoke will always take the path of least resistance and therefore if a vent is made before the PPV fan is used the smoke will be forced out of the vent and not into the voids within the structure.

PPV may induce a Flashover

A flashover occurs due to the massive increase in radiant heat flux at ceiling level caused by the smoke reaching its auto ignition temperature. This increase in radiant heat from the smoke layer to all of the surfaces within a compartment causes the surfaces to rapidly increase in temperature and auto-ignite. This point of total involvement of all surfaces within the compartment denotes a flashover.

A fire, which is accelerating towards flashover, will already have an excellent supply of air to fuel its growth. Adding more air via PPV will not cause this fire to reach flashover more quickly.

The use of PPV will actually reduce the chances of a flashover occurring for the following reasons:

1. The creation of a vent will increase the height of the smoke layer. This decreases the radiant heat flux to the surfaces within the compartment meaning they will not reach their ignition temperature as quickly, if at all
2. The induction of cool clean air into the fire compartment will reduce the temperature of the fire plume and hence reduce the temperature of the fire gasses at ceiling level to below their ignition temperature. Because of this the amount of radiation emitted from the smoke layer is massively reduced, and this reduces the radiant heat flux to the surfaces within the compartment and prevents them from reaching their ignition temperature, therefore the likelihood of a flashover occurring is reduced
3. The temperature of the compartment boundaries and surfaces of items within the compartment is reduced by the cool air, therefore this decreases the temperature within the compartment making flashover less likely.

Backdraught – implications for ventilation

Backdraught

Limited ventilation in a compartment can lead to a fire situation in the compartment that will eventually consume all the oxygen. This will produce fire gases with significant proportions of partial combustion products and unburnt pyrolysis products.

If these accumulate then the admission of air when the opening is made, a sudden deflagration may occur. This will move through the compartment and out of the opening. This phenomenon is referred to as a backdraught.

The intensity of the blast wave that a backdraught has within it can be extremely forceful, and potentially life threatening to both Firefighters and casualties.

PPV must not be used in situations where backdraught warning signs are present, or it is suspected that a backdraught may occur. The backdraught must be controlled using natural ventilation techniques before PPV use can be considered.

Warning signs of backdraught

If any of the following signs and indicators of a backdraught are present at an incident, **prior to ventilation being considered,** the backdraught must be dealt with first:

- Dense smoke with no obvious sign of flame
- Smoke blackened windows
- ‘Greasy’ windows (caused by the water vapour produced during the combustion process)
- Smoke pulsing from gaps in doors and windows (simply mini backdraughts)
- Whistling sounds coming from around doors and windows
- Signs of heat around and on the door when temperature checking with water spray
- Rapid inrush of air at the bottom of an opening when it is opened
- Fire is ventilation controlled.

Safety Note

PPV must not be used in situations where backdraught warning signs are present, or it is suspected that a backdraught may occur.

Ventilation operations

Vent size and location

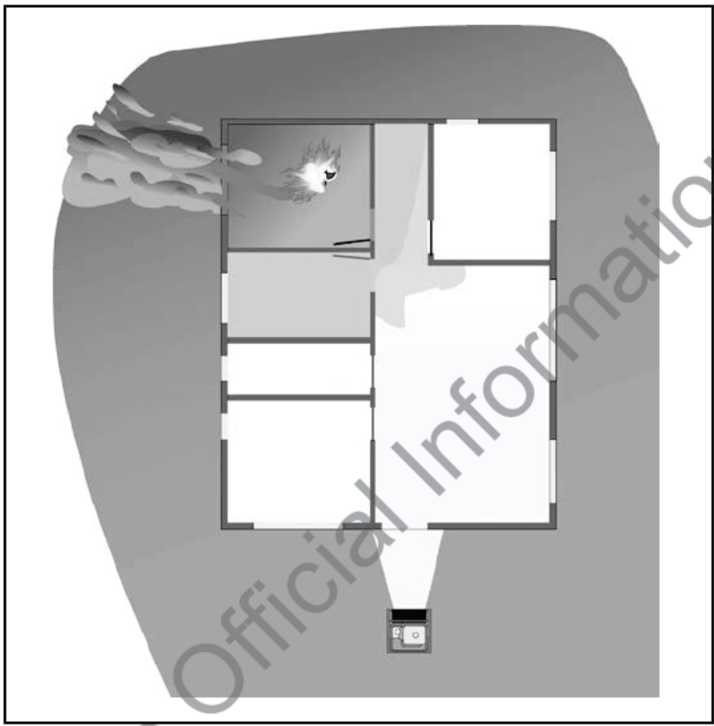


Figure 3.4: Correct Vent

Safety Note

A suitable outlet vent must always be created before PPV can be used.

Never use PPV before the outlet vent has been made, doing so can lead to a backdraught or rapid escalation of the fire, and will put Firefighters lives in danger.

Effective practical ratios

For practical purposes the outlet : inlet vent ratio should be a least 1 : 1 however this can be reduced to:

- 0.5 : 1 for higher wind conditions or increased to
- 1.5 : 1 where there is little or no wind.

Deciding upon the appropriate vent size is a skill that will only be perfected through practice and experience. The most important factor in the selection of an appropriate size is the wind condition.

Fires that have already vented

Often the vent will have already been made by the fire, in these cases the Incident Controller will have to assess the vent size made versus the wind conditions to determine if PPV can be effectively deployed.

Start small then increase

When making the outlet vent it is important not to make it too big too quickly. A vent should be selected so that it can be increased in stages. It is much easier to make a vent larger if required, than to reduce the size of it. Also, making the vent smaller than the maximum ratio builds in a level of safety. For example, if the fire unexpectedly breaks through a window increasing the total outlet vent ratio, the overall ratio should still be below the maximum and PPV will still be effective.

The maximum outlet : inlet ratio should not exceed 1.5 : 1.

Figure 3.5: Creating a small vent using a ceiling hook then enlarging it. The lower pane could also be broken to double the vent size if required.

Safety Note

The maximum outlet : inlet vent ratio must not exceed 1.5 : 1.

The outlet vent size must be determined by the wind conditions.

Higher wind = small outlet : vent ratio = outlet 0.5 : inlet 1

Lower wind = large outlet : vent ratio = outlet 1.5 : inlet 1

Fan operator safety

Operator safety

At all times when PPV tactics are in operation, the PPV fan operator must wear ear defenders and safety goggles and have their helmet visor down.

The fan should not be used in areas where ventilation is insufficient as the operator may be overcome by the exhaust fumes.

The fan must not be moved whilst the blades are rotating. The fan must be turned off, relocated, and then restarted.

Communications

Chain of command

PPV must only be used upon the order of the Incident Controller. However, when carrying out the PPV Fire Controlled tactic, the internal crews will inform the Incident Controller that the fire is controlled and that PPV is needed. PPV must not be used in this instance until the internal crew have informed the Incident Controller that the fire has been controlled.

PPV can only begin when the Incident Controller gives the PPV operator the command.

All personnel on the fireground must be informed that PPV is in use.

The Incident Controller must inform Communication Centre that PPV is in use when making Sitrep, which should be as soon as possible but is normally within 5 min, or on arrival of the second pump. This ensures that all further appliances en-route or mobilised to the incident will be aware that PPV is being used. Communication SOPs must be followed and arriving crews fully briefed.

This reduces the chances of subsequent crews freelancing on arrival, which could have drastic effects on the safety of the internal firefighting crews.

Dangerous situations

Any person on the fireground who notices a dangerous situation must inform the Incident Controller immediately and the Incident Controller will give the order to stop PPV.

Before PPV is stopped the internal fire crews must be informed so that they will have time to alter their fire attack strategy.

Safety Note

PPV is only commenced upon the order of the Incident Controller.
PPV is only stopped upon the order of the Incident Controller. However, if the internal fire crew requests that the fan be turned off the Incident Controller should do this.

Fan configurations

Single fan

Figure 3.6: Single Fan

Multiple fans in line

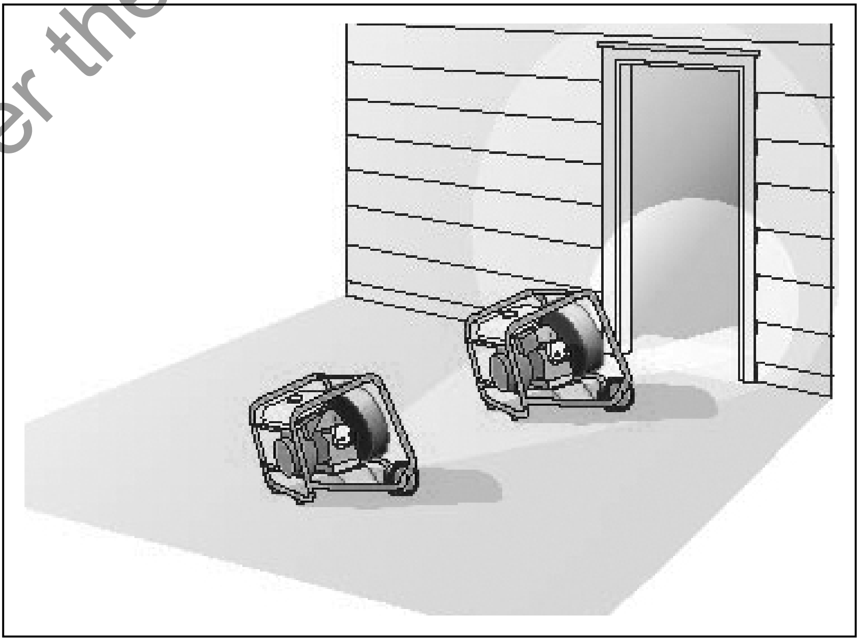


Figure 3.7: Fans in line

The 'V' attack

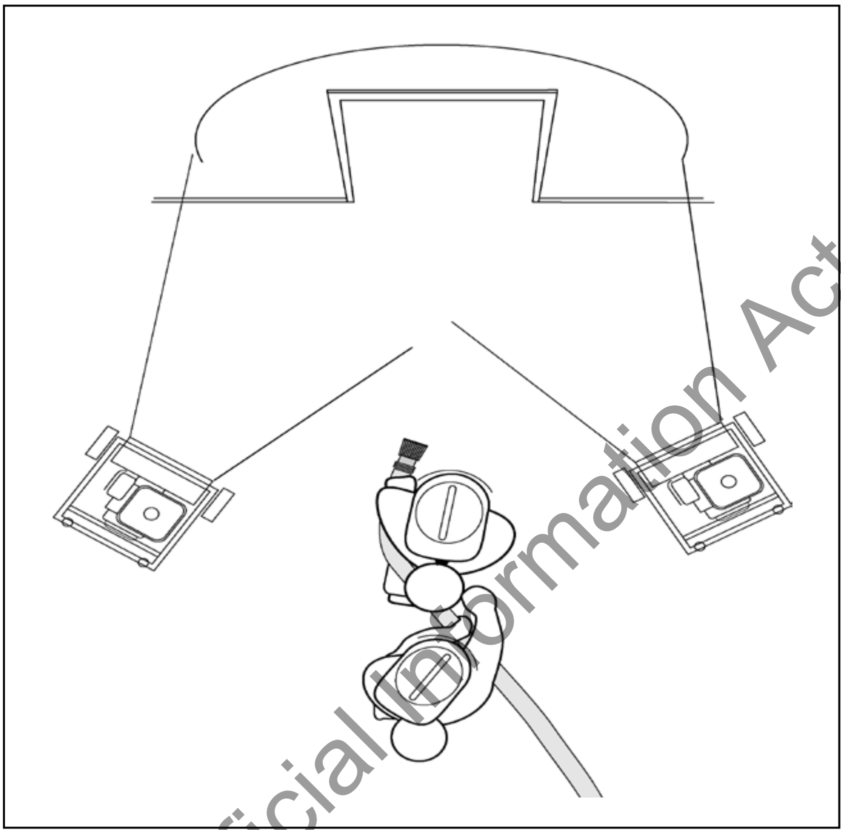


Figure 3.8: The V Attack

Fans side by side

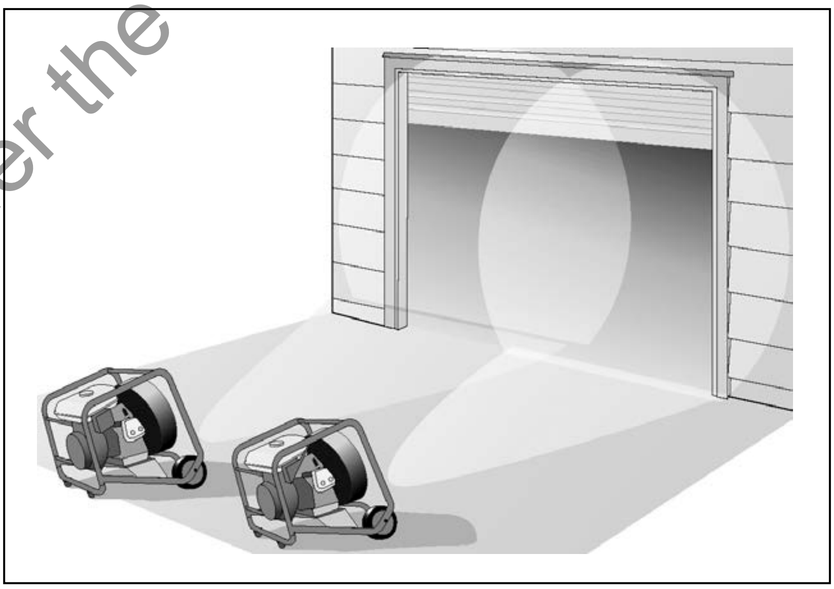


Figure 3.9: Side by side

Sequential ventilation

Where multiple rooms or floors require ventilation the process of sequential ventilation will achieve the best results. This entails providing the maximum volume of pressurised air to vent each area in turn.

The doors to all rooms should be closed initially, and then starting with the room nearest the ventilator, open the door and window to maximise the positive pressure available. Once cleared, this room can be isolated and others tackled sequentially in the same manner.

The same principle is used for multiple floors starting at the lowest affected area.

This tactic can be adopted in all ventilation phases. However, it is imperative that a vent is maintained from each room being ventilated.

Pressurising stairwells

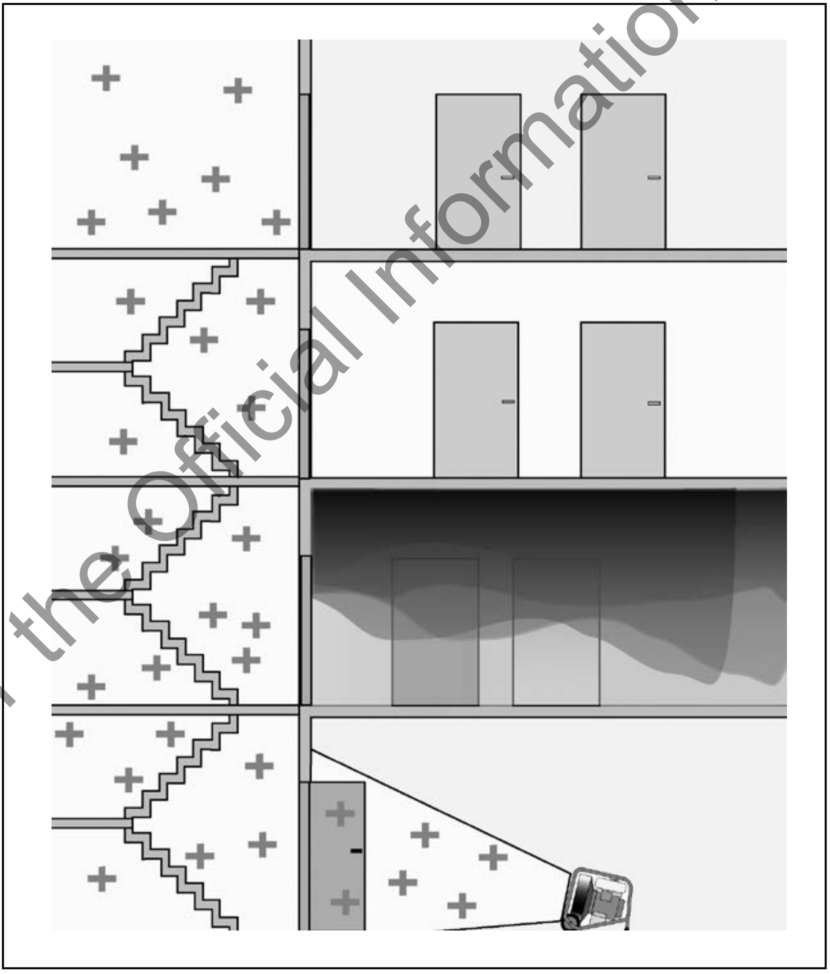


Figure 3.10: Pressurised stairwell

Firefighting considerations

Decide on a plan

The route the smoke / steam will take through the structure should be decided on before ventilation takes place. **Closing relevant doors should isolate any areas not affected.** The fan should be placed in position and started up only after other crewmembers have opened the exhaust vent.

Airflow management

It is important to control the flow of air between the inlet opening and the exhaust vent. This may require closing windows and doors that are already open, to isolate unaffected areas, all personnel should be kept aware of the position of the fan and the exhaust vent so as not to disrupt the flow of air. The potentially negative consequences of randomly opening doors and windows in a building should be stressed during operations.

Impact on fire dynamics

Changes to fire behaviour

Using PPV will have significant effects on the dynamics of the compartment fire. For example:

- The neutral plane within the room will be raised, improving visibility. This also reduces the radiation from the smoke layer to unignited items within the room meaning they are less likely to ignite, and therefore decreasing the chances of a flashover occurring
- The increased flow of cool air into the fire plume will reduce the temperature of the gas layer and is likely to cool fire gases below their auto-ignition temperature therefore reducing the likelihood of flashover occurring
- The fire will appear to flare up due to the increased airflow, but the speed at which the fire is located and extinguished is increased. The increased fire growth is seen as an acceptable trade off for better visibility and quicker extinguishment
- Any by-products of the extinguishment process such as steam are carried out of the outlet vent which helps maintain cooler temperatures and better visibility within the fire compartment.

Figure 3.11: Smoke filled room adjacent to the unvented fire compartment

Figure 3.12: Floor plan showing correct venting and use of PPV

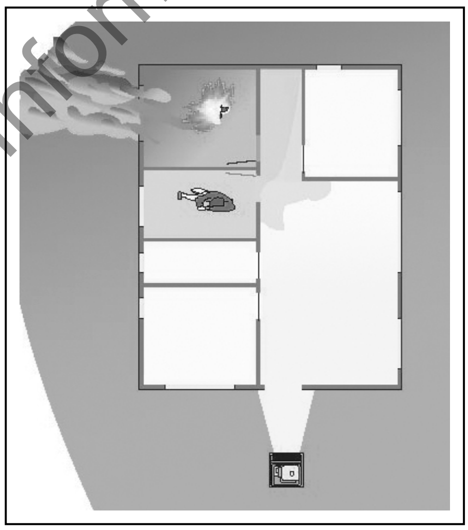


Figure 3.13: Improved conditions for the casualty resulting from PPV use.

Crew action on fan failure

Changes to fire dynamics

The fan is used to pressurise the structure, forcing the hot gasses out of the outlet vent and increasing the fire size in the process. A failure of the fan system will alter the dynamics of the fire significantly. The visibility is likely to decrease, the smoke layer will descend rapidly, heat levels will increase and the fire may accelerate rapidly towards flashover.

Risks to crew

The rapid change in conditions caused by a fan failure could seriously jeopardise the safety of the crews in the building therefore it is imperative that internal crews are informed immediately of a fan failure so that they can either modify their fire attack or withdraw from the building safely.

Crew action

The fan operator must inform the internal fire crews and the Incident Controller immediately upon failure of the fan. The crews should withdraw from the incident immediately, unless they are sure that they have the fire sufficiently controlled.

Firefighters withdrawing from the risk must be highly aware of any change in the development of the fire, and must protect their escape route by cooling the overhead gasses as it is likely that the compartment will accelerate rapidly towards flashover.

Where resources permit, use two fans if PPV is used for fire attack. In the event of a failure of one of the fans, the other will maintain a sufficient flow of air.

Safety Note

In the event of a fan failure the PPV Operator must inform the Incident Controller and the internal firefighting crews immediately, as the fire dynamics will change rapidly.

Tactical use of PPV

Definition of tactical options

Introduction

There are many definitions for PPV tactical options commonly in use throughout the world. These include the terms **Offensive**, **Defensive**, and **Post Fire**. The NZFS believes that many of these terms are easily confused with other major fireground tactical options such as Offensive and Defensive fire attack.

The potential for confusion of terms over radio transmissions could also be a problem. Therefore the following tactical options were adopted to describe the use of PPV in fireground operations as they provide a more clear and distinct picture of how the fan is being deployed tactically, and confusion of terms is minimised.

The tactical options are:

1. PPV salvage
2. PPV attack.

The three attack options are:

- PPV fire suppressed
- PPV fire attack
- PPV fire isolated.

No PPV use

This covers situations where PPV use is not appropriate based upon the Incident Controller's dynamic risk assessment.

PPV salvage

This option refers to the use of PPV for salvage operations. It covers use during overhaul where the fan is used to circulate fresh air through the building after the fire has been extinguished, or when pressurising adjacent structures / compartments to prevent the ingress of smoke. It covers any situation where the fan is deployed after a fire has been extinguished, or where the fan is supplying air to an adjoining building which is completely separated from the one in which the fire is located.

PPV fire suppresed

This tactical option refers to the use of PPV when crews have located the fire and suppression has begun, and a suitable ventilation opening has been made within the fire compartment. When the crew is satisfied that the situation is suitable for ventilation they inform the Incident Controller who gives the order to commence ventilation. The crew stay within the fire compartment throughout the process to ensure that the fire does not grow due to the increased ventilation.

This stage is also seen as an essential step in the training of crews in the use of PPV for attack or isolation. The tactical option allows the crews to build up confidence in the equipment and familiarity in its deployment, while reinforcing the need for excellent fireground communications. This tactical option allows the Firefighters to learn in a highly controlled environment as any increase in fire size, or worsening of the situation, can be dealt with immediately by the interior crews.

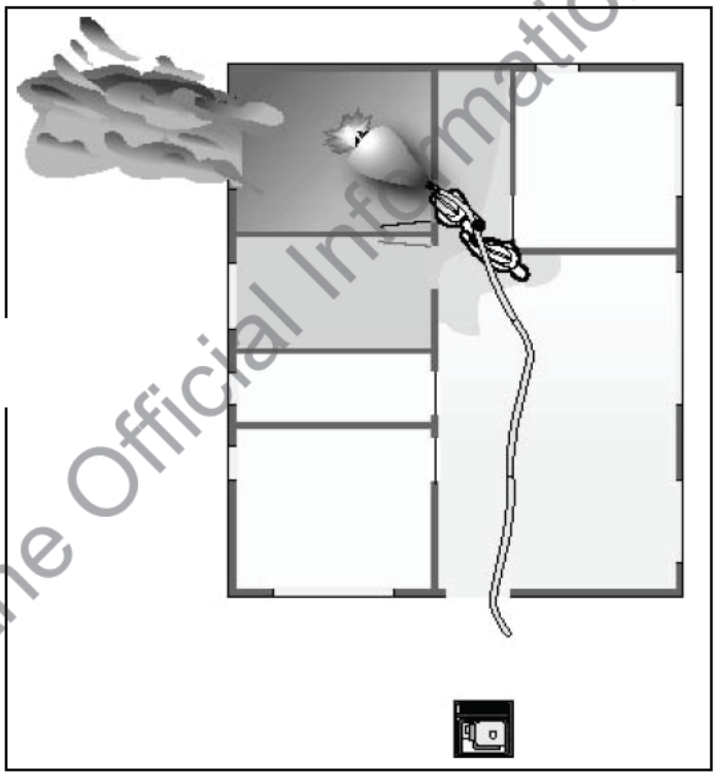


Figure 3.14: Fire suppressed option

Safety Note

Where PPV is deployed using four persons the crew members must be fully trained and experienced. The OIC must always be within close distance of the PPV fan, so that it can be turned off swiftly if required.

Due to the noise levels within the vicinity of the fan the Fan Operator must wear the dedicated headset. The headset will ensure that the Fan Operator will protect their hearing and also still be able to maintain communication with all parties on the fireground.

PPV fire attack

This option describes the use of PPV to attack the fire when it is uncontrolled. It offers the maximum benefit to the crews entering to fight the fire as the heat is reduced and visibility increased, and the fire can be quickly located and extinguished. However, this option is also the most hazardous as any negative effects of ventilation will also be accelerated.

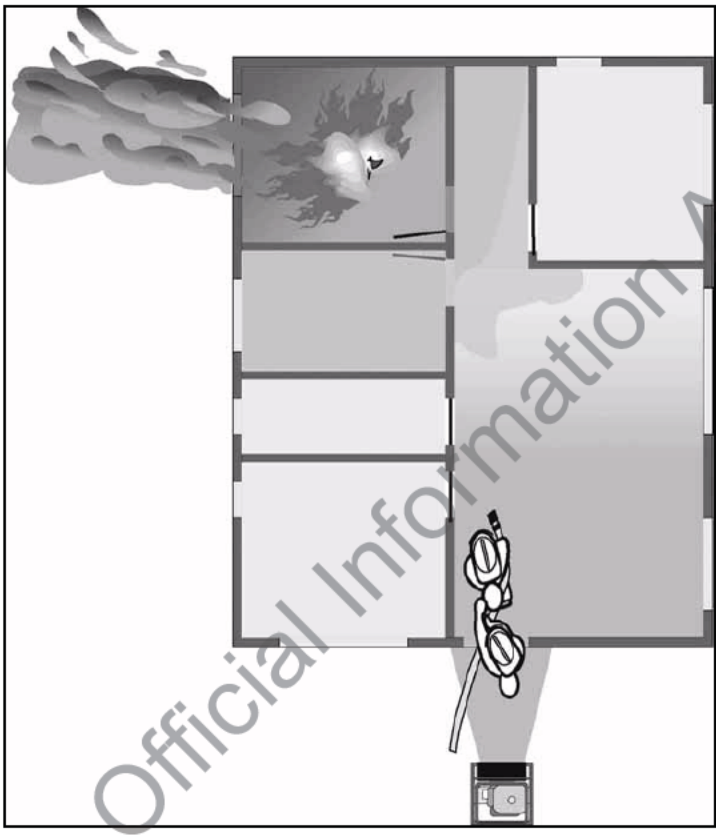


Figure 3.15: PPV Fire Attack

Safety Note

It s critical that the outlet vent is made prior to the fan being directed into the building. Failure to make the outlet vent before the fan is directed into the building will lead to conditions within the compartment worsening, and may lead to a backdraught.

Where PPV fire attack is deployed using four persons, the crew members must be fully trained and experienced. A crew member must always be within close distance of the PPV fan, so that it can be turned off swiftly if required.

Due to the noise levels within the vicinity of the fan, the operator must wear the dedicated headset. The headset will ensure that the operator will protect their hearing and still be able to maintain communication with all parties on the fireground.

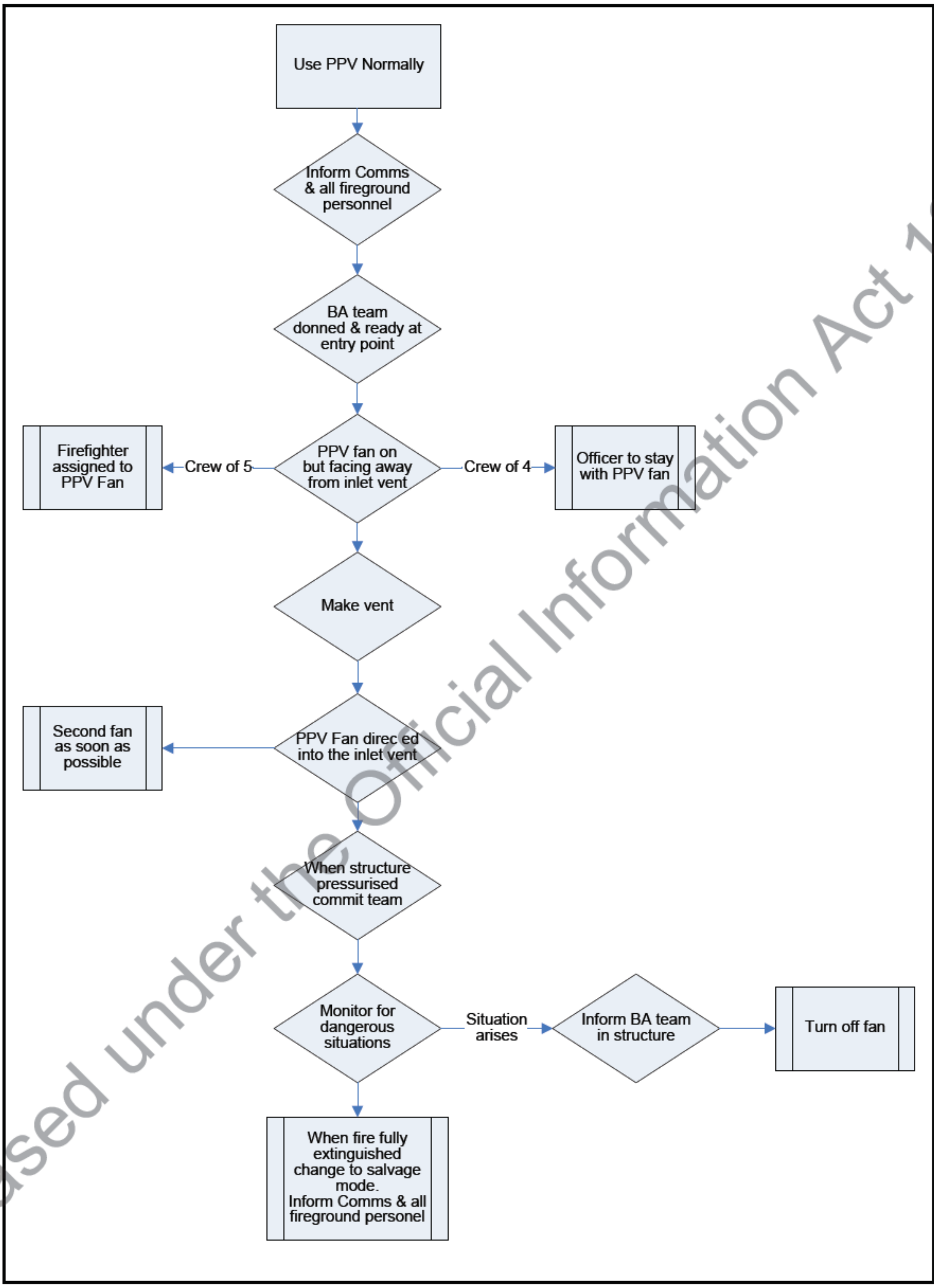


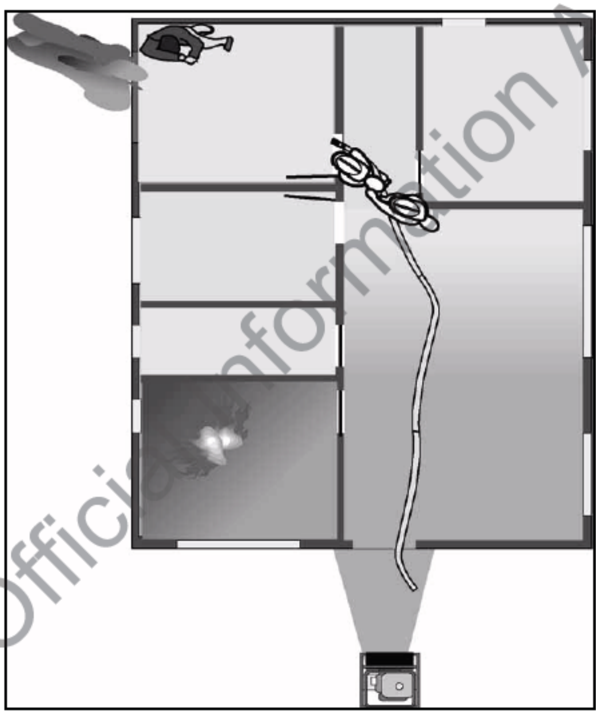
Figure 3.16: PPV fire attack procedure

PPV fire isolated

This option requires the internal fire crews to locate and isolate the fire before ventilation is commenced. No attempt is made to control or extinguish the fire at this stage. The remainder of the structure is then ventilated. This improves the conditions for casualties trapped within the structure by reducing the heat and raising the smoke layer, allowing Firefighters to rapidly search the structure to rescue them. Once the building has been searched, the fire crews can attack the fire in a suitable manner whether that is using conventional means or PPV.

Note: If PPV is also used to fight the fire, a vent must be created within the fire compartment before the door to the fire is opened.

Figure 3.17: PPV Fire isolated option



Safety Note

The PPV fan must not be deployed in the fire attack, fire controlled, or fire isolated cases until a suitable outlet vent has been made within the fire compartment and a BA team are in position with a charged hoseline ready to advance into the structure.

PPV fire isolated is an inherently more complicated procedure than the other tactical modes. The potential for things to go wrong is increased.
This mode must only be used with crews who are very experienced in the use of PPV fire attack.

Due to the increased complexity of the fire isolated PPV tactic, it is **not** suitable for use with a four person team.

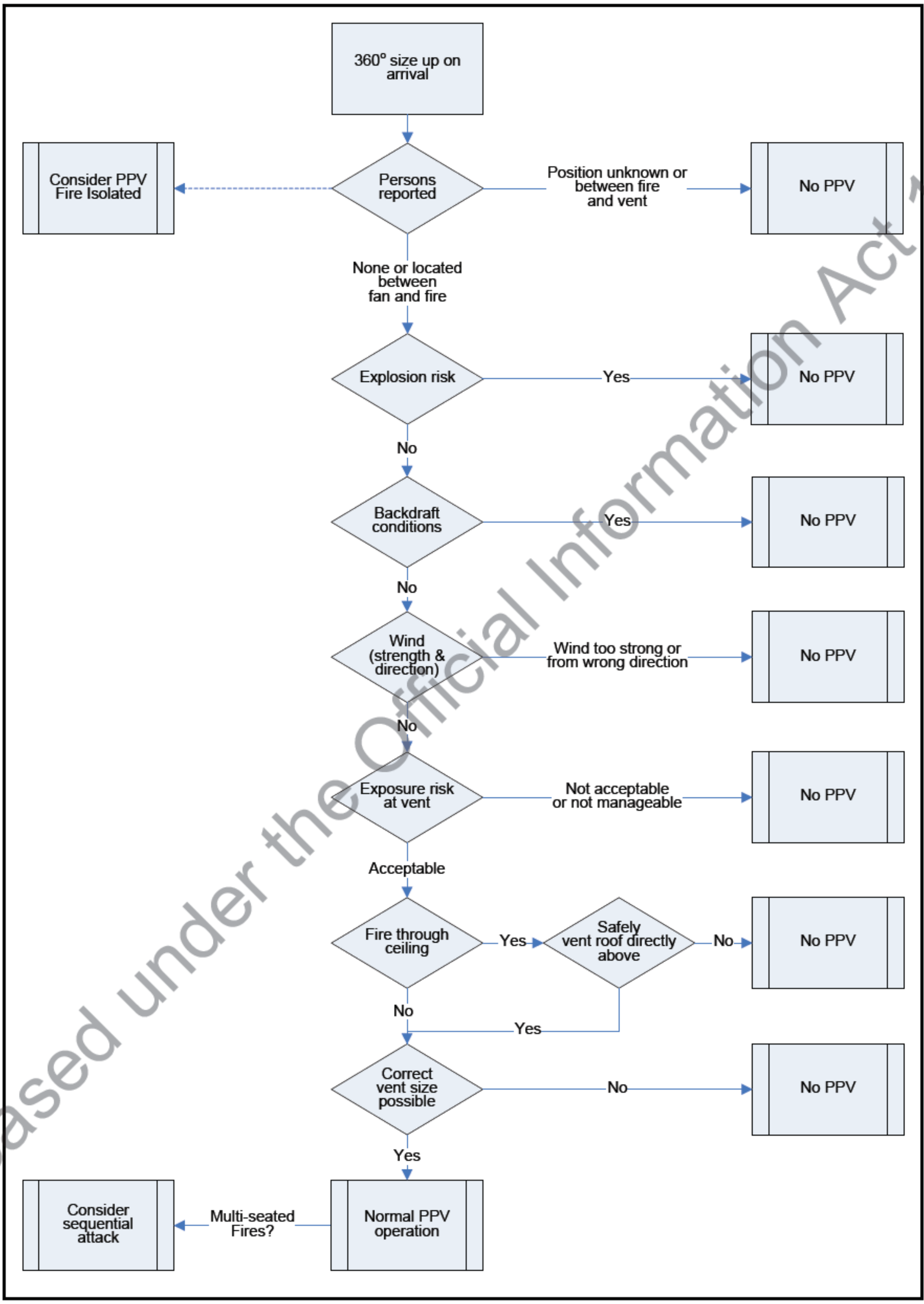


Figure 3.18: PPV decision making flowchart

Summary

The following summary checklist sums up the main points of the section.

Ventilation

Used to release smoke and heat from a compartment. Consider ventilation when:

- Heat, smoke, and gases rising from the fire create a life hazard
- You are unable to gain entry
- Smoke has damaged the contents and structure
- The seat of fire cannot be found.

Types of ventilation:

- Natural (using existing air currents)
- Horizontal ventilation (e.g. through windows, doors)
- Vertical ventilation (e.g. through roof)
- Forced
- Negative pressure ventilation (sucking smoke and fumes out)
- Positive pressure ventilation (blowing air in).

Horizontal ventilation:

- Involves creating openings in a wall (e.g. breaking a window as high up as possible)
- Can be easily accessible
- Doesn't risk Firefighters by venting above the fire
- Can cause a potential backdraught (ventilation allows more oxygen in, so the fire size may increase).

Vertical ventilation

Risks include:

- Working on a roof almost above the fire
- Cutting the roof requires close supervision, safety equipment, and height awareness training
- Co-ordination needed with hose crews waiting to directly attack the fire.

Outlet vent size

For practical purposes the outlet : inlet vent ratio should be a least 1 : 1 however this can be reduced to:

- 0.5 : 1 for higher wind conditions or increased to
- 1.5 : 1 where there is little or no wind. and gases rising from the fire create a life hazard

PPV operator safety

When PPV tactics are in operation the:

- PPV fan operator must wear ear defenders and safety goggles and have their helmet visor down
- The fan should not be used in areas where ventilation is insufficient as the operator may be overcome by the exhaust fumes
- The fan must not be moved whilst the blades are rotating. The fan must be turned off, relocated, and then restarted.

PPV communications:

- PPV must only be used upon the order of the Incident Controller.
- PPV can only begin when the Incident Controller gives the PPV operator the command.
- When carrying out the PPV fire controlled tactic, the internal crews will inform the Incident Controller that the fire is controlled and that PPV is needed. PPV must not be used until the internal crew have informed the Incident Controller that the fire has been controlled.
- All personnel on the fireground must be informed that PPV is in use.
- The Incident Controller must inform Communication Centre that PPV is in use when making Sitrep.
- In the event of a fan failure the PPV operator must inform the Incident Controller and internal firefighting crews immediately.

Fan configurations

- Single fan
- Multiple fans in line
- The ‘V’ attack
- Fans side by side
- Use sequential ventilation where multiple rooms, or floors, require ventilation.

Tactical options

The tactical options are:

1. PPV salvage
2. PPV attack.

The three attack options are:

- PPV fire suppressed
- PPV fire attack
- PPV fire isolated.

If you are unsure about part of this section, go back and review it. Then if you still want to know more or want to make your own notes, write them in the space marked **Notes and questions** below, and discuss with your officer.

Notes and questions

Appendix 1: Street Stories – Flashover and Backdraught

Hardware supermarket – North Stockholm, Sweden (1986)

In October 1986, the Taby Fire Brigade responded to a fire in a hardware supermarket measuring 90m × 90m. As Firefighters entered the structure, they noted the high ceiling, but were unable to locate the fire due to heavy smoke conditions.

Approximately 25 min after arrival, Firefighters inside noted a sudden increase in the temperature and tried to make their escape. However, fire gases had been accumulating above their heads and, as they ignited, the fire blew out into the street like a giant gas burner. Two Firefighters were killed.

Two-storey factory – London

The two-storey factory had a brick and timber joist construction with a shallow-pitched slate roof, measuring 20 m × 10 m. The fire had originated at one end of the building on the ground floor, and was spreading through the timber floor above, to the upper storey.

A BA crew took a hose line into the upper storey via the only stairway. This took them to the opposite end of the floor from the fire – an ideal vantage point. However, their attempts to move against the fire were severely hampered as heavy wired-glass windows were holding the heat in.

Roof and end window ventilation was called for, to assist the Firefighters' advance, but was not forthcoming. An eventual flashover knocked the Firefighters off their feet and prompted a hasty retreat back down the stairs. The roof eventually vented itself. This enabled crews to finally advance and complete extinguishment.

Mattress store – Kent, England (1975)

An incident that became known as the Chatham Dockyard Fire caused the deaths of two Kent Country Firefighters in 1975. A storeroom containing foam rubber latex mattresses was sited on the ground floor of a three- and four-storey building used for stores, office, and sleeping accommodation.

When the fire brigade arrived, the ground floor was found to be smoke-logged. Two Firefighters wearing BA entered the store, where no particular build-up of heat could be found. To assist locating the fire, they opened several windows, which caused a backdraught, and an intense fire followed.

Two-storey brick house – Baltimore, USA (1986)

A fire in a basement of a two-storey house caused problems when Firefighters responded. The design of the structure allowed the upper portion of the basement to rise above the ground level at the rear. As Firefighters made their approach to the fire from the ground floor stairs leading to the basement, a window failed at the rear, allowing a massive in-flow of air.

The effect was so pronounced that one of the Firefighters was actually sucked down the stairs and into the ensuing backdraught. He later died from the burns he received.

(Basement areas have always provided a huge risk for backdraught conditions. The absence of ventilation and the general use of storage create a slow smouldering fire with large amounts of carbon monoxide given off.)

Video shop – Glen Eden, Auckland (1992)

In November 1992, Glen Eden Station arrived at the Glen Eden Video Shop. As two Firefighters started to get out of the appliance, they noticed a small amount of fire coming from the top right corner of the window section. At a quick glance, it looked to be coming from a section of broken glass.

The two Firefighters made entry together through a created access, while cautiously dragging the high-pressure delivery. Thick black smoke rolled out of the shop and into the mall. On entering they gave a quick wash-down above and closed the high-pressure delivery while advancing further into the shop. Visibility was zero, the smoke was thick and black, and the only sign of a physical fire was possibly from a glow at the right rear of the shop.

After proceeding approximately three metres inside, the heat became extreme, and the Firefighters reported feeling their ears start to burn, but visibility was still zero. Both decided to retreat. At this point, it was about 60 seconds after they had entered.

Without warning, the entire area went from total blackness to a brilliant orange glow, lighting up the entire shop. There seemed to be fire everywhere. While trying to edge their way out, one of the Firefighters tried to use the high-pressure delivery to protect themselves, and at the same time hit the button on the distress signal unit.

Both men were rescued, but were seriously injured, receiving severe burns to a large part of their bodies.

A full investigation and inquiry was held, and found the actions of all crew members – and especially the injured Firefighters – was worthy of the highest praise, having done everything they could to protect each other.

However, as a result of the inquiry, significant recommendations were made to changes in protective clothing, gloves, and helmet (and to notification procedures to next of kin). *Union Inquiry into Fire Call No. 9324, Video Shop, Glen Eden. March 1994, Vol 26, No 3. The Professional Firefighter, pp. 9–35.*

Glossary

Auto-ignition temperature	Minimum temperature required to cause self-sustained combustion in any substance, in the absence of a spark or pilot flame. The source of heat is *external*. The substance does not create the heat itself.
Automatic ventilation	Occurs when pre-installed vents are activated automatically, usually in the early stages of fire, by the fire detection system or fusible link devices.
Backdraught	An explosion that can occur when additional air is suddenly let into an oxygen-starved (under-ventilated) fire compartment.
Branch	A device fitted to the end of a hose line to allow water or another extinguishing medium, travelling through a hose, to form an effective firefighting jet or spray.
BLEVE (boiling liquid expanding vapour explosion)	The rupture of a container, when a confined liquid boils and creates a vapour pressure that exceeds the container's ability to hold it.
Boiling point	The temperature at which a liquid boils and changes rapidly to a vapour (gas) state at a given pressure. (See also 'Evaporation'.)
Carbon dioxide (CO_2)	An inert, colourless and odourless gas that is stored under pressure as a liquid, and is capable of being self-expelled. CO_2 is effective in smothering class B and C fires.
Carbon monoxide (CO)	A colourless, odourless, poisonous gas that, when inhaled, combines with the red blood cells to exclude oxygen.
Charring	The production of a solid carbon residue on heating or burning a solid (e.g. wood).
Combustion	The chemical action between vapours of a combustible material and oxygen. It releases heat, light and / or flame. Heat maintains the chemical chain reaction to continue the combustion process.
Combustible liquid	A liquid that has a flash point above 60°C. (See also 'Flash point' and 'Flammable liquid').
Conduction	The point-to-point transmission of heat energy (i.e. when one object is heated as a result of direct contact with a heat source).
Controlled burst	Application of water in a spray pattern. Short controlled burst at a 45° angle towards the ceiling.
Convection	The transfer of heat energy by the movement of heated liquids or gases from one (warmer) area to another (cooler) one.

Defensive attack	A calculated fire attack on part of a problem or situation, in an effort to hold ground until sufficient resources are available to convert to an offensive form of attack.
Density	The mass per unit volume of a substance, under specified conditions of pressure and temperature.
Diffusion	The movement of molecules from an area of high concentration to an area of low concentration (e.g. gas in a compartment).
Direct burning	Any combustible item threatened by something burning nearby that has caught on fire.
Direct (aggressive) fire attack	An attack on a fire made by aiming the flow of water directly at the material on fire.
Dry powder	An extinguishing agent (Dry chemical powder is usually pressurised *sodium bicarbonate)*.
Endothermic reaction	A chemical reaction in which heat is absorbed, and the resulting mixture is cold. (See also 'Exothermic reaction').
Entrain, entrainment	The process of air or gases being drawn into a fire plume or jet.
Evaporation	A process in which the molecules of a liquid are released into the atmosphere at a rate greater than the rate at which the molecules return to the liquid. Ultimately, the liquid becomes fully airborne in a gaseous state.
Exothermic reaction	A chemical reaction in which heat is emitted, and the resulting mixture is hot. (See also 'Endothermic reaction' – the opposite.)
Fire	An uncontrolled chemical reaction producing light, heat and energy.
Fire hazard	A condition, situation or operation that could lead to the ignition of unwanted combustion, or result in controlled combustion becoming uncontrolled.
Fire point	The lowest temperature at which a substance gives off enough vapour to ignite when an ignition source is applied, and to continue to burn when the source is removed.
Fire plume	The flames and gases rising from a burning object.
Fire resistant	The property of a structure or a barrier to stay intact under prolonged fire conditions.
Fire retardant	The property of a chemical or material to resist ignition and to slow flame spread.
Fire tetrahedron	The four-sided pyramid diagram representing how heat, fuel, oxygen and chemical chain reaction are necessary for combustion.
Fire triangle	The triangle diagram representing how heat, fuel, and oxygen (or other supporter of combustion / oxidiser) are necessary for combustion.

Flammable limits (lower and upper)
The concentration level of a substance at which it will burn. The flammable range of a fuel is given using the % by volume of gas or vapour in air for the:

- *Lower Flammable Limit (LFL)*
  The minimum concentration of fuel vapour and air that supports combustion, i.e. if the concentration is below the LFL, there is too much air to burn (i.e. it is 'fuel-lean')
- *Upper Flammable Limit*
  The maximum concentration of fuel vapour, above which combustion cannot take place (i.e. if the concentration is above the UFL, there is too much fuel to burn – making it 'fuel-rich').

(See also 'Flammable range').

Flammable liquid
A liquid that has a flash point 60°C or below. (See also 'Flash point' and 'Combustible liquid').

Flammable range
The ratio of gas to air that will sustain fire if exposed to a flame or spark. (See also 'Flammable limits').

Flash point
The lowest temperature at which a substance produces enough vapour to ignite and momentarily flash when an ignition source is applied, but will stop when the source is removed.

Flashover
The situation where heat from a compartment fire raises the temperature of the compartment's contents to the ignition point simultaneously. The contents of the compartment then rapidly 'flashover' into fire. Flashover is dependent on fuel vapours and availability of oxygen. It can occur when the smoke temperature reaches 500–600°C.

Freezing point
The temperature at which a liquid substance changes state to become solid.

Friction
The loss of energy caused by two moving objects rubbing against each other. Energy is lost in the form of heat.

Fuel-lean
See 'Flammable limits' and 'Flammable range'.

Fuel-rich
See 'Flammable limits' and 'Flammable range'.

Fully-developed (burning or flaming) fire
The phase of a compartment fire during which the flames fill the entire compartment, involving all the combustibles.

Gas
The state of matter in which material is in a form that moves freely about and is difficult to control. Oxygen is an example. (See also 'solid'.)

Heat flux
Often it is not sufficient to know that a burning object releases a certain quantity of heat (see 'Heat Release Rate (HRR)'), but also the heat flux – how much heat is being received by an adjacent object (i.e. the concentration of heat flow).

Heat Release Rate (HRR), burning rate
The amount of heat energy released over time in a fire – how hot a fire gets. HRR is directly related to the amount of fuel being consumed over time, and the heat of combustion of the fuel being burned. Some materials burn much hotter than others do (i.e. the HRR varies for different fuels).

Heat transfer	The transmission of energy from a high-temperature object to a low temperature object.
Haemoglobin	The component of blood that transports oxygen (or carbon monoxide) around the body.
Horizontal ventilation	Horizontal ventilation (e.g. through a window or door) involves creating openings in a wall, such as breaking a window as high up as possible.
Hydrocarbon	An organic compound that contains only carbon and hydrogen (e.g. oil, methane, propane, and butane).
Ignition	The point in the phases of a fire at which the need for outside heat application stops, and combustion is sustained due to its own generation of heat.
Ignition point	The temperature at which a substance will continue to burn after an ignition source is removed.
Ignition temperature	The surface temperature that a solid substance needs to reach to cause ignition.
Indirect fire attack	An attack made on interior fires by applying a fog stream into a closed room or compartment, converting the water into steam to extinguish the fire.
Latent heat of fusion	The amount of heat energy absorbed or released when a substance changes state at a constant temperature. The same amount of energy is involved in the reverse change of state. **Example:** The same energy is released when ice melts, as is absorbed when it freezes (solidifies).
Latent heat of vaporisation	The amount of energy absorbed when one kilogram of liquid is converted into a gaseous state at its boiling point (temperature). **Example:** Water has a high latent heat of vaporisation, which contributes to its cooling effect, as it removes heat from the fire when it turns water into steam.
Lower flammable limit	See ‘Flammable limit’.
Matter	Physical substance that occupies space, has mass, and exists as a solid, liquid or gas.
Miscible (immiscible) liquids	Two or more liquids that can be mixed and will remain mixed under most conditions. **Example:** Water and alcohol are miscible. Liquids that do not mix, or will not remain mixed, are immiscible. **Example:** Water and oil are immiscible.
Natural ventilation	Opening doors to take advantage of normal air currents.

Negative-pressure ventilation	Reducing the air pressure within a burning structure by drawing out the smoke, e.g. with smoke extractor equipment or the building's air-conditioning system, or by using a hose stream.
Neutral (thermal) plane	The height within a compartment, above which smoke will or can flow out of a compartment: the level area where there is zero pressure difference between the over-pressure and under-pressure zones. This principle means a fully formed plume will resemble a mushroom as the upper level of the heat plume cools, stratifies and begins to drop outside the rising column.
Piloted ignition	Ignition of a flammable fuel-air mixture by a hotspot, spark, or small flame (a 'pilot').
Positive-pressure ventilation	Increasing the atmospheric pressure in the structure so that smoke is forced out.
Pyrolysis	The decomposition or transformation of a solid compound into another form, caused by heat.
Radiation	The transmission of energy as an electromagnetic wave (e.g. light waves) without an intervening medium. Radiation is the cause of many exposure fires (fires ignited in a fuel package, or in a building remote from the fuel package or the building of origin). Radiation is a major contributor to flashover. (See also 'Flashover'.)
Rollover ('tongues of fire', 'dancing angels')	A key warning sign of flashover, describing sporadic flashes of flame or rolling flames at ceiling level in a compartment fire. (See also 'Flashover'.)
Self ventilation	This happens when the structure is damaged by fire and increased ventilation occurs.
Sequential ventilation	Where multiple rooms or floors are ventilated through a process of sequential ventilation. This entails providing the maximum volume of pressurised air to vent each area in turn.
Smoke	Gases (which are no longer chemically reacting) plus carbon particles (soot), that come from a fire.
Smouldering	A slow combustion between oxygen and a solid fuel.
Solid	A state of matter in which a material may exist in chunks, blocks, chips, crystals, powders, and other types. Ice is an example. (See also 'Gas').
Specific density (specific gravity)	The weight of a liquid in comparison to water. (Water is rated as 1).

Specific heat (capacity)	The amount of heat required to raise the temperature of one kilogram of a substance by one degree, Celsius (°C) or Kelvin (°K). The higher the specific heat capacity of a substance, the more energy it takes to raise the temperature by a given amount. **Example:** Water has a high specific heat (i.e. it takes a lot of energy to heat water), therefore, it is an efficient cooling agent.
Spontaneous ignition	The lowest temperature at which a substance will ignite without the introduction of an ignition source; involves combustion between a fuel and an oxidiser. The source of heat is internal (i.e. it creates its own heat). **Example:** Ignition through heat created by a biological or chemical reaction.
Stratification	The layered configuration of heat, with higher temperatures at upper levels, and cooler temperatures at lower levels.
Sublimation	The change of a substance from a solid state directly into a gaseous state, without changing to a liquid first.
Surface- (area-) to-mass ratio	The amount of exposed exterior surface area of a material, divided by its weight.
Tactical ventilation	The intervention of the fire service to open up the building releasing the products of combustion.
Toxicity	The degree to which a substance or mixture of substances can harm humans or animals.
Upper flammable limit	See 'Flammable limit'.
Vapour	A substance in the state between liquid and fully gaseous, consisting of a mass of tiny droplets of liquid suspended in the air. It can look like a mist or fog. Vapour can be returned to a fully liquid state by the application of pressure; a gas cannot be. (See also 'Gas'.)
Vaporisation	The process by which a substance in a liquid state is converted to a gaseous or vaporous state.
Vapour density	The weight of a gas in comparison to air. (Air is rated as 1).
Vapour pressure	A measure of the amount of vapour above a liquid. All liquids will vaporise to some degree at any temperature; vapour pressure increases with temperature.
Ventilation-limited (ventilation-controlled)	The state of a compartment fire where the air supply is limited; smoke gases will have nearly zero oxygen left (i.e. the fire is under ventilated).
Vertical ventilation	Vertical ventilation (e.g. through the roof) usually involves creating openings in the roof.

Wet chemical

An extinguishing agent that is a water-based solution of:

- Potassium carbonate-based chemicals
- Potassium acetate-based chemicals
- Potassium citrate-based chemicals.

It is also any combination of these solutions.

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