Northern Ireland
Fire & Rescue Service

STANDARD OPERATING PROCEDURE (SOP) NO 28

Tactical Ventilation

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NORTHERN IRELAND FIRE & RESCUE SERVICE

STANDARD OPERATING PROCEDURE NO 28

TACTICAL VENTILATION

INTRODUCTION

The primary aim of this Standard Operating Procedure (SOP) is to put in place operational procedures with regards to the tactical ventilation of compartments that are involved in fire. The correct application of tactical ventilation will improve compartment firefighting techniques and as a result, enhance Firefighter safety.

Northern Ireland Fire & Rescue Service (NIFRS) has identified a need for an SOP with regards to tactical ventilation for compartments involved in fire. This need has transpired as part of a review on compartment firefighting and has been developed to increase awareness of ventilation; as a result, it is a tactical firefighting tool. NIFRS wish to consider the future use of mechanical fans as part of a forced ventilation strategy. This SOP is intended to provide the starting point for that strategy.

Ventilation is defined as "*The removal of heated air, smoke and other airborne contaminants from the structure and their replacement with a supply of fresher air*" - Fire Service Manual, Volume 2: Fire Service Operations: *Compartment Fires and Tactical Ventilation*.

Tactical ventilation can be best described as the planned, methodical and systematic removal of pressure, heat, fire gases and flame from a structure through pre-determined paths.

As soon as a Firefighter enters a building or a jet is directed through a window, then the ventilation within that compartment is being impacted upon. This SOP is designed to assist the Incident Commander (IC) in ensuring that these changes have a positive impact on his/her overall tactical plan. The key to a successful operational plan is that the ventilation should be intentional and controlled in order to reduce the risk of an escalation of the fire or avoidable damage.

1 – SECTION A

1.1 TACTICAL VENTILATION

1.1.1 The products of combustion are toxic, narcotic and often highly flammable.

1.1.2 The primary hazards are backdraught, flashover and death from toxic smoke inhalation or asphyxiation.

1.1.3 The addition of water to a fire will produce vast quantities of steam, reducing visibility.

1.1.4 Proper gas cooling techniques, coupled with proper entry procedure to a room, can greatly reduce the risk of a backdraught and increase survivability.

1.2 CONSIDERATIONS

Observe for signs and symptoms of both backdraught and flashover:

1.2.1 BACKDRAUGHT

1.2.1.1 **Indicators are:**

- dense smoke with no obvious sign of flame;
- smoke-blackened windows;
- smoke pulsing from doors and windows;
- signs of heat around the door.

1.2.1.2 **Safety:**

- ensure you are properly protected;
- keep the door closed and cover with a charged branch;
- if possible, keep out of the room and ventilate from outside;
- check escape routes are secure and if necessary, protected;
- cool and ventilate the outer compartment;
- plan an escape route for the gases before releasing them;
- stay low and to the side of the door;
- open the door slightly and spray through, directing the spray upwards;
- cool as much of the compartment as possible;
- keep out of the way of the steam and hot gases;
- only enter the room if you have to – there may still be flammable gases present;
- **oxygen (or the lack of it) is the key ingredient.**

1.2.2 FLASHOVER

1.2.2.1 **Indicators are:**

- a rapid increase in compartment temperature and in heat from hot gases at ceiling level;
- tongues of flame visible in the smoke layer;
- other surfaces giving off fumes.

1.2.2.2 **Safety:**

- make sure you are properly protected;
- ensure entrance is covered by a charged branch;
- check escape routes are protected;
- check the outside of the door for signs of heat;
- stay low;
- use spray pulses on hot gases at ceiling level;
- ventilate only when safe to do so;
- be aware of the potential for flashover and backdraught;
- **temperature is the key ingredient.**

1.2.3 Identify the structural features and wind directions suitable to assist in venting.

1.2.4 Treat smoke as an explosive atmosphere. Do not underestimate the heat within smoke and downward radiated heat will be a major issue for the safety of Firefighters entering a compartment.

1.2.5 Identify exit points for smoke prior to opening up the compartments.

1.2.6 It is best practice to deploy covering jets prior to venting (resources permitting).

1.2.7 **NEVER** commit Firefighters into smoke without firefighting media to defend themselves.

1.2.8 Have a systematic plan to direct the smoke where you want it to go.

1.2.9 Communicate your plan and supervise the crews to ensure co-ordination of approach.

1.2.10 Efficient venting will increase survivability and improve the opportunity for rapid extinguishment of the fire.

1.2.11 Uncontrolled venting will greatly increase the potential for a backdraught.

1.2.12 In basement fires, do not use pavement or other breakable lights at ground floor level to assist with ventilation if Firefighters are engaged in firefighting in the basement.

1.2.13 Venting of a basement compartment via a second compartment is not advisable.

2 – SECTION B

2.1 HAZARDS OF SMOKE

For the purposes of this document, the term "smoke" will include all the by-products of a fire and include pyrolosis products, gases and steam/water vapour.

2.1.1 The toxic products of fire consist of irritant and narcotic components, which can lead to disorientation, incapacitation or death. The exact effects of inhalation of smoke will have many variables but will depend upon the health/fitness of each individual exposed, along with the concentration of smoke and the duration of the exposure.

2.1.2 The irritant component of smoke will consist of various organic products and acidic gases such as Hydrogen Chloride (HCl). HCl, being water soluble, will readily dissolve into mucous areas of the body to produce a weak Hydrochloric Acid, which, in turn, will result in pain to the eyes, throat and lungs, accompanied with difficulties in breathing.

2.1.3 Given that the composition of and concentrations of gases present in smoke can vary greatly and cannot be accurately measured, Firefighters must assume and treat smoke as a flammable gas.

2.1.4 The predominant narcotic components of smoke are Carbon Monoxide (CO) and Hydrogen Cyanide. These are more common in pre-flashover fires where combustion is incomplete and the oxygen supply to the fire is restricted.

2.1.5 The effects of narcotic gases will include disorientation and collapse, depending upon exposure, etc.

2.1.6 One of the most significant issues relating to the smoke is the temperature as the downward radiated heat may prevent escape despite clear visibility below the smoke layer. For design purposes the smoke layer in the mall area of a shopping centre should never be less than 3 m and in all other circumstances it should not be less than 2 m. Where there are no sprinklers to cool the smoke, the smoke layer will usually need to be increased to 2.5 m or more, in order to reduce the downward radiated heat onto escaping persons.

2.1.7 It is generally accepted that visibility levels of 8 m is the minimum design requirement in order to permit safe escape. It is recognised that smoke at this density may cause some eye irritation but is highly unlikely to result in collapse or prevent escape.

One of the key issues with reduced visibility may be the delayed escape, allowing fire to overtake persons rather than the discomfort from smoke exposure.

2.1.8 A visibility distance of 2 m is considered the safe toxic limit to permit escape. A smouldering fire with partial combustion may have a greater concentration of irritant/toxic materials than a clean burning fire and visibility distances as a measure of escape guidance are not applicable to smouldering fires.

2.1.9 At a visibility distance of 2 m in smoke from a clean burning fire, eg, in large compartments/shops, etc, the critical danger is from the downward radiated heat as flashover becomes a distinct possibility.

2.2 PRODUCTION OF STEAM

2.2.1 It is vital for Firefighters to recognise that apart from the heat and smoke that is emitted from a fire, a large quantity of steam will be released on the application of water.

2.2.2 In order to provide an appreciation of the amount of steam vapour released, it is important to remember that water turning to steam expands at a ratio of approximately 1,700:1, that is one litre of water will produce 1,700 ltrs (1.7 m^3) of steam.

2.2.3 A 70 mm hose and Akron branch will supply approximately 500 ltrs of water per minute to a fire.

Assuming half of the water is vaporised:

250 ltrs x 1,700:1 water = 425,000 ltrs in one minute
= 42.5 m^3

An average living room could be assumed as:

3 m x 4.5 m x 2.5 m high = 34 m^3

Therefore, one minute with a 70 mm jet will produce sufficient steam to completely fill an average living room. This room will already be full of hot smoke and the extra steam and products of combustion will be forced out of the room due to the additional pressure created.

2.2.4 It is important that prior to water being applied onto a fire, Firefighters have identified a safe exit vent for this additional steam and smoke.

2.3 THE NEUTRAL PLANE

2.3.1 The hot gases will expand and create a positive pressure at the ceiling whilst the cold air coming into the room will be drawn into an area of low pressure at the floor. The meeting point of the high pressure zone and the low pressure zone is known as the *"neutral plane"* (see Diagram 1).

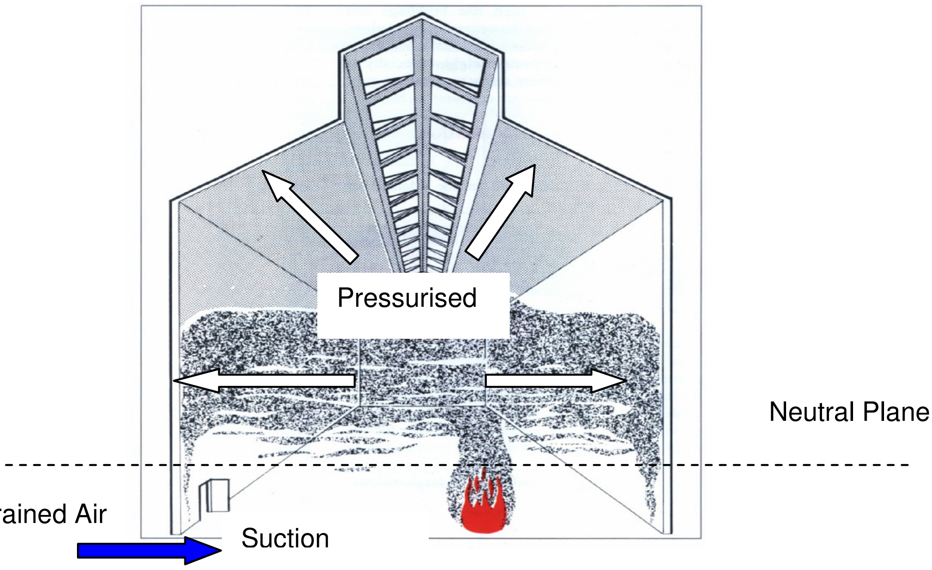


Diagram 1

The result is that all gases above the neutral plane are pressurised and pushing out of the room whilst there is a suction into the room below the neutral plane. As a rule of thumb, the neutral plane can be assumed to be approximately one third of the ceiling height up from the floor and this will roughly coincide with the door handle into the room. Therefore, if Firefighters preparing to enter the room inside which backdraught conditions are present, crouch below the door handle level, then hot or ignited gases should be expelled above their heads.

2.4 FLASHOVER

2.4.1 The definition of a flashover[(1)] is:

"In a compartment fire there can come a stage where the total thermal radiation from the fire plume, hot gases and hot compartment boundaries causes the generation of flammable products of pyrolosis from all exposed combustible surfaces within the compartment. Given a source of ignition, this will result in the sudden and sustained transition of a growing fire to a fully developed fire. This is called flashover."

[(1)] Fire Service Manual, Volume 2: *"Compartment Fires and Tactical Ventilation"* – ISBN 0 11 341175 8

2.4.2 In order to explain this, the process of pyrolosis is where flammable materials are heated, they begin to decompose and give off flammable vapours. The heat at the ceiling from the smoke layer becomes so great that it is radiated down across the whole room, heating all the contents of the room, causing pyrolosis vapours to be given off. Either a flame will ignite these vapours or they will rise above their auto-ignition temperature. The result will be that all the contents of the room become engulfed in flames at the same time and the fire continues to burn; it is not a momentary flash.

2.4.3 A backdraught can initiate a flashover but there is a clear distinction – the key difference between a flashover and a backdraught is **a flashover is temperature orientated**, whereas **a backdraught is oxygen orientated**.

2.5 BACKDRAUGHT

2.5.1 The definition of a backdraught[(2)] is:

"Limited ventilation can lead to a fire in a compartment, producing fire gases containing significant proportions of partial combustion products and unburst pyrolysis products. If these accumulate then the admission of air when an opening is made to the compartment can lead to a sudden deflagration. This deflagration moving through the compartment and out of the opening is a backdraught."

2.5.2 In order to explain this, when a fire starts in an enclosed room, it will burn the contents and use up all the available oxygen in the room. The fire will seek more oxygen and if the fire can only draw in around the doors and windows, it will die down due to suffocation. The heat from the fire will cause flammable vapours and gases to be released from wood, plastics, etc. When a Firefighter opens the room door or a window breaks, this will provide plenty of oxygen to the room; the oxygen will mix with the CO and bring it into its flammable range.

Once a gas ignites, the heat causes a rapid expansion and increase in pressure in the room. If there is a door or window open, then the hot, burning gases will be forced out through that opening, resulting in an effect similar to a fireball or blowtorch.

2.5.3 Another and potentially more hazardous possibility is that the closed up room will produce a flammable atmosphere but the gases will be below their auto-ignition temperature when Firefighters enter the room; they only have to disturb burning debris which will provide the ignition source for a backdraught.

[(2)] Fire Service Manual, Volume 2: *"Compartment Fires and Tactical Ventilation"* – ISBN 0 11 341175 8

This second scenario exposes Firefighters to greater danger as the fireball occurs whilst they are inside the room. This is often referred to as a delayed backdraught.

2.6 THE STACK EFFECT

2.6.1 In conditions where the outside temperature is colder (as normally found in Northern Ireland) the air inside a building will be forced upwards by a buoyancy force (convection), causing it to rise within vertical shafts (including staircases) in the building. The upwards force on the warmer air will create an area of low pressure at the bottom of the building which, in turn, will draw cold air in at the base. This action will continue so long as the air inside the building is subjected to heat from either a fire or the central heating (see Diagram 2).

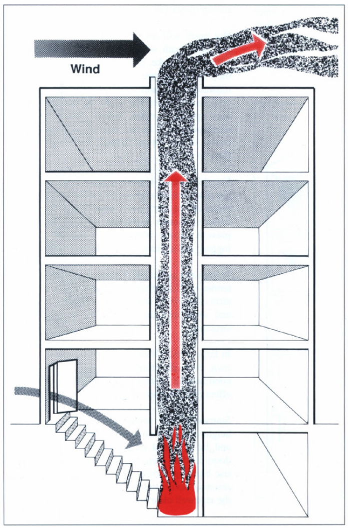


Diagram 2

2.7 WIND PRESSURE FORCES

2.7.1 When wind blows towards the side of a building, it is slowed down, resulting in a building of pressure on the windward (upwind) face of the building. At the same time the wind is deflected and accelerated around the sides, walls and over the roof, creating a reduced pressure on the leeward (downwind) side of the building.

2.7.2 The greater the wind speed, the greater will be the suction. The main effect of these pressures is to produce a horizontal movement of air through the building from the windward to the leeward sides.

2.7.3 In a fire, where a broken window exists on the windward side of the building, the wind will raise the air pressure inside the building in the vicinity of the open/broken window. This increased pressure can force smoke, both horizontally and vertically, through the building in search of an exit point (see Diagram 3).

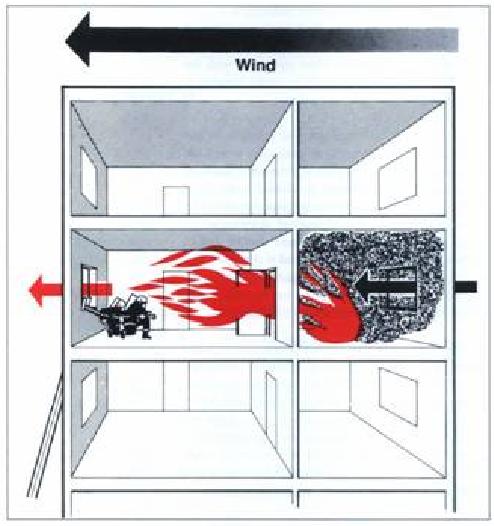


Diagram 3

2.8 INITIAL CONSIDERATIONS

2.8.1 Tactical ventilation **MUST be planned, resourced and communicated** and form part of the overall tactical plan. *This plan must be continually reviewed as part of the IC's ongoing Dynamic Risk Assessment (DRA).*

2.8.2 To effectively plan ventilation, personnel must have an understanding of:

- the behaviour of fire within a compartment;
- how the design of buildings impacts on firefighting tactics;
- how to effectively ventilate.

2.8.3 The use of tactical ventilation as a firefighting tool should be considered at an early stage, however, ICs can instigate ventilation:

- after arrival of NIFRS but before control is achieved;
- after control but before fire extinction;
- after fire extinction.

2.8.4 As with all firefighting operations, the IC must gather information before implementing a tactical plan. This information falls into 3 headings:

- information on the incident;
- information on the hazards and the risk from each hazard;
- information on the resources required.

2.8.5 Specifically, before the IC starts to ventilate, he/she should ascertain the:

- location of fire;
- location of any occupants;
- location of any Firefighters committed (snatch rescues);
- fire loading within building;
- use of the building;
- structure of the building;
- extent of fire;
- wind direction/strength;
- indications of backdraught/flashover;
- potential for fire spread.

2.8.6 Consideration must be given as to whether the resources available are sufficient to safely ventilate. This includes suitable supervision and covering jets where the exhaust vent is created.

2.8.6.1 Once windows are broken there is no going back, therefore, sufficient resources should be available to deal with a fully developed fire.

2.8.6.2 Resources should also be in place to prevent any fire spread to adjoining properties when ventilation is applied.

2.8.7 The IC must ensure effective communication takes place between him/her, remaining crews and those involved in the ventilation strategy. **It is imperative that there is close co-ordination of actions to prevent uncontrolled and unplanned ventilation.**

2.8.8 Can ventilation be carried out safely?

2.8.8.1 Consideration must be given to the removal of Firefighting Teams internally.

2.8.8.2 Can exhaust vents be made from a safe working platform?

2.8.9 Consider the withdrawal of Firefighters before ventilating.

2.8.10 Wind strength and direction are usually the dominant factors in tactical ventilation and it is important to use prevailing wind; do not try to fight against wind conditions. In most cases the wind will determine the direction in which the smoke and hot gases will move within the building.

2.8.11 The outlet vent should be created first and then start the inlet on the upwind side of property soon after. If the inlet is opened first, the wind will help oxygenate the fire and pressurise the compartment; once an outlet is created, the fire will exit under pressure and may well injure or kill those persons at the exit point.

2.8.12 Damage caused to property by ventilation activities must be in proportion to the size of fire and risk to crews, ie, does the benefit outweigh the risk, or does the risk outweigh the benefit?

2.8.13 Ensure the outlet is covered by a charged hose line before the exhaust vent is made and never allow a jet to be directed into a ventilation opening; resources to ensure this is carried out should be in place before ventilation commences.

2.8.14 Constantly monitor the effects of ventilation and change the plan if required.

2.9 TACTICAL OBJECTIVES

2.9.1 As part of this tactical plan the IC must evaluate the impact ventilation will have on his/her firefighting tactics and ask what ventilation will achieve.

2.9.2 The 3 broad ventilation strategies are:

- vent for life;
- vent for the fire;
- vent for safety.

2.9.2.1 Venting for ***life*** situations means that Firefighters may create openings or break windows to gain access from an exterior position to carry out a primary search in a high risk area of the structure **(vent, enter and search)**.

The venting and entry action, as with any tactical venting process, demands great *precision* (venting the correct windows) and *anticipation* of potential fire spread. Such an approach should also be **communicated** to the IC and also crews working on the interior, where possible. The overall approach to venting should be carefully **co-ordinated** in order that all affected parties are aware of what is taking place.

2.9.2.2 Venting for ***fire*** will improve interior conditions for Firefighters by reducing heat levels and improving visibility.

The rule here is to vent windows ahead of the branch and near to the fire to enable combustion products to be forced safely out of the structure.

The addition of air may cause the fire to achieve a greater rate of burn, increasing its *heat release rate*; it may actually become hotter. Therefore, it is essential that Firefighters crewing the hose line have adequate flow at the branch to deal with any escalation of the fire; consider the use of a hose line rather than a hose reel. **BIG FIRE – BIG WATER!**

Pay close attention to wind force and direction prior to creating an opening, eg, an opening, especially on the windward side of the structure, may cause the fire to rapidly spread towards advancing Firefighters.

2.9.2.3 Venting for ***safety*** is reserved for situations where fires are burning in an **under-ventilated** state. The fire may be developing slowly, due to a "sealed" structure or compartment, presenting a heavy (probably hot) smoke build-up within a confined space.

In this situation careful attention must be paid to door entry procedures and it may well be a viable action to vent a compartment from the exterior prior to gaining entry.

The decision to create openings within a fire-involved structure to gain tactical advantage should be carefully considered because the outcome may be irreversible.

2.9.3 Tactical openings made to release combustion products may serve to reduce smoke logging, lower compartmental temperatures, prevent flashovers and backdraughts and generally ease the firefighting operation. However, it is also possible that such openings may achieve undesirable and opposing effects, causing temperatures to rise with resulting escalations in fire spread, leading to flashovers, backdraughts and smoke explosions.

2.9.4 In most cases where ventilation is considered a suitable tactic, it is most effective if used in the early stages of firefighting.

However, the uncontrolled movement of hot gases inside the building is the main cause of fire spread, therefore, the decision to commence tactical ventilation must be as part of an overall strategy of controlling air and smoke movement within the building.

2.10 POSITIVE EFFECTS OF VENTILATION

2.10.1 Assist occupants to escape by restricting smoke spread, improve visibility and increase available safe escape times.

2.10.2 Aid rescue by reducing toxic smoke and gases, improving visibility, thus increasing survival times and making search procedures less complicated.

2.10.3 Improve Firefighter safety by reducing the risk of backdraught by clearing flammable gases in a controlled manner.

Note: **If the compartment door is opened, that is the most likely exit route for the backdraught, endangering the Firefighters in the vicinity of the open door. Ventilation, properly used, can release the gases externally, directing any flame or explosion away from Firefighters.**

2.10.4 Improve Firefighter safety by reducing the risk of flashover through the controlled removal of hot fire gases, which will raise the neutral plane and reduce thermal feedback within the compartment.

2.10.5 The removal of hot gases and smoke will make firefighting operations easier and safer. If there has been a build-up of hot gases within the building, making conditions for the Firefighters very arduous, ventilation can produce a much more tolerable environment, increasing a Firefighter's working duration.

2.10.6 There will be an increased speed of attack on the fire because it can be reached and tackled due to the improved visibility from the ventilation.

2.10.7 Ventilation can reduce fire spread by controlled removal of fire gases and reducing smoke damage.

2.10.8 A decision not to ventilate a compartment should also be considered as a possible tactical option. However, ICs must be aware that this can create an over-rich atmosphere within a compartment, with the possibility of this leading to conditions favourable for backdraught.

2.11 VENTILATION TACTICS

2.11.1 Smoke movement occurs due to 2 principal factors – the wind and the inherent buoyancy of hot gases produced by the fire. The fire compartment will either be directly or indirectly ventilated by means of horizontal or vertical ventilation.

2.11.2 Wind strength and direction are usually the dominant factors in tactical ventilation. In most cases it will determine the direction in which the smoke and hot gases will move within the building.

2.11.3 At its most, basic tactical ventilation is achieved by opening a planned exhaust or exit route on the downwind side (side away from the wind) and then opening an inlet on the upwind side (side facing the wind).

2.11.4 There are a number of tactical options when considering ventilation.

2.12 DIRECT VENTILATION

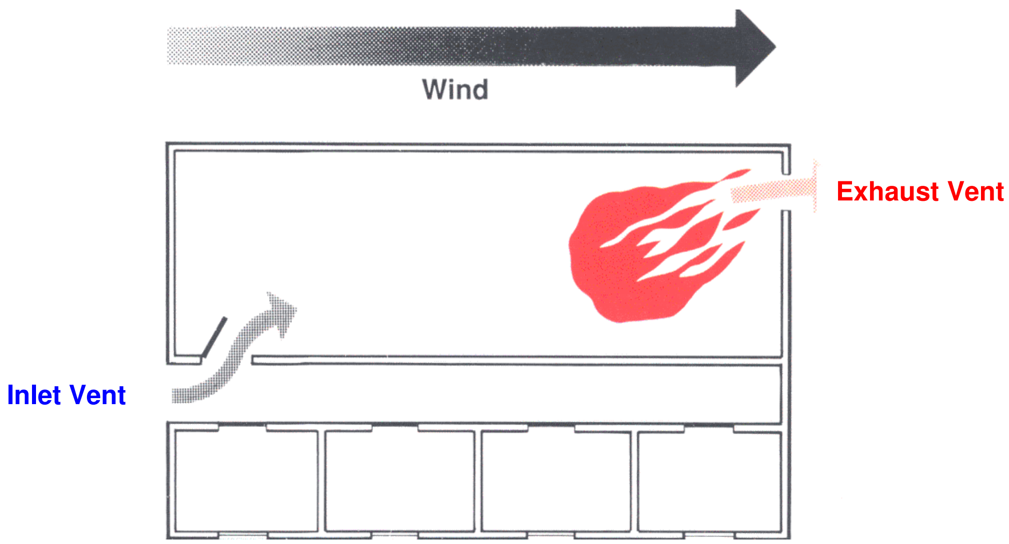


Diagram 4

2.12.1 This is ventilating close to the fire, to have a direct effect on the fire itself, to limit fire spread and to make conditions safer for Firefighters (see Diagram 4).

2.13 INDIRECT VENTILATION

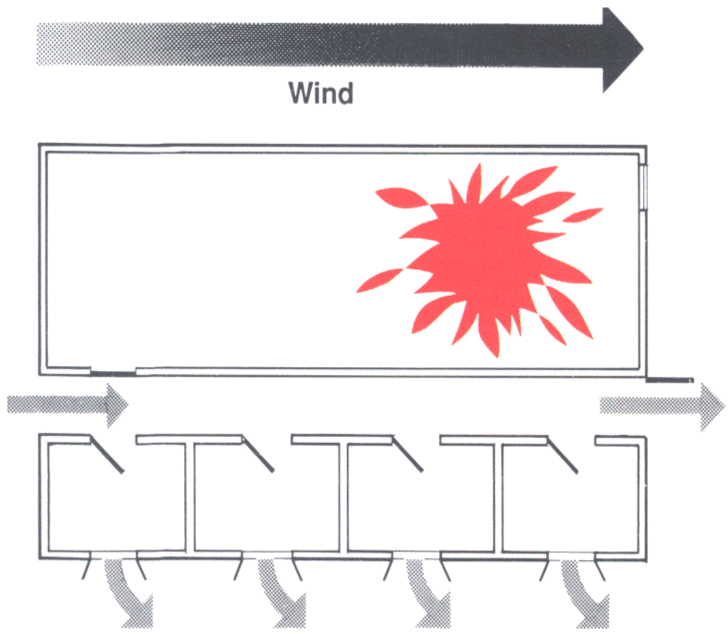


Diagram 5

2.13.1 This is ventilating away from the fire or after the fire is out, to have an effect on the hot gases and smoke, particularly to improve access and escape routes and to control smoke movement to areas of the building involved in the fire (see Diagram 5).

2.13.2 Consideration must be given to the effect of closing down of a compartment that contains a fire. This will produce an over-rich mixture of gases (outside flammable range). This tactic should only be applied after a full assessment of the increased risk of a *"ventilation induced backdraught"* is considered and the appropriate control measures are applied.

2.13.3 As stated earlier, ventilation is achieved through 2 principal factors - wind direction and the inherent buoyancy of hot gases produced by the fire. These factors, together with the design of the building, the location, size and severity of the fire, the wind speed and direction, will shape the techniques and tactics used to achieve ventilation.

2.14 VERTICAL VENTILATION

2.14.1 Vertical ventilation is when the exhaust vent is created high up or near the roof of a compartment and close to the fire to maximise buoyancy.

2.14.2 Vertical ventilation maximises the use of the hot fire gases' buoyancy. Using this buoyancy, the planned path of the gases is out of an exhaust to atmosphere, by the most direct route possible.

2.14.3 This means vertical ventilation is most applicable in buildings where the fire is directly below the roof or ceiling. Where the ceiling or roof space is not involved in the fire, vertical ventilation will result in fire spread to that area.

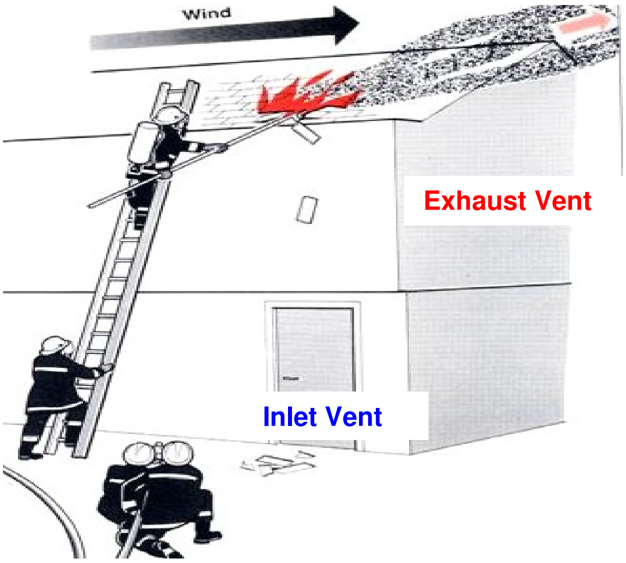


Diagram 6

2.14.4 When making a vent for vertical ventilation:

- use the easiest point of entry, eg, roof or dormer lights;
- always communicate the ventilation plan to all those involved;
- it may be appropriate to remove crews before ventilation takes place. **Note:** the incident may still be in offensive (Oscar) mode due to crews being in position of danger;
- crews must work from a safe working platform, such as a ladder or an Ariel appliance. Crews **should not** attempt to ventilate from the roof itself;
- crews should not be downwind or above the vent;
- always create the outlet vent before the inlet vent to prevent pressurisation of the building, which can endanger the personnel close to the exit point;
- a covering jet must be in place and work within a safe area, considering the probability of falling debris and again not downwind or above the vent (see Diagram 6).

2.14.5 ADVANTAGES OF VERTICAL VENTILATION

2.14.5.1 Vertical ventilation can minimise the risk of a backdraught. Initially, the pressure in the compartment will drive the hot gases out. An inlet vent (preferably at low level) is then necessary or fresh air will start coming in through the outlet vent, mixing with the smoke to increase the likelihood of smoke logging the compartment.

2.14.5.2 Vertical ventilation can minimise fire spread because the smoke and hot gases travel the shortest possible distance before leaving the building.

2.14.5.3 Vertical ventilation can provide rapid smoke clearance because of the high velocity of the smoke and hot gases leaving through the roof vent. Large amounts of fresh air are drawn in to replace these.

2.15 HORIZONTAL VENTILATION

2.15.1 Horizontal ventilation is the most common and usually the most convenient method with which to ventilate a building. Firefighters entering a building for search and rescue or fire attack start a form of horizontal ventilation by opening doors or windows to make entry, therefore, it is important to ensure this initial ventilation is planned and controlled.

2.15.2 Horizontal ventilation is when the exhaust vent is placed (preferably high) in the compartment wall, either by forcing an opening in the wall or the use of windows to create vents.

2.15.3 Horizontal ventilation requires the **CONTROLLED** release of smoke and hot, possibly flammable, gases from a building and their replacement by fresher air. The operative word in this description is "controlled". Opening doors and windows at random will make matters worse, causing fire spread, increased smoke damage and increasing the possibility of a backdraught. All ventilation operations should form part of the overall tactical plan by releasing the gases in a planned and co-ordinated manner. The optimum approach is to create an exhaust vent as high as possible on the downwind side of fire, then create an inlet vent on the upwind side as low as possible.

2.15.4 Horizontal ventilation may be appropriate when:

- vertical ventilation is not possible due to the character of the building;
- it is not safe to commit Firefighters to open a vent in the roof;
- the fire is not large enough to necessitate opening of the roof;
- there are windows and doors close to the seat of the fire;

- the fire and products of combustion are not being carried into other floors;
- the fire has not entered structural voids or concealed spaces.

2.15.5 For indirect horizontal ventilation, the location of the vents is determined by the route between them. The overall objective is to let as much fresh air into the building as possible. The building layout will determine the route the air takes once the vents are opened. Their locations need to be chosen to avoid directing fresh air towards the site of the fire.

2.15.6 For direct horizontal ventilation the outlet vent should be as close to the fire as practicable. It is desirable to use the Firefighter's route to the fire as the inlet vent, as this reduces smoke and heat along their route, making their job safer and tolerable.

In this case the gases coming out of the vent are likely to be very hot and possibly flammable. Flames are likely to appear outside the vent if the smoke and gases are above their auto-ignition temperature and there is a risk of fire spread. Therefore, before the outlet vent is opened, its position must be covered by an appropriately protected Firefighter with a charged branch – a covering jet. This branch can be used to cool the smoke and gases as they come out; under no circumstances should the water be directed in through the vent as long as ventilation is in progress. This will interfere with the ventilation process and could place Firefighters inside the building at risk (see Diagram 7).

Inlet Vent

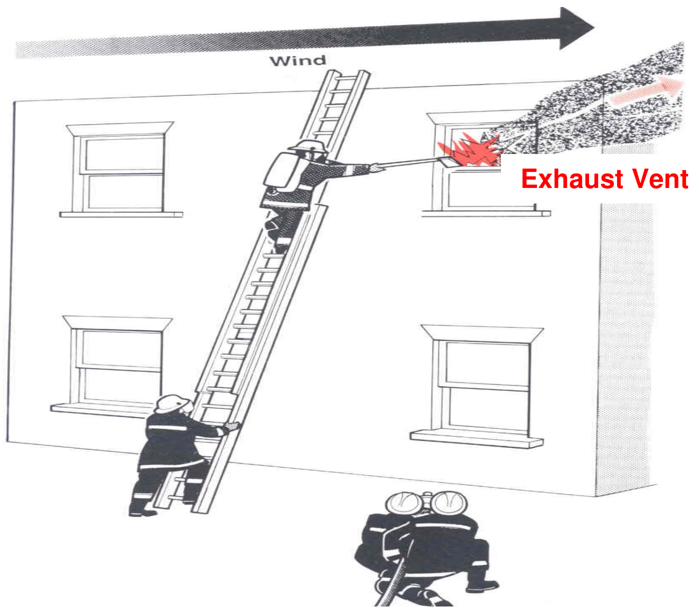


Diagram 7

2.15.7 If the compartment containing the fire has become oxygen starved, there is a risk of backdraught. Creating an outlet vent to this compartment may trigger a backdraught; the risk of this is minimised if the vent is high in the compartment and on the downwind side, allowing the release of hot gases without mixing them in the room with fresh air. Consideration should be given to withdrawing any Firefighters from all or part of the building whilst fresh air is being let into the compartment, as this route is likely to become the path for any backdraught. Particular consideration should be given to the safety of Firefighters on storeys above the fire, especially where their access and/or escape routes run through part of the fresh air inlet path.

Note: In these conditions the safety of any crews committed to the property will be severely undermined; the withdrawal of crews before the exhaust vent is made may be the only appropriate control measure.

2.15.8 The force of any backdraught may be directed out of the vent. As a result, the Firefighters making the vent should take appropriate precautions, such as keeping clear of the path of any possible backdraught, wearing breathing apparatus (BA), staying low and having a charged branch available for use.

2.15.9 For Firefighters inside a building, the simplest method of making a vent whilst doing the least damage is to open a window or door. This should be planned and communicated as part of the tactical plan. Firefighters should also have an understanding of the effects of the introducing of oxygen into the compartment.

Firefighters should place themselves as far to the side of the window as possible and use a ceiling hook or an axe to break the window from a position upwind of the outlet. Venting from above the fire should be avoided due to the nature of hot smoke and gases

The use of wedges for doors and handles for windows can assist in ensuring ventilation paths remain clear. If you feel that windows could potentially close of their own accord, then the window should be broken to ensure the continued ventilation of the compartment.

The IC must constantly monitor the situation, paying particular regard to the quantity and nature of the smoke issuing and to compartment doors and windows for any sign of rapid fire development, eg, flashover or backdraught.

2.16 TRENCH VENTILATION

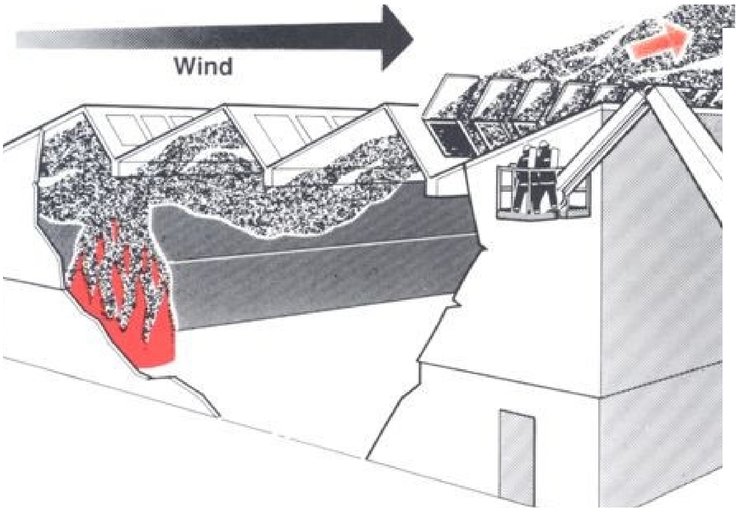


Diagram 8

2.16.1 Trench ventilation is accomplished by making an opening in the roof at a safe distance from the fire and large enough to allow all hot smoke and gases to vent through it, preventing it from travelling past the exhaust vent. This will cause the hot gases to spread towards the opening but prevent further spread beyond this point and improve conditions in the compartment below. This tactic can also be useful in terraced houses to prevent fire spread to adjoining roof spaces (see Diagram 8).

Note: **Any working at height must be assessed as to its safety and suitability before personnel are committed.**

2.17 HYDRAULIC VENTILATION

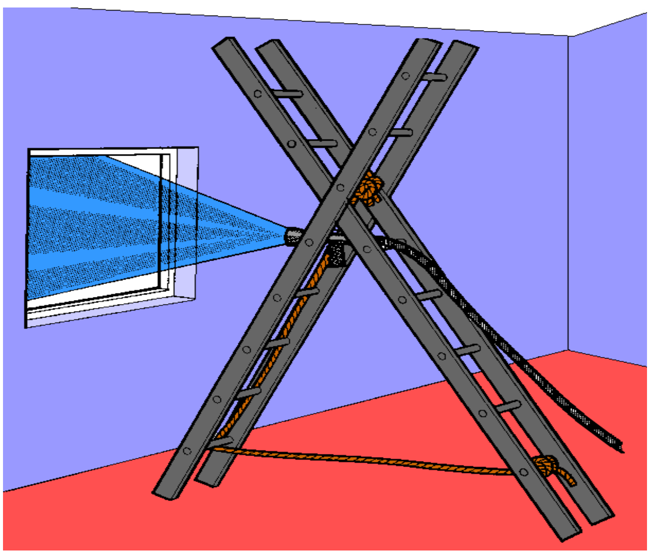


Diagram 9

2.17.1 Hydraulic ventilation is achieved by using a branch set on a conical spray to entrain air and draw the gases out from an opening.

2.17.1.1 The angle of spray should be approximately 60^{o}.

2.17.1.2 85 to 90% of opening should be covered.

2.17.1.3 The branch should be approximately 0.6 m away from the opening.

2.17.2 Consideration should be given to the lashing of the branch to a short extension ladder to reduce the time personnel are required to stay within punishing conditions. The technique is effective in removing smoke from smaller compartments to reduce further damage (see Diagram 9).

2.18 SEQUENTIAL (SYSTEMATIC) VENTILATION

2.18.1 It is essential to state that sequential ventilation is a systematic approach which may be applied to the removal of smoke only **AFTER** all rescues are complete and **AFTER** the fire has been extinguished.

2.18.2 SEQUENTIAL VENTILATION OF A SINGLE-STOREY DWELLING

2.18.2.1 In a structure with numerous smoke logged compartments (rooms), individual compartments may be ventilated by closing the doors to the other compartments not in the vicinity and creating an outlet point in the compartment to be ventilated.

2.18.2.2 By progressing from one compartment to another, keeping all doors closed, except the one to the compartment being ventilated, an entire floor or an entire building can be sequentially (systematically) cleared of smoke relatively quickly (see Diagram 10).

Diagram 10

2.18.2.3 Where possible, Firefighters will seek to enter from the windward side of the building, permitting pressurisation of the hallway. Ideally they will close all the doors to the rooms off the hallway and using correct entry techniques, enter the kitchen, extinguish the fire and ventilate the kitchen.

2.18.2.4 Once the kitchen has been vented, the process of sequential ventilation can commence with the utility room. Firefighters will then withdraw from the kitchen and close the door to the hallway. The crews will open the door to bedroom 4 and the window until the smoke is cleared, close the bedroom door (leaving the window open) and repeat the process systematically with each room in turn until all rooms are cleared of smoke.

2.18.2.5 Once the compartment has been cleared, the outlet point (normally the window) can be left in the open position. This will allow natural ventilation to occur within the compartment via the original outlet point. The door to that compartment must be closed before moving onto the next area to be ventilated.

2.18.2.6 For the most effective use of ventilation, it is imperative that Firefighters do not randomly open windows as they progress through the building. The effect of creating too many openings would be the failure to achieve pressurisation of the compartment or structure using available wind and a slow uncontrolled movement of contaminants.

2.18.3 SEQUENTIAL VENTILATION OF A MULTI-STOREY DWELLING

2.18.3.1 In buildings with more than one floor level, it is good practice to ventilate the lower floor first and progress upwards. By ensuring all windows and doors on the top floor are shut, this will provide the maximum pressurisation effect on the lower floor.

2.19 BUILDINGS WITH AN OPEN (UNDIVIDED) STAIRCASE

2.19.1 The first step in ventilation is to enter at ground floor level and wedge the door open to permit the inflow of fresh air. Firefighters will make their way up the staircase to the highest level and open a window in the staircase; using the stack effect this will clear the staircase (see Diagram 11).

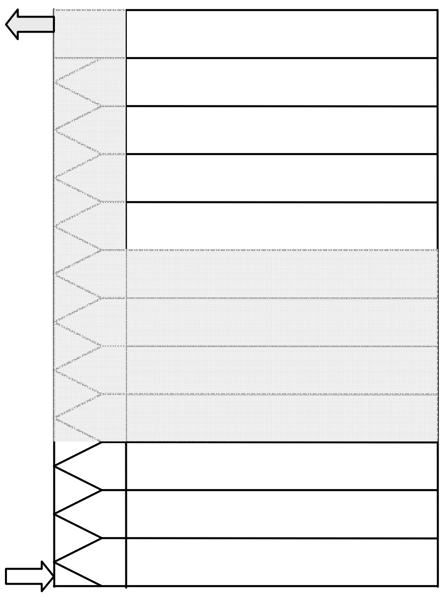


Diagram 11

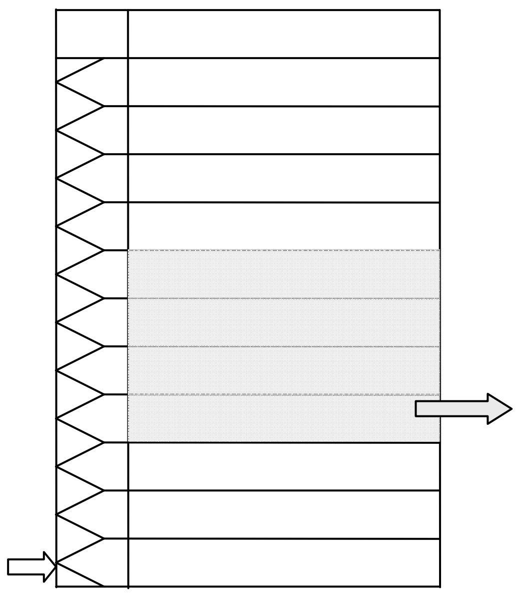


Diagram 12

2.19.2 Once the staircase is clear of smoke, Firefighters will close all windows in the staircase to maximise the wind pressurisation of the lobby at each floor level.

2.19.3 The Firefighters will then commence a systematic ventilation of the lowest smoke logged floor first. Once this floor level is cleared the process will be repeated upwards in a floor-by-floor basis (see Diagram 12).

OPEN - VENT - CLOSE - MOVE ON

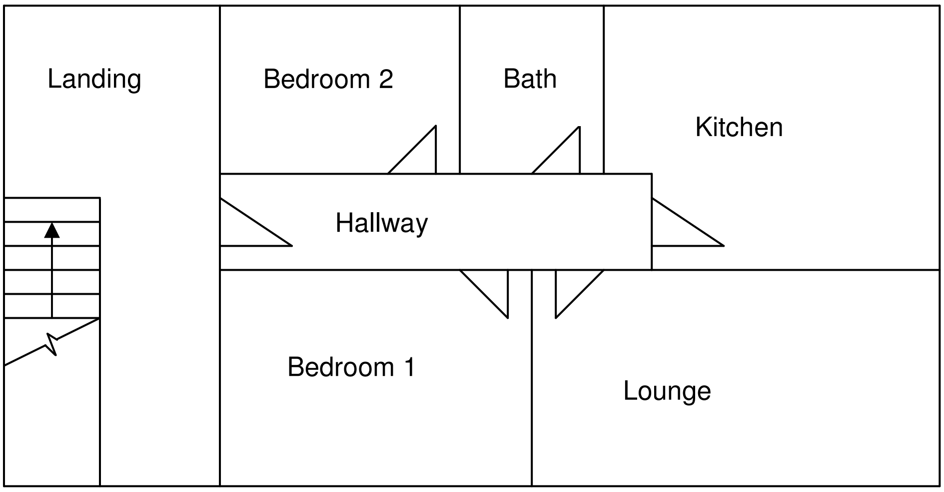


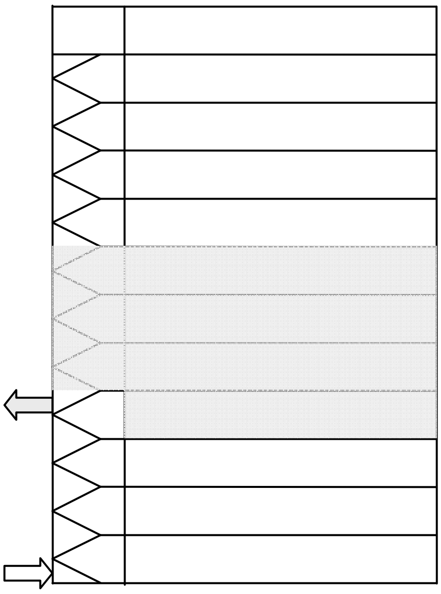
Diagram 13

2.19.4 The process of sequential ventilation of a floor level is similar to that applicable to a ground floor premises. Firefighters will enter the hallway and start a systematic process of entering the first room and open the window, vent the smoke, leave the room and close the door to the hallway. This process will be repeated for each room in turn until that particular floor level is clear of smoke (see Diagram 13).

2.20 BUILDINGS WITH A DIVIDED STAIRCASE (Fire doors at each floor level)

2.20.1 Firefighters will enter the staircase, wedging open all doors within the staircase as they go; they will move up to the lowest level of smoke logging, open the window, clear the smoke and close the window. The Firefighters will then vent that floor level as described in section 2.19.4 above. The Firefighters will then repeat the process of venting the stairs at the next level and then the habitable space and so on until the building is cleared (see Diagrams 14 and 15).

OPEN - VENT - CLOSE - MOVE ON



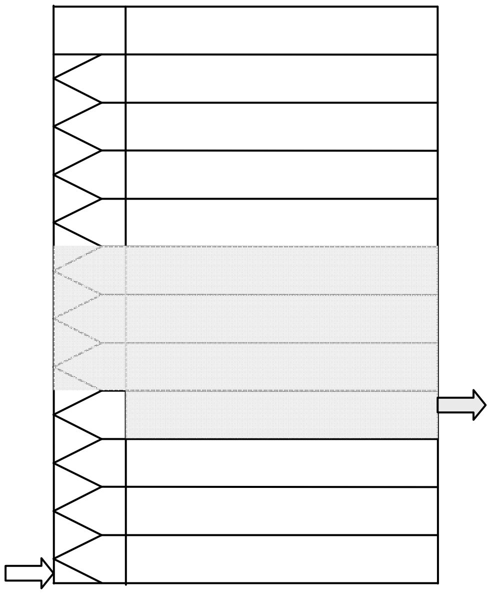


Diagram 14 **Diagram 15**

Understanding this process will assist once positive pressure ventilation is introduced into NIFRS.

2.21 PRINCIPLES OF SMOKE CONTROL DESIGN

2.21.1 It is important for Firefighters to recognise that designers and developers of most modern buildings have invested significant time and energy developing a systematic approach to the control of smoke in the event of a fire.

2.21.2 Where a system is specifically designed to manage smoke production, it would be unwise to apply a firefighting plan which did not utilise the smoke controls in place. Therefore, it is vital that Firefighters have both an understanding of the basic principles of smoke control and also, through the SOP 12 process, local or specific details of smoke control systems should be integrated into site specific plans.

2.21.3 The techniques used for smoke control entail either limiting the spread of smoke or controlling the effects of that smoke spread. The list below summarises the basic approaches.

2.21.3.1 SMOKE CONTAINMENT

ICs will use a system of physical barriers to inhibit the spread of smoke from the fire affected space to other parts of the building. Examples of physical barriers vary from walls and doors to drop-down smoke curtains or glass panels.

The principles of *"defend in place"* apply in that the design intention is to contain the fire to the room of origin. This principle is applied inter alia to purpose-built flats and maisonettes where the floors, walls and doors provide a high degree of fire compartmentation. The compartmentation restricts the spread of smoke and fire and is intended to restrict the fire to room of origin and avoid evacuating beyond the dwelling of origin.

2.21.3.2 SMOKE CLEARANCE

This involves using any method of assisting NIFRS in removing smoky gases from a building, post-extinction. Examples may include the use of powered fans.

2.21.3.3 SMOKE DILUTION

This involves deliberately mixing the smoky gases with sufficient clean air to reduce the hazard potential. This technique is generally applied to extend the time available to permit occupants of a building to escape.

2.21.3.4 SMOKE EXHAUST VENTILATION

This involves having a system of natural ventilators, such as automatic opening windows/vents, or one or more electric fans which are connected by ducting to the outside. A key component of an exhaust system is that it must have the ability for clean replacement air (known as *"make-up air"*) to either the compartment or beneath the smoke layer.

2.21.3.5 PRESSURISATION

Pressurisation involves having a system of fans which will force fresh air into compartments such as staircases. The air pressure is usually in the region of 50 Pascal (Pa), which is approximately 10 times greater than the pressure created by a fire (5 Pa). Therefore, fire in a compartment, eg, offices, adjoining a staircase will produce heat and smoke to approximately 5 Pa of pressure which, if undetected, would filter into adjoining compartments and staircases, so obstructing routes required for escape or rescue purposes (see Diagram 16). The effect of the pressurisation of a staircase is to prevent smoke ingress, ie, "pushing" the smoke back into the fire compartment, leaving a clear escape route.

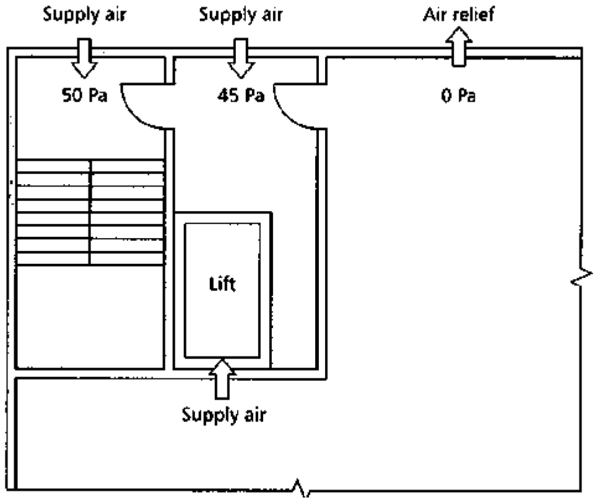


Diagram 16

In order to have an appreciation of what effect 50 Pa of pressure will have on doors or on a building, the pressure inside a BA facemask is in the region of 35 Pa.

2.21.3.6 DEPRESSURISATION

This process entails a system where the risk compartment is filled with exhaust fans similar to Smoke Exhaust Ventilation. The key difference is that there is no provision for "make-up air", which means that the compartments adjoining the fire compartment (being at atmospheric pressure) will remain smoke-free because the (clear) air in these compartments is being drawn into the fire compartment.

2.22 SMOKE CONTROL SYSTEMS

Smoke control systems are designed with one or more of the following 3 key objectives in mind:

2.22.1 LIFE SAFETY

The purpose is to ensure that conditions (from smoke and heat) are maintained tenable for a sufficient period of time to permit full evacuation. The design approach will anticipate maximum escape time and then incorporate an additional safety factor.

2.22.2 DEDICATED FIREFIGHTING ROUTES

In order to enable firefighting operations to proceed efficiently, protected firefighting access routes, eg, firefighting shafts should be maintained essentially free of smoke so that access to the fire-affected storey can be achieved without the use of BA. The system will be designed to permit the establishment of a bridgehead which, in turn, will extend the working duration of BA and should ensure that the staircase is essentially smoke-free under normal fire conditions.

2.22.3 PROPERTY PROTECTION

In some premises there will be compartments especially vulnerable to smoke damage, eg, those containing artefacts or data processing suites. A system will be designed to prevent any smoke from entering these areas.

2.23 TACTICS FOR VENTING AND ENTERING A COMPARTMENT

2.23.1 WHERE A BACKDRAUGHT **IS NOT** ANCICITPATED

2.23.1.1 In this scenario the key objective is to direct the smoke, fire gases and steam away from a corridor or staircase and successfully extinguish the fire.

Step 1

Lay out and ensure there are adequate means for firefighting - BA, jet or hose reel jet, etc.

Step 2

Identify a suitable exhaust vent and prepare personnel to stand by.

Step 3

Create an exhaust vent as high as possible, to fresh air ideally and preferably diametrically opposite the door.

Step 4

Have Firefighters open the door using correct techniques, pause to assess smoke conditions, enter the room using water spray to extinguish the fire and force smoke/steam out through the exhaust vent.

2.23.2 WHERE A BACKDRAUGHT **IS** ANTICIPATED

2.23.2.1 In this scenario the key objective is to permit Firefighters to ventilate and extinguish the fire in a controlled and safe manner using a tactical plan to manage the smoke and fire gases.

Step 1

Provide and prepare suitable means for firefighting, including covering jets.

Step 2

Identify a suitable exhaust vent and prepare someone to stand by.

Step 3

Create the exhaust vent and observe the effect on the conditions.

Step 4

Using correct techniques, ie, Firefighters crouch low using a covering jet, firstly, check the door for signs of heat, open the door in a controlled manner and observe conditions, applying suitable gas cooling techniques as required.

Step 5

When backdraught risk is addressed, enter the room and extinguish the fire.

2.23.2.2 The key to any attack plan is preparation of personnel and resources and effective co-ordination of response with strong lines of communications.

2.23.3 SINGLE DOMESTIC PREMISES

2.23.3.1 **Options**

- Close up the room of origin and protect the escape routes for rescue purposes. Once the rescues are complete, then move to extinguish the fire.
- Attempt ladder and/or window rescues whilst containing the fire.
- Keep persons in their rooms protected by closed doors until the fire is extinguished and then ventilate the escape routes and assist people to safety.

2.23.3.2 **Conflicts**

It is vital that the plan employed for each specific fire is clear and unambiguous. If a fire is tackled at ground floor level, permitting smoke and steam into the hallway and/or staircase, then this will endanger people if simultaneously escapes or rescues are in progress. An IC must clearly decide how he/she will ensure the smoke and steam will be managed to ensure that life is not further endangered.

2.23.4 FLATS, HOUSES AND MULTIPLE OCCUPANCIES

2.23.4.1 The principle for fire containment in these premises is *"defend in place"* with early warning for occupants. The staircase is provided with structural fire protection in the form of fire resistant walls and doors. Should a fire occur in a room within one flat, the design seeks to firstly contain the fire within that room and then prevent fire spread beyond the flat to the common staircase.

2.23.4.2 The options for firefighting are as for single domestic premises, except that in properly designed and built flats, houses in multiple occupation (HMOs), the IC's DRA can recognise the additional safeguards of firstly early warning from an automatic fire alarm (AFA) to predict pre-burn time and secondly, the fire rating of the fabric of the building can be more reasonably predicted than in single domestic premises.

2.23.4.3 The key decisions again are whether to protect the staircase by closing up the fire or by putting in covering jets; alternatively to extinguish the fire first and then complete any necessary rescues or tasks. It is essential that Firefighters recognise that during search operations, the opening of doors may permit smoke spread and this consideration must form part of the risk assessment.

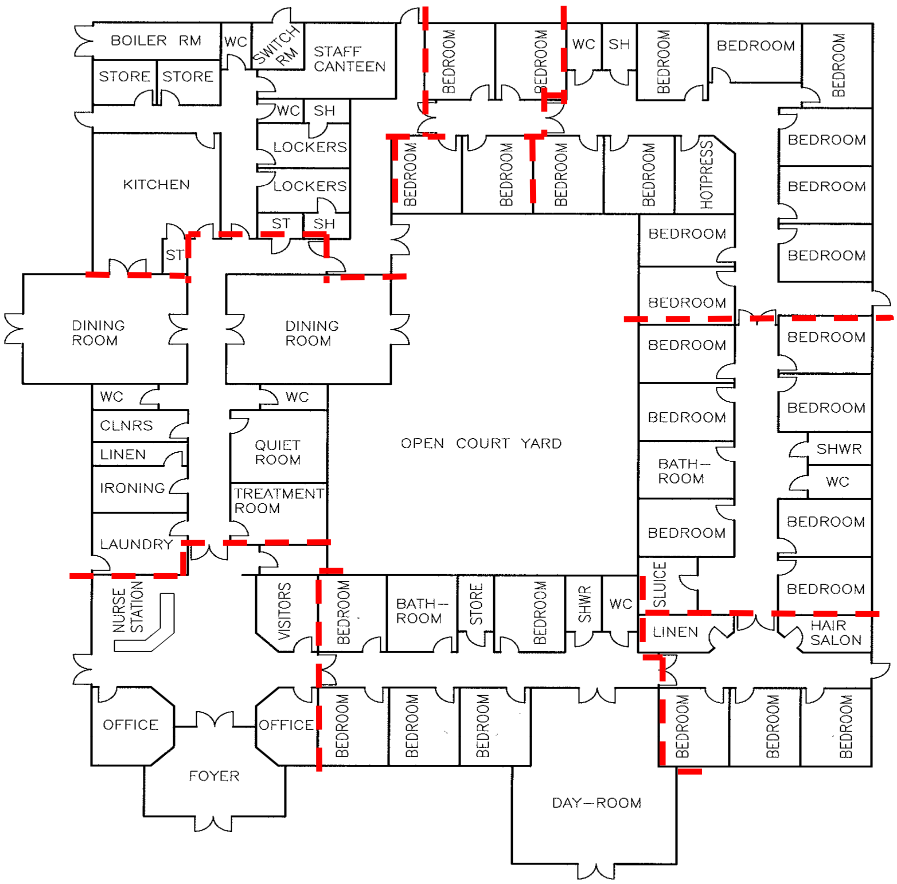
2.23.5 HOTELS

2.23.5.1 The principles of *"defend in place"* apply, however, unlike a flat, there is not normally a lobby entrance to each room and with only one fire resistant door between the room and the corridor, the likelihood is that the common corridor may become smoke-logged once firefighting commences.

2.23.6 NURSING HOMES/RESIDENTIAL CARE PREMISES

2.23.6.1 The design standard of Health Trust Manual No 84 (HMT 84) permits that each room shall be fitted with a 30 minute fire resistant door, but not necessarily fitted with a self-closing device. The bedrooms are contained within a series of sub-compartments with an average of 6-9 persons sleeping in each sub-compartment. Firefighters should make themselves aware of the size and number of each sub-compartment during familiarisation visits or as part of the SOP 12 process.

2.23.6.2 The extent of the sub-compartments can be identified by the location of the cross-corridor doors (see Diagram 17).



NURSING HOME FLOOR PLAN
NOT TO SCALE

Diagram 17

2.23.6.3 Each sub-compartment is fire resistant from the floor right up to the floor above or through the roof void to the underside of the roof. The rationale means that a fire has 30 minutes containment inside each room and then another 30 minutes containment within each sub-compartment. In the event of a fire, staff should firstly evacuate the room of origin, if possible to do so safely. Then ideally, the remainder of the persons in the affected sub-compartment should be moved to another sub-compartment, preferably into a room with a final exit in case total evacuation becomes necessary. In reality, some patients may be sedated or in poor health and staff may decide to leave them in situ as the actual disturbance from the evacuation may result in a greater risk to their life.

2.23.6.4 An IC must, on arrival, determine evacuation requirements and implement a plan to extinguish the fire and prevent the smoke and steam spreading from the sub-compartment of origin to any adjoining sub-compartments.

2.23.6.5 The decision process will require an assessment of the extent of the fire and the potential for smoke spread throughout the building. Therefore, the IC will need to ensure that assessment is made at the room door for heat and smoke and preferably a second person goes to the room window to confirm the extent of the fire.

2.23.6.6 An IC then has 2 basic choices:

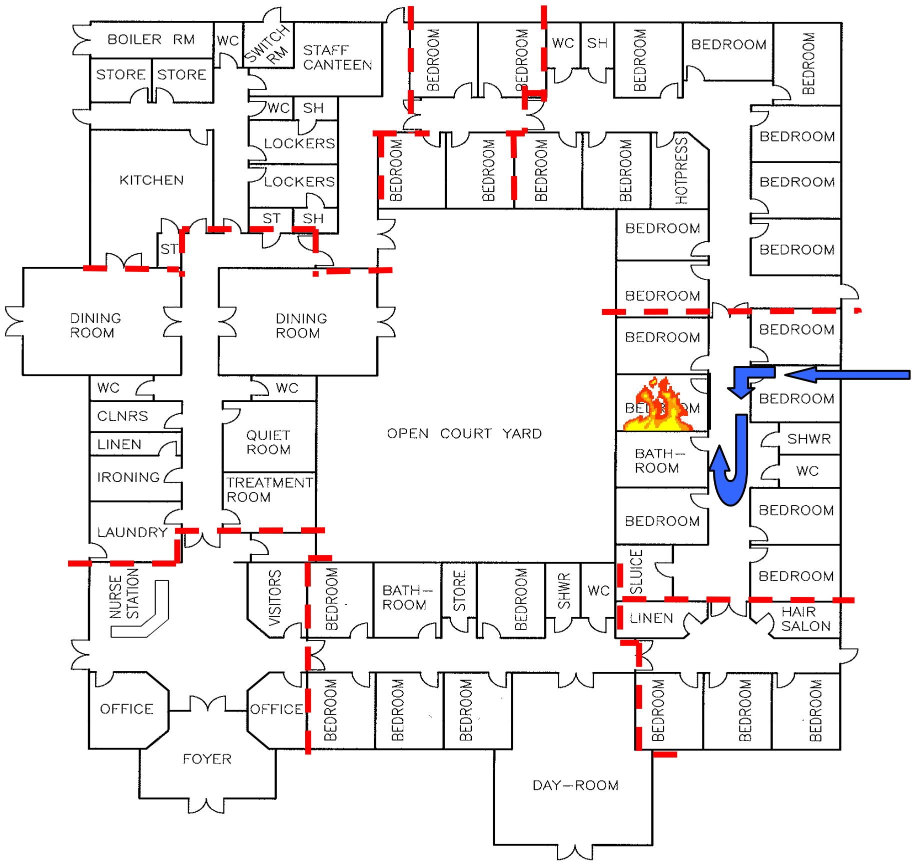
- the fire and smoke risk is very small and it is possible for Firefighters to enter the room of origin and extinguish the fire without causing significant smoke spread;

- the fire risk from the room is significant and the priority is to maintain the integrity of the sub-compartment.

Where protecting the integrity of a sub-compartment is determined as a key objective, the IC must implement a tactical plan to extinguish the fire, which will result in the least smoke spread possible.

2.23.7 SCENARIO 1 – FIRE IN A BEDROOM WITH EXTERIOR VENTING

An assessment from the corridor and window indicates a significant fire with considerable smoke emissions.



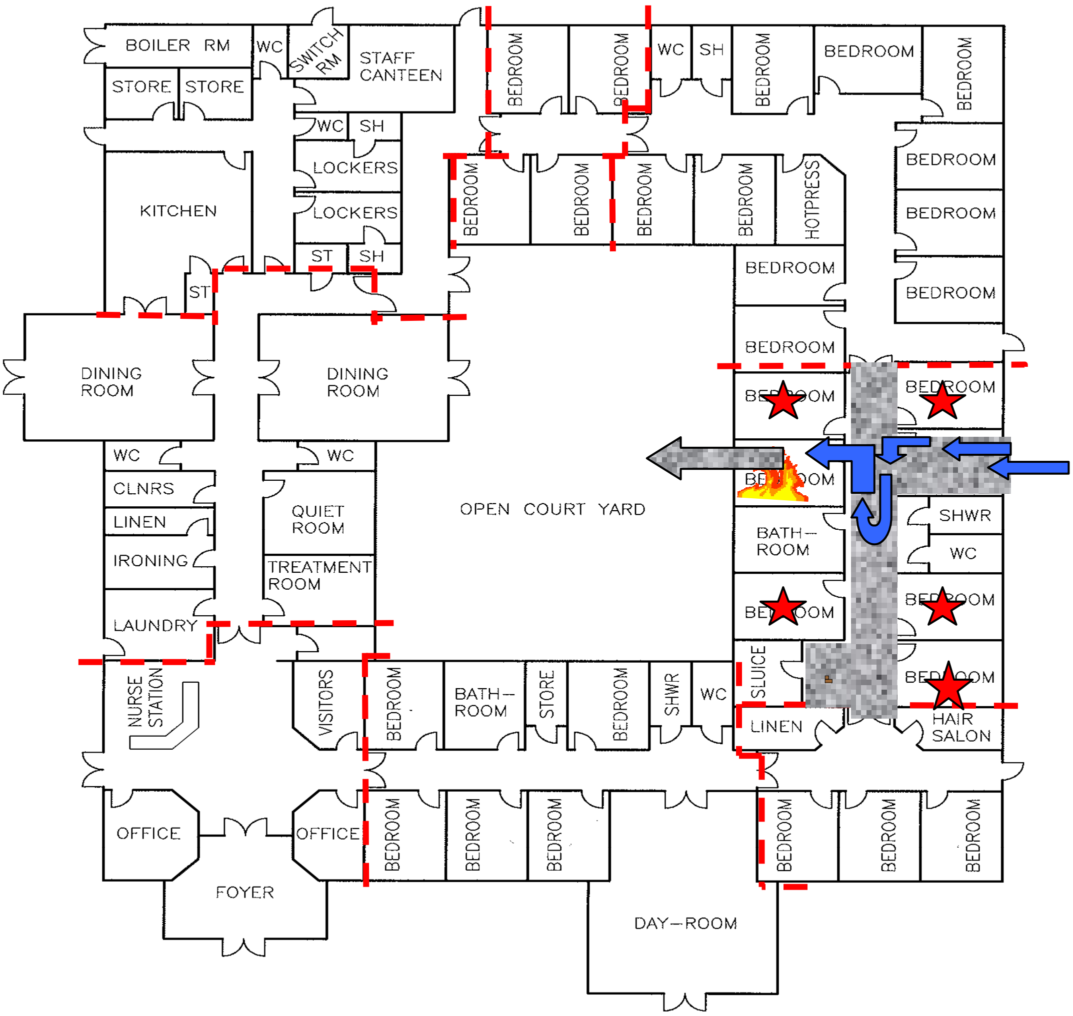
NURSING HOME FLOOR PLAN
NOT TO SCALE

Diagram 18

2.23.7.1 **Option 1** (Diagram 18)

The fire is in the indicated bedroom, which has been evacuated prior to NIFRS arrival. Crews will deploy a hose reel jet utilising a window from an adjacent room (after evacuation of the occupant). Where the adjacent room is on an upper floor, the crews will use a line to haul the high pressure hose reel aloft.

The IC will co-ordinate the venting of the room window with the BA Teams entry into the bedroom. The smoke from the fire and the steam will be mostly pushed out through the window. It is accepted that some smoke will make its way into the corridor, but there are only 5 additional bedroom doors exposed to smoke (Diagram 19). In effect, the IC has restricted the smoke exposure to 5 bedrooms, which have now only 30 minutes' protection; all other bedrooms having 60 minutes or more separation from the smoke.



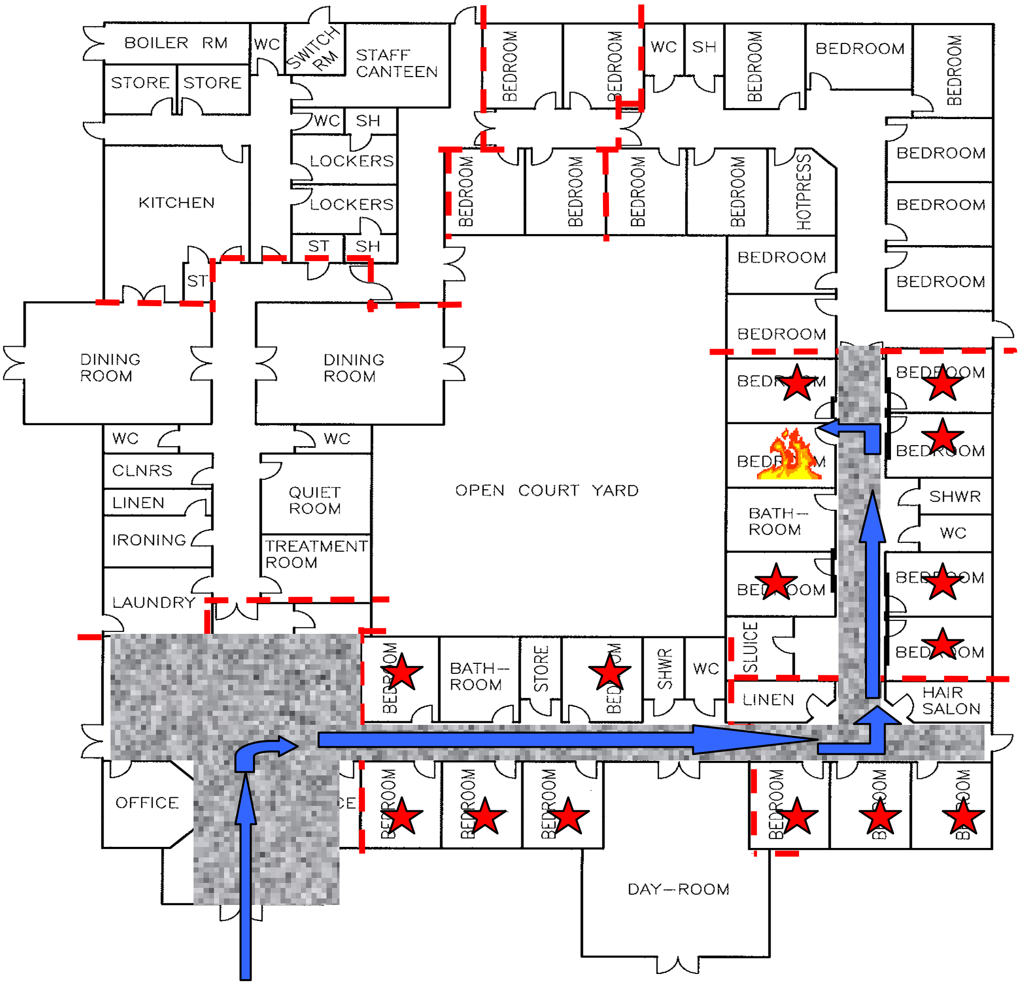
NURSING HOME
FLOOR PLAN
NOT TO SCALE

Diagram 19

★ Risk rooms where residents are under immediate threat.

2.23.7.2 **Option 2** (Diagram 20)

The fire again is in the indicated bedroom, except in this case, the hose reel jet is taken in the main entrance along the corridor and has wedged open all the smoke-stop doors. This situation results in a total of 14 bedrooms which now have smoke immediately threatening their bedrooms.



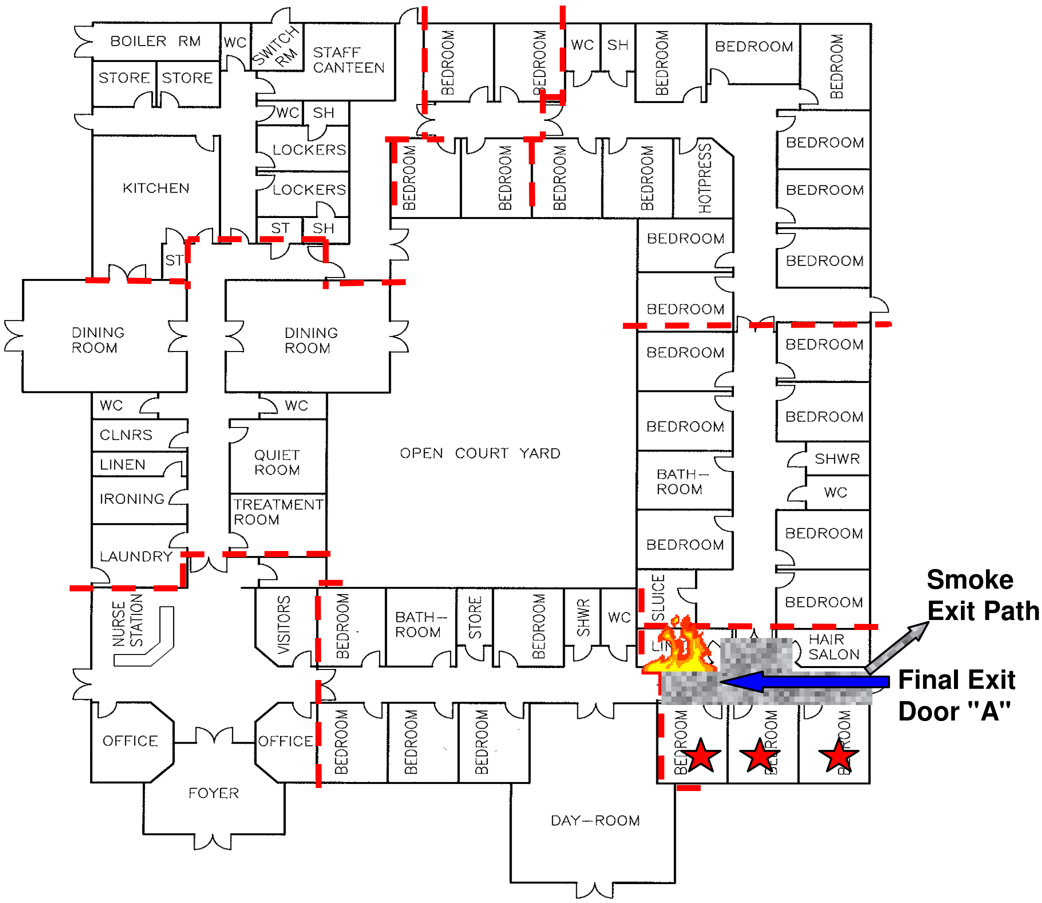
NURSING HOME
FLOOR PLAN
NOT TO SCALE

Diagram 20

★ Risk rooms where residents are under immediate threat.

2.23.8 SCENARIO 2 – FIRE IN A ROOM WITH NO EXTERNAL VENTING

This scenario assumes a linen cupboard with considerable fire loading to be producing significant heat and smoke.



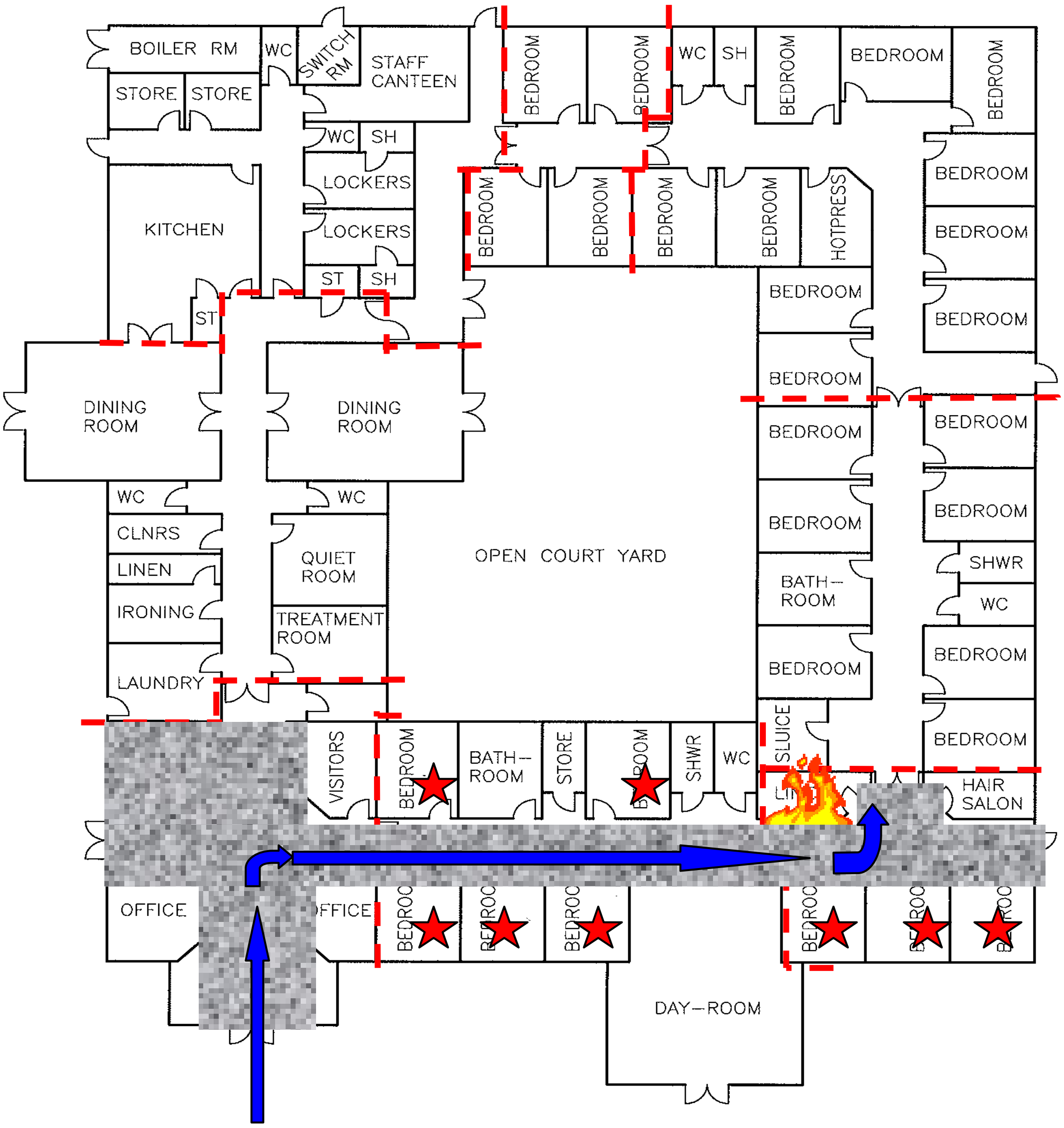
NURSING HOME FLOOR PLAN
NOT TO SCALE

Diagram 21

★ Risk rooms where residents are under immediate threat

2.23.8.1 **Option 1** (Diagram 21)

The occupants of the sub-compartment are evacuated to the day room and a hose reel jet is taken into the building in the external door "A". It is accepted that the sub-compartment corridor will be smoke-logged, but it will be stopped at the cross-corridor; smoke-stop doors and the external door "A" will assist venting. In this case only 3 bedrooms are compromised. Where no external door is available, one of the 3 bedroom windows can be used for hose reel jet deployment.



NURSING HOME FLOOR PLAN
NOT TO SCALE

Diagram 22

★ Risk rooms where residents are under immediate threat.

2.23.8.2 **Option 2** (Diagram 22)

Again, the occupants of the sub-compartment are evacuated into the day room, but in this case, a hose reel jet is taken in via the main entrance. The corridor is now smoke-logged right to the foyer and the occupants of 6 additional bedrooms are exposed to a greater risk due to the hose reel jet holding the smoke-stop doors open.

2.24 SHOPPING CENTRES WITH A MALL CORRIDOR

2.24.1 A shopping mall is designed to equate to the traditional High Street with shops on both sides of a street, only in the case of the mall, the street is roofed over.

2.24.2 In the case of fire in a High Street shop, the persons have simply to evacuate into fresh air in the street and this represents a place of safety. In the case of a mall, however, the smoke could potentially fill the mall and still endanger persons elsewhere in the shopping centre.

2.24.3 The design criteria for shopping centres has 3 basic approaches:

2.24.3.1 All shop units within a mall will be sprinklered to suppress and maintain any fire to a manageable output of heat and smoke (5 mega watt anticipated).

2.24.3.2 The smoke from a particular shop unit will be prevented from entering the mall, but the shop unit will have its own integral smoke extraction system.

2.24.3.3 The smoke from a particular shop unit will be encouraged to enter the mall from where it will be contained into defined sections or zones. The smoke will be evacuated from the mall by either automatic opening ventilators and natural exhaust, or alternatively by a mechanical extraction system.

2.24.4 One of the problems for Firefighters is that shop units within the same mall may employ different smoke management strategies. Thus, within one shopping centre, Firefighters could find that some shop units are designed to evacuate the smoke into the mall, whilst a number of others are designed to prevent the smoke from entering the mall. It is very difficult to identify which strategy is employed for an individual shop unit whilst trying to deal with a fire. Therefore, it is essential that the SOP 12 process identifies the design standard for each shop unit, prior to a fire occurring.

2.24.5 Firefighters need to be aware of the smoke management strategy employed so that firefighting actions do not conflict with smoke management systems which could easily be used to their advantage.

2.24.6 If a fire occurs in a shop unit which is designed to contain its own smoke reservoir and extract that smoke by a stand alone extract system, then, should Firefighters commence firefighting from the rear of the shop, their firefighting jets will push the smoke and steam away from the extraction and out into the mall. The mall may not necessarily be designed to remove the smoke, resulting in smoke-logging.

2.24.7 Conversely, where firefighting operations are commenced from the mall and the shop unit is designed to evacuate the smoke into the mall, then the force from the firefighting jets will push the smoke back into the shop unit from where there is no means to extract it. The smoke will then be forced to wrap around the Firefighters towards the mall and result in an unnecessary escalation in the complexity of the operation.

2.24.8 The SOP 12 process for a shopping mall should identify the smoke management systems for each shop unit and identify the extraction points so that Firefighters can modify their firefighting to utilise the smoke extraction to the best advantage possible. For example, a slit extract will be found along the main entrance from the shop into the mall; it is designed to work in conjunction with a smoke barrier (down stand) to stop smoke entering the mall.

2.24.9 One other feature now found more commonly in shopping malls is where the major anchor tenants employ a "stand alone" philosophy. That is, in the event of a smoke detector actuating in the shop unit, a 2-hour, fire resistant, motorised roller shutter will close down to approximately 2.2 m–2.4 m from the floor level. In the event of smoke spread, to involve certain additional smoke detectors, the roller shutter will automatically close fully, providing a full 2-hour fire separation between the shop unit and the mall.

This is vitally important for Firefighters to consider prior to deployment, as a Firefighting Team deployed from the mall into the shop unit could easily find their path for emergency withdrawal obstructed by the roller shutter. It would be much preferable if Firefighters can withdraw following the hose or their original path of entry, also Emergency Teams will have a greater chance of search and rescue if they too can follow the hose on the original path.

2.24.10 Operational crews should recognise that the plan drawing (see Diagram 23) indicates the preferred positioning of firefighting media, but individual circumstances on a particular day, may render that plan obsolete. The key to any tactical plan is to identify smoke management strategies employed in a building and attempt to use these to assist with firefighting and damage control.

2.24.11 It is important to note that this plan drawing should be considered as an illustration only and is representative of some of the issues to be considered as part of the SOP 12 process. Each individual site plan will require specific knowledge of the smoke management systems and the plan should permit the first attendance officer to commence deployment of equipment in a manner compatible with the smoke management system. The details for premises will vary, thus the SOP 12 plan will require some research as these details are almost impossible to acquire in the early stages of an incident.

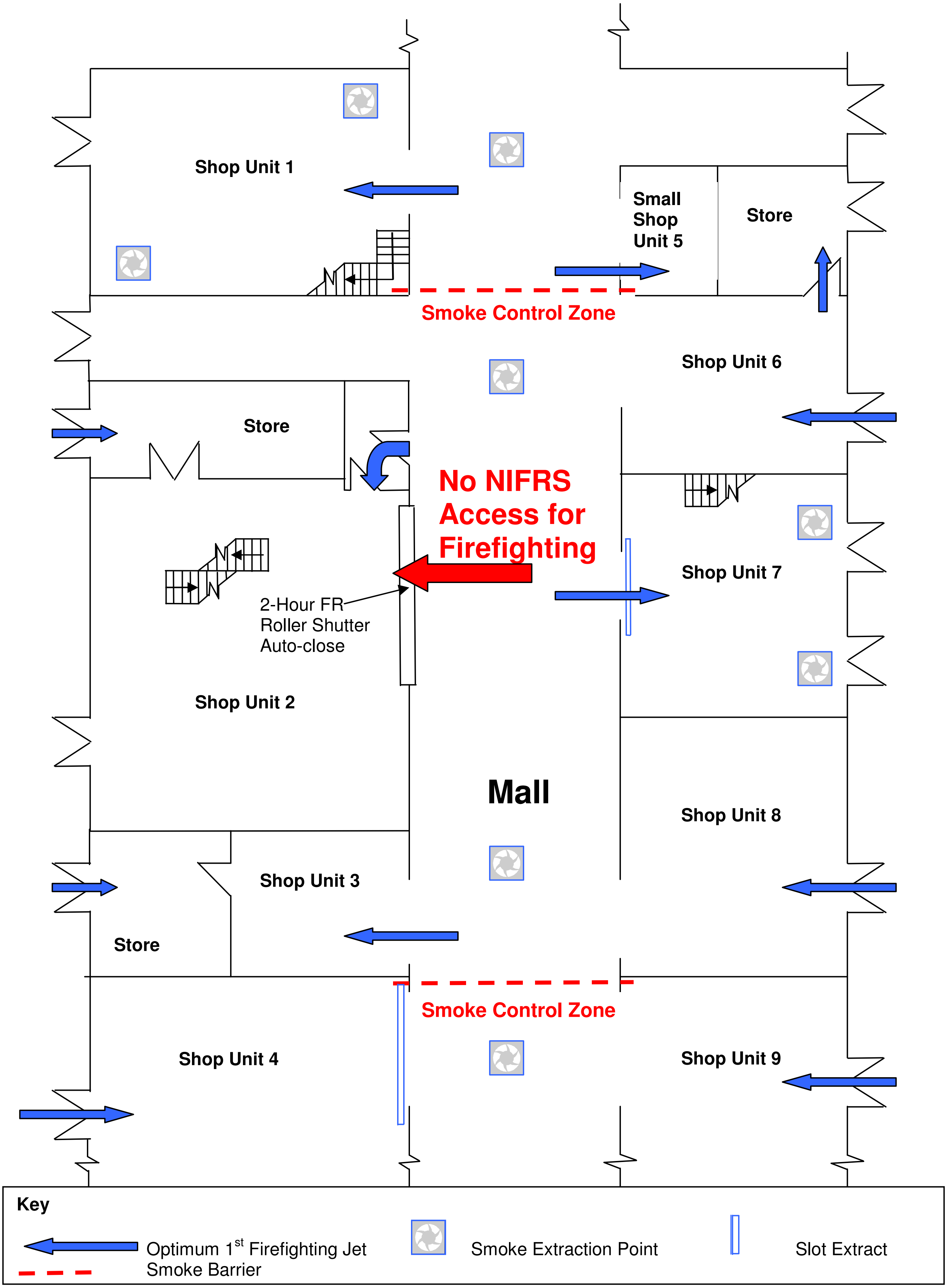

Shop Unit 1
Small Shop Unit 5
Store
Smoke Control Zone
Shop Unit 6
Store
No NIFRS Access for Firefighting
2-Hour FR Roller Shutter Auto-close
Shop Unit 7
Shop Unit 2
Mall
Shop Unit 8
Shop Unit 3
Store
Smoke Control Zone
Shop Unit 4
Shop Unit 9
Key
Optimum 1st Firefighting Jet
Smoke Barrier
Smoke Extraction Point
Slot Extract

Diagram 23

The symbols and detail on Diagram 23 should not be taken as compulsory but are representative of a means to provide the IC with immediate detail which will assist with a tactical plan.

2.24.12 SHOP UNIT 1

The design requirements are to maintain the smoke within the shop unit and have a stand alone extraction; therefore, the firefighting strategy should be compatible with the design. The optimum tactic is for the firefighting jet to work from the mall, pushing the smoke and steam back from the mall, away from the staircase and towards the extract point at the rear of the shop.

2.24.13 SHOP UNIT 2

The design is that in the event of an AFA alert the roller shutter will partially drop down to 2.5 m of headroom and act as a bulkhead to retain the smoke in the shop; it also allows members of the public to escape into the mall. Firefighters **MUST NOT** enter via the main entrance as any further smoke spread to additional AFAs will cause the roller shutter to fully close and will both trap the hose and close off the egress route. The Firefighters should deploy via the by-pass doors and use the jet to keep the fire and smoke from entering the mall.

Consideration may need to be given to pushing the fire away from the staircase or escalators to reduce smoke logging of the first floor. A fire in the store of Unit 2 may be fought from the service doors with another team closing the doors from the store into the shop unit. In this way, the smoke and steam will not be pushed into the shop; also the jet will be maintained as short as possible.

Firefighters must recognise that the smoke can only exit via the final doors and will wrap around them as they extinguish the fire. Alternatively, local circumstances may dictate that the fire in the store may be fought through the shop and push the smoke out through the service doors.

2.24.14 SHOP UNIT 3

The smoke from a fire in this unit is designed to enter the mall, whereupon, the smoke management system will extract the smoke to atmosphere. The Firefighting Team may decide to close the door to the store to prevent smoke damage to the stock within and firefight from the mall, recognising the smoke must wrap around and out into the mall. A fire in the store may be tackled as in Shop Unit 2.

2.24.15 SHOP UNIT 4

The smoke is designed not to enter the mall but be handled by a slot extract system along the main entrance. Firefighting should then avail of the extract and work from the service entrance towards the extraction.

2.24.16 SHOP UNIT 5

Where a shop is no more than 5 m deep from the mall, it will not necessarily have an alternative exit, therefore, firefighting must be done from the mall.

2.24.17 SHOP UNIT 6

The smoke is designed to enter the mall from where it will be extracted to atmosphere; firefighting will be from the rear of the shop, pushing the smoke into the mall. It is very important that prior to firefighting, the IC ensures that the public are evacuated beyond the Smoke Control Zone within the mall. In this way the smoke logging in the mall is restricted in size; members of the public are moved from the immediate hazard area to a place of relative safety. A fire in the store may be fought via the rear shop doors and through the shop, so pushing the smoke away from the shop and out the service doors.

2.24.18 SHOP UNIT 7

The design intention is to prevent smoke from the shop entering the mall. The smoke will be extracted via ducting points at the rear of the shop and a slot extract at the main entrance will prevent cold smoke entering the mall. The optimum tactic will be to firefight from the mall, pushing the fire away from the mall and the staircase and towards the extraction points.

2.24.19 SHOP UNITS 8 AND 9

The firefighting will be from the rear of the shop, pushing the smoke into the mall from where it can be extracted; as in unit 6, it is important to move bystanders outside the immediate Smoke Control Zone.

2.25 ENCLOSED OR MULTI-STOREY CAR PARKS

The current building regulations require that an enclosed car park be provided with either a mechanical ventilation system or a national ventilation capability.

2.25.1 MECHANICAL VENTILATION

2.25.1.1 The system must be designed with a capacity for 6 air changes per hour for normal extraction and 10 air changes per hour in a fire condition. The system must be designed to operate in 2 parts, each capable of 50% of the rates as set out above.

2.25.1.2 The extract points must be split with 50% at a high level and 50% at a low level. It is important that Firefighters familiarise themselves with the extract points so that they can maximise the effectiveness during firefighting.

2.25.2 NATURAL VENTILATION

2.25.2.1 For a car park to be considered as "open-sided" it must not be a basement and have a minimum of 5% of the floor area on each level as permanent openings. These openings must be equally divided on opposing walls in order to provide for cross-ventilation.

2.25.2.2 Where a car park is not considered as open-sided, it will have a minimum of 2.5% of the floor area on each level as permanent openings; again these will be arranged as above for cross-ventilation.

2.25.2.3 For Firefighters, the significance of this arrangement of ventilation is that the normal or prevailing winds for the area will determine which side of the building is upwind; therefore, the direction from which firefighting should be deployed.

2.26 TACTICAL VENTILATION IN HIGH RISE BUILDINGS

2.26.1 There are a number of safety critical issues with regards tactical firefighting within high rise properties and personnel should be familiar with Occupational Health, Safety and Welfare Bulletin No 10/2006 – *"High-Rise Firefighting"* and SOP No 13 - *"High-Rise Procedures"*. The SOP 12 process should also be used to inform crews of the features and resultant dangers with regards any high-rise buildings within their locality.

2.26.2 The **stack effect** is where an undivided stairwell or shaft in a high-rise building acts as a chimney and encourages the fire and its products to rise through the height of the property. This can be advantageous if the stairwell is not being used as an escape route and horizontal fire spread can be avoided at higher levels.

2.26.3 The effects of the wind on tactical firefighting in high-rise buildings must be considered before ventilation is carried out. Wind speeds generally increase with height and high pressure builds up on the upwind side, whilst low pressure is created on the downwind side. Any ill-considered ventilation at higher levels could result in strong air currents travelling through the property and will have a serious effect on fire growth in any compartment exposed to these air movements. Smoke and air movements are less predictable due to these increased pressures.

2.26.4 SPECIFIC CONSIDERATIONS

2.26.4.1 The risk of backdraught greatly increases due to the possibility of fresh air being forced in under pressure to a compartment which previously contained an over-rich atmosphere. This pre-mix could result in a potentially fatal deflagration.

2.26.4.2 If openings fail and the winds blow into the fire compartment, there is the potential for what is called the "blowtorch effect". This is where fire and its gases are driven under pressure towards an exhaust vent; if Firefighters are trapped between inlet and outlet in these circumstances, the consequences can be fatal (see Diagram 24).

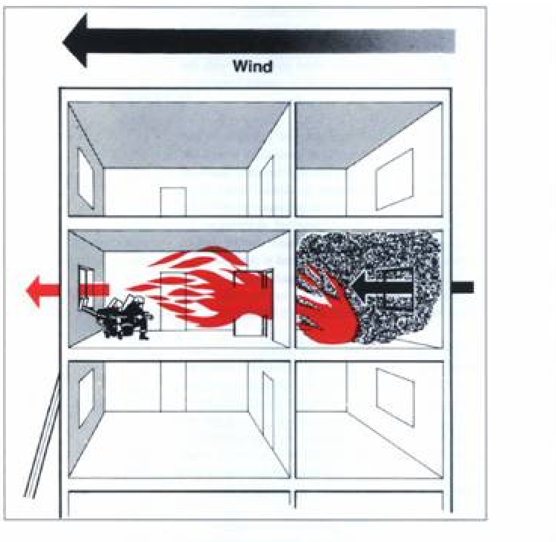


Diagram 24

2.26.4.3 Conversely, if the fire compartment is on the leeward or downwind side then the high pressure can be used to the IC's advantage.

2.26.4.4 Consideration should be given to the impact any ventilation carried out will have on fire safety measures designed into the premises.

2.26.4.5 Ventilating above the fire may be necessary to help with evacuation and also to avoid the build-up of hot fire gases, leading to potential backdraught conditions.

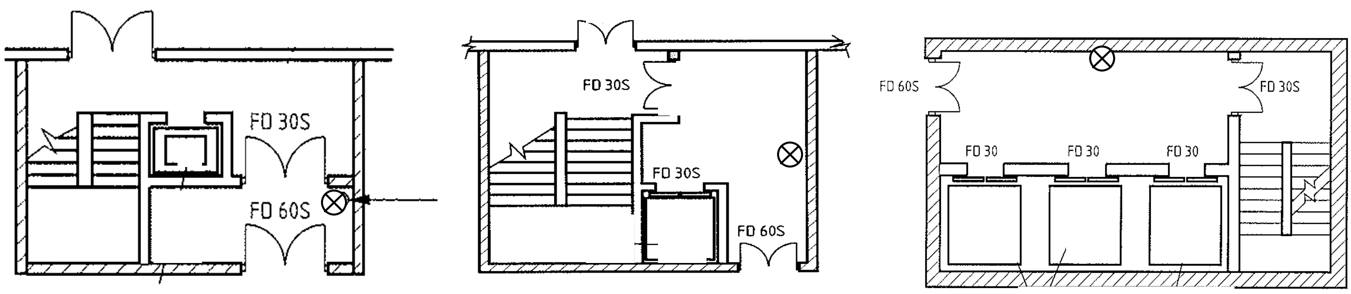
2.26.4.6 Consideration must be given to the design of the building and the possible high pressure air movements before ventilation is carried out on the fire floor compartment itself. The provision of a large outlet compared to a smaller outlet vent may ease the build-up of dangerous pressure differentials.

2.26.4.7 Extra care should be taken when breaking windows for ventilation in high-rise properties, due to the increased distances falling glass may travel at these heights.

2.27 FIREFIGHTING STAIRCASES

2.27.1 DESIGN FEATURES

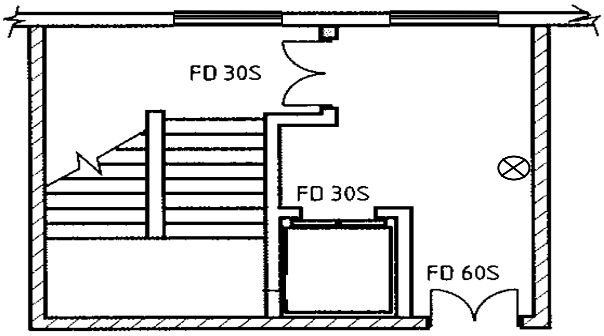
2.27.1.1 Where a building is provided with a wet or dry rising main, the outlet valves will be placed within a ventilated lobby at each floor level. The lobby will usually be ventilated using openable windows or may have a series of ducted vents (see Diagram 25).



⊗ Rising main outlet point.

Diagram 25 – Some Optional Layouts

2.27.1.2 The staircase serving each floor level will also be provided with either openable windows on each floor level or, alternatively, be pressured (see Diagrams 26 and 27).



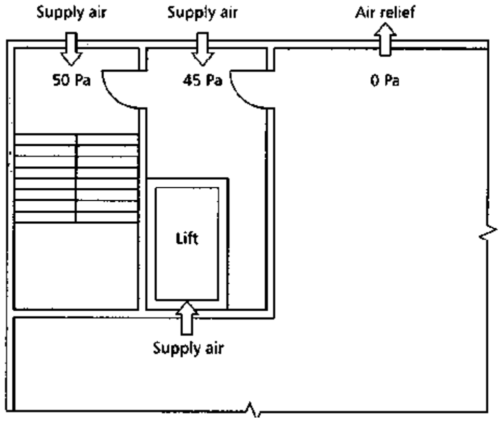


Diagram 26 **Diagram 27**

2.27.1.3 The purpose of both the ventilation and the pressurisation is to permit Firefighters to maintain the staircase essentially smoke-free so that a bridgehead can be formed and utilise the staircase without the need for BA. The working duration of BA commences once BA wearers leave the staircase, so permitting a greater period of time firefighting. Without a clear staircase, most of the BA working duration would be spent whilst ascending and descending the stairs.

2.27.1.4 The term "ventilation" with reference to the staircase and lobby refers to openable windows most commonly of a minimum of 1 m^2 per floor level. An alternative to openable windows at each floor level may be a 1.5 m^2 ventilation opening at the highest point of the staircase, this vent will often be automatic or remotely operated.

2.27.1.5 No point on any floor level should be located further than 40 m in a direct line from a fire main outlet valve. Allowing for internal diversions and obstructions, the actual distance from the most remote part of a floor to a fire main outlet valve should never exceed 60 m. For Firefighters, the significance of this is to know how many lengths of hose to lay out in the lobby prior to commencing an attack.

2.27.2 PRESSURISED STAIRCASES/LOBBIES

2.27.2.1 A pressurised staircase will be immediately obvious to Firefighters because there will be no openable windows at any floor level.

2.27.2.2 It is **<u>ESSENTIAL</u>** that an IC prevents Firefighters from breaking windows in a pressurised staircase as this will completely override the in-built smoke management design.

2.27.2.3 One significant advantage of a pressurised staircase is that the design standard permits firefighting hose to hold a door ajar and the pressurisation will overcome the fire pressure and prevent the smoke from entering the staircase.

2.27.2.4 **BE AWARE, PRESSURISATION WILL FORCE AIR IN THROUGH AN OPENED DOOR AND INCREASE THE POTENTIAL FOR A BACKDRAUGHT.**

2.27.2.5 Due to the nature of the use of pressurisation in building design, each building may have its own individual characteristics. Therefore, it is essential that Firefighters have a pre-plan through the SOP 12 process to determine the correct options for firefighting in each individual building.

2.27.3 SEQUENCE OF ACTIONS

Ideal Options

2.27.3.1 After an IC has made a reconnaissance of the fire and decided to use the fire main to attack a fire, he/she will establish a bridgehead 2 floors below the fire floor on a suitable landing in the staircase.

2.27.3.2 It is important to open **ONE** window on the fire floor level or one floor above inside the staircase in order to utilise the stack (chimney) effect to create an up-flow of fresh air from the ground floor door (left open). The stack effect will be reduced if Firefighters open lots of windows at immediate levels.

2.27.3.3 The staircase should remain relatively smoke-free, provided the fire doors are reasonably intact. Where this is not the case, the IC may have to consider relocating the bridgehead at an appropriate level below the smoke or to the ground level.

2.27.3.4 The IC will confirm that the lobby on the fire floor is smoke-free and safe to enter. It must be recognised that in taking the jet up from a lower floor and in through the doors from stairs, the jet will hold open the smoke doors and the result may smoke-log the staircase.

2.27.3.5 Considering the lobby as relatively smoke-free, Firefighters shall enter the lobby and open the window to permit an exit path for smoke. The Firefighters shall then deploy and charge a jet consisting of 2 x 25 lengths of hose. At this point the lobby should still be relatively smoke-free (see Diagram 28).

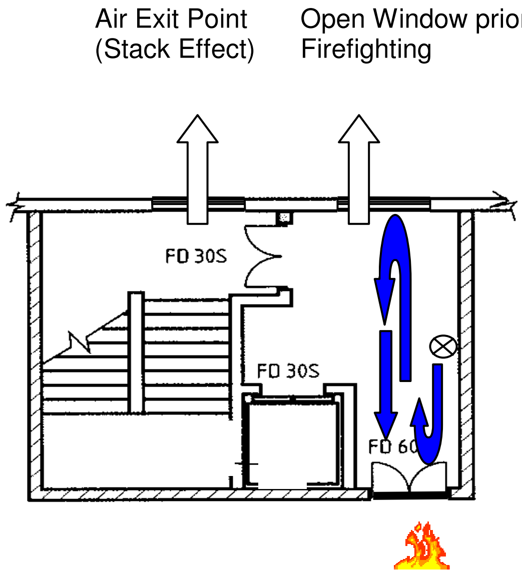


Diagram 28

2.27.3.6 The BA Entry Control Officer will consider the point of entry as being the doors from the stairs to the lobby on the fire floor.

2.27.3.7 The BA Team will enter the lobby and using the jet, enter the building to firefight. The result will be the smoke-logging of the lobby as the hose holds open the smoke doors. The smoke can exit the lobby via the open window and this will prevent a pressure build-up against the smoke doors to the staircase (see Diagram 29).

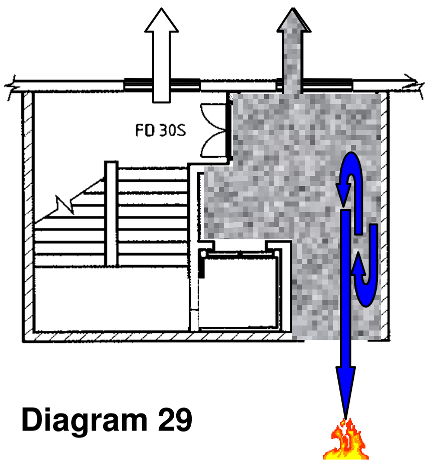


Diagram 29

2.27.3.8 The IC will provide a covering jet, when possible, but take into consideration the effect on holding open fire doors and permitting smoke-spread.

Other Options

2.27.3.9 Where an IC finds the lobby on the fire floor to be smoke logged, a jet shall be deployed from the fire main outlet on a floor below the fire. The jet will enter the staircase, upwards and into the smoke-filled lobby, providing protection for the BA Teams (see Diagrams 30 and 31). The BA Entry Control Officer shall consider the point of entry as being the doors from the Bridgehead into the staircase.

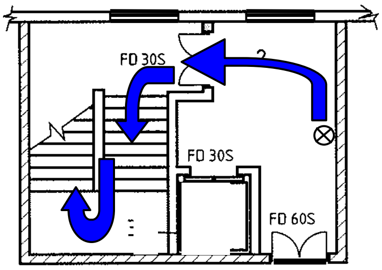


Diagram 30

2.27.3.10 At this time the BA crew have an option (resources permitting) of venting the lobby and deploying a jet from the fire main on the first floor. The first jet can then be withdrawn into the staircase to act as a covering jet and the jet at fire floor level can be used to firefight (see Diagram 32). This option permits the doors from the lobby to the staircase to be closed, reducing the chances of compromising the bridgehead.

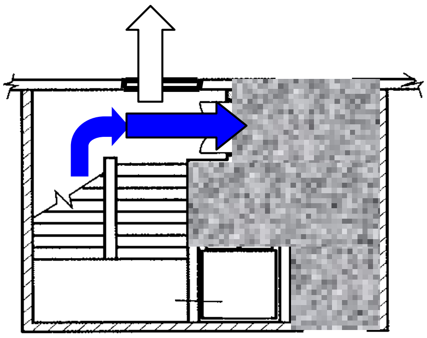


Diagram 31

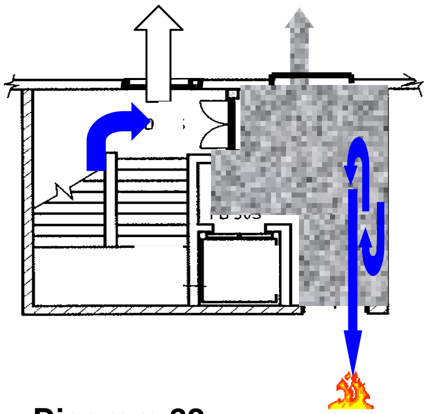


Diagram 32

2.27.3.11 Where the resources do not permit, the IC may decide to use the jet from the lower floor level to firefight. This is an acceptable option but the IC must expect additional smoke leakage into the staircase and a covering jet will be required from a lower floor level.

3 – SECTION C

3.1 FLAMMABLE RANGE

3.1.1 Any flammable gas (this includes gases contained in smoke such as CO) requires a mixture of gas and air inside a definite concentration level for ignition to occur. CO requires a lower concentration level of 12.5% of CO (and thus 87.5% air) before it will burn; this is called the lower explosive limit (LEL). At concentrations above 74% of CO (16% air), it will not ignite – upper explosive limit (UEL). Thus, the flammable range of CO is 12.5–74.2% **in air**. If there is an abundance or deprivation of oxygen in the atmosphere, these figures will no longer be valid.

When a fire occurs inside a closed up room, the fire will burn up the fuel and oxygen until one of these is used up. If the fuel is gone, the fire will self-extinguish but if the air is used up, the fire will subside but not fully extinguish as enough air can be drawn in around doors and windows to maintain some element of fire.

3.1.2 When a fire burns freely with unlimited fuel and oxygen supply it can be represented as:

$$\mathbf{C + C + O_2 \Rightarrow CO_2 + CO_2 + O_2}$$
$$\mathbf{+ O_2}$$
$$\mathbf{+ O_2}$$

C = Carbon atom (the key component in all flammable fuels);
O_2 = Oxygen molecule and consisting of 2 oxygen atoms;
CO_2 = Carbon Dioxide molecule;
CO = Carbon Monoxide molecule.

3.1.3 When there is limited oxygen such as in a closed up room, the combustion process will result in the production of CO:

$$\mathbf{C + C + C + O_2 \Rightarrow + CO + CO + C}$$

As there is not enough oxygen for one molecule to "pair-off" with each carbon atom, the oxygen molecule will split with one oxygen atom per carbon atom and result in the production of CO, which is one of the major components of the flammable atmosphere. The reason the CO does not immediately ignite is that it is below its LEL, with insufficient oxygen for combustion.

If a door or window is opened to permit oxygen to enter the room, the gases are now inside their flammable range; if the gases are at a temperature above 600°C, then the CO mixture will auto-ignite and the result will be a fire ball moving through the flammable atmosphere:

$$\mathbf{CO + CO + O_2 \Rightarrow CO_2 + CO_2}$$

3.2 FIRE RESISTANCE OF BUILDING COMPONENTS

3.2.1 DOORS

3.2.1.1 A door within a domestic property can be expected to hold back smoke for some considerable time and if the room is well sealed, a closed door will encourage smothering of the fire by restricting the oxygen flow into the room.

3.2.1.2 A standard door can be assumed to hold back a fire for approximately 20 minutes and the following photographs demonstrate how even the most basic "egg box" (Photograph 1) type door has restricted fire spread. It is difficult to comprehend but these 2 rooms (Photographs 2 and 3) were adjacent and the closed door (Photograph 1) is proof of the potential benefits in reducing heat/smoke-spread. Firefighters can use the benefit of closed doors to their advantage by protecting a staircase and extending the tenability of a staircase for escape or rescue purposes.

Photograph 1 – the room door demonstrating the benefit of closure

Photograph 2 – the room of origin of the fire

Photograph 3 – the adjoining room on the ground floor

3.2.1.3 A purpose-fitted fire door with self closer, intumescent strips, etc, will act in a similar manner to a domestic door, except that the fire door is tested and intended for at least 30 minutes of fire/smoke containment.

3.2.2 WINDOWS

3.2.2.1 Normal glazing will suffer 2 basic effects when exposed to fire:

Thermal Shock

- Thermal shock arises from rapid heating of the glass, resulting in expansion and cracking which may cause the glass to expand beyond the constraints of the window frame and shatter or break into large pieces, thus venting the fire.

- This breakage of glass can occur very rapidly and result in uncontrolled venting of a fire compartment.

Softening/Melting

- Where glass is subjected to a slow or indirect heat build-up, it will soften at approximately 500°C and melt at approximately 700°C. As the glass softens, it will sag much in the manner of a wet towel. In sagging, the weight of the glass will pull downwards and leave a gap at the top of the frame, again resulting in venting. The main difference between cracking and sagging is that sagging is a more gradual process.

3.2.2.2 **Fire Resistant Glass**

- Georgian wired glass will normally hold back a fire for at least 30 minutes. The wire in the glass conducts the heat more evenly through the pane and reduces thermal shock. When the glass softens, the glazing is reinforced or held together by the wire mesh and it prevents/reduces sagging, thus maintaining the integrity of the window.

- Intumescent/laminated glass is 2 panes of glass with a clear sheet of material sandwiched between them. On exposure to heat, the central core of the pane will often become opaque but will maintain the integrity of the pane in much the same way as the Georgian wire.

3.2.2.3 **Double Glazing**

Double glazing will not have a significant increase in the time from exposure to heat until venting occurs; the delay is in the region of 30-60 seconds longer than a single pane of glass.

3.2.3 WINDOW FRAMES

3.2.3.1 PVC window frames will soften and melt at relatively low temperatures (approximately 300^{o}C), thus may result in sudden venting if the glass falls out of the window frame.

3.2.4 GYPSUM PLASTERBOARD ON CEILINGS AND WALLS

3.2.4.1 12.5 mm plasterboard with taped joints or covered in plasterwork is normally considered as providing 30 minutes integrity for fire, that is, it will take more than 30 minutes for a fire to make its way through to the other side. Plasterboard sheets can be double thickness (25 mm) with the joints staggered; this will provide 60 minutes of fire protection.

3.2.5 CONCRETE BUILDING BLOCKS AND BRICKS

3.2.5.1 A 100 mm wall built from blocks or bricks will provide 60 minutes of fire resistance.

3.2.6 UNDERSTANDING THE IMPORTANCE OF FIRE RESISTANCE

3.2.6.1 Where fire resistance can be reasonably predicted, eg, 30 minutes integrity for a Gypsum ceiling, then an IC's DRA will consider the pre-burn time prior to his/her arrival, eg, time of ignition to summoning of assistance (factors – AFA, waking occupants, high fire load and rapid fire development) and also time from fire alert until arrival (travel time, etc).

3.2.6.2 Where time of ignition to time of arrival may be close to 30 minutes, an IC may consider failure of a ground floor ceiling, resulting in the fire spread to the first floor. This scenario occurred at a fire in Bliana in Wales (1996); the fire spread ignited the pyrolosis vapours on the first floor and resulted in a backdraught, with fatal consequences for 2 Firefighters.

CONCLUSION

Ventilation is defined as "*The removal of heated air, smoke and other airborne contaminants from the structure and their replacement with a supply of fresher air*" - Fire Service Manual, Volume 2, Fire Service Operations: *Compartment Fires and Tactical Ventilation*.

Tactical Ventilation **MUST be planned, resourced and communicated** and form part of the overall tactical plan. *This plan must be continually reviewed as part of the IC's ongoing DRA.*

To effectively plan ventilation, personnel must have an understanding of:

- the behaviour of fire within a compartment;
- how the design of buildings impacts on firefighting tactics;
- how to effectively ventilate.

It must be remembered that as soon as a Firefighter enters a building or a jet is directed through a window, then the ventilation within that compartment is being impacted upon. This SOP is designed to assist the IC in ensuring that these changes have a positive impact on his/her overall tactical plan.

Before the IC starts to ventilate, he/she should ascertain the:

- location of the fire;
- location of any occupants;
- location of any Firefighters committed;
- fire loading within the building;
- use of the building;
- structure of the building;
- extent of fire;
- wind direction/strength.

A clear plan of action, properly communicated and co-ordinated, can make the difference between avoidable fire spread or a fatal backdraught. One of the key aspects to controlled tactical ventilation is strict supervision and the application of Incident Command System principles.

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16 January 2008