

Fighting fires: using positive pressure ventilation

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1 Scope

This document examines the hazards, risks and controls that relate to the use of Positive Pressure Ventilation (PPV) during operational incidents.¹

PPV can be achieved by forcing air into a building using a fan. These fans force air into the structure to create a slightly higher pressure inside the structure relative to the external atmospheric pressure.

This pressure differential drives heat, gases and other products of combustion from parts of the structure through an outlet vent to open air.

Activities which involve additional specific, significant hazards are covered in generic risk assessments (GRAs).²

As with all GRA's this assessment provides a starting point for brigades to conduct their own assessments within the context of local conditions and existing organisational arrangements.

Reference is made throughout the document to technical, and other reference material.

2 Significant hazards and risks

There are many studies available, which illustrate the hazards to health, (both chronic and acute as well as cumulative and immediate) of exposure to heat and the products of combustion. These products include large quantities of carbon monoxide (CO) as well as the wide variety of toxic and/or carcinogenic products, which may be present during and after a fire.

The displacement of this heat and the combustion products by cool clean air should significantly enhance the health and safety of all persons who are in or need to enter a building or compartment fire.³ The use of a PPV fan can improve conditions for firefighters by both rapidly improving visibility and reducing air temperatures between the inlet opening and the fire.⁴

At its best, PPV can result in greatly increased visibility in smoke filled areas even during the firefighting stage⁵ although the benefits of using PPV are demonstrable, there are a number of hazards and risks associated with its use including:

- Uncontrolled spread of fire
- Worsening of internal conditions
- The noise of operations

2.1 Uncontrolled spread of fire

It has been suggested that the most significant risk arising from the use of PPV is the possibility that either the occupants of the building or fire service personnel may become trapped between the fire and the outlet vent.⁶ This is a fact in all ventilation operations not just PPV. Tests⁷ have shown the risk to be much lower than first thought and the benefits far outweigh the disadvantages.

Ignition of heated smoke as it mixes with air (oxygen) at the outlet vent is a potential hazard to personnel, both from direct contact and from secondary fires caused by this ignition. This event will only occur if the vented smoke is above its auto-ignition temperature. The risk is easily controlled by awareness training and by providing a covering jet at the outlet vent.

One of the key features of ventilation is that pressurised air will always take the path of least resistance. Particular types of building construction and building conversion can present hidden voids that will offer a path for heated gasses to travel unseen through the building which may cause unseen fire spread.

Where 'engineered solutions' are installed, such as roof vents, smoke control systems etc, their

relevance as to whether to ventilate is mainly proportional to the degree of knowledge of the Incident Commander. Where the system design is known PPV may often be used to advantage.

However, if it is known that an engineered solution is present, but the details of its operation and design limitations are not well understood, the use of PPV may lead to unexpected routes of fire spread.

2.2 Worsening of internal conditions

The use of PPV is an extension of natural ventilation and the same principles apply to both. PPV is used to accelerate the effects of natural ventilation. As with any ventilation tactic, PPV should not be applied until it is certain that the location of the fire is known and that there is an outlet vent.⁸

The use of forced ventilation is likely to increase the intensity of the fire, and if incorrectly used it may increase the risk of injury to any persons within the building.

Recent studies have indicated that the likelihood of increasing the risk to the occupants of the building are far outweighed by the benefits of, rapid improvements in the internal conditions and by more effective fire attack.

Experience has shown that it is possible for the flames in gas fired heaters to be "blown out" during the operation of PPV. In certain circumstances this can lead to a build up of unburnt which could lead to the development of a potentially explosive atmosphere.

2.3 Noise of operations

The noise of petrol driven fans can will add to the normal operating noise levels at a fire and will lead to localised communication difficulties on the fire ground. In addition, excessive noise levels add to the psychological stress to firefighters. The chronic effect as well as both short term and long term hearing damage. (temporary/permanent threshold shift and tinnitus)

3 Key control measures

When applying PPV during firefighting operations, there a number of key risk control measures that brigades will need to consider, including:

- Preplanning
- The training of crews
- Command and control
- Fire ground communications
- Application techniques
- A phased approach to introduction

3.1 Pre-Planning

When purchasing PPV equipment brigades will need to consider the following:

- The suitability of the selected fan⁹
- Fan performance¹⁰
- The necessary stowage and maintenance arrangements
- The necessary mobilising arrangements
- The training of personnel
- The manual handling implications¹¹

- The levels of noise¹²

3.2 The training of crews

PPV should not be introduced as part of fireground operations until fire-fighters have a clear understanding of the use of ventilation and its effect on fire behaviour.

Fire-fighters should also be aware of the advantages and disadvantages of PPV and that it can be used as a firefighting tool.

The supplements to the Manual of Firemanship 'The Behaviour of Fire - Compartment Fires' and 'Behaviour of Fire - Tactical ventilation of Buildings and Structures' have been combined in one manual and updated to include the results of this research into PPV.¹³

A video is available from the Home office entitled 'Positive Pressure ventilation'¹⁴ which outlines the principles and application techniques of PPV.

3.3 Command and Control

PPV is only one element of the overall firefighting strategy and must be co-ordinated with other activities to ensure that differing requirements are not in conflict. The decision to use PPV will have implications for safety and resources.

Inlet and outlet vents should be clearly identified. Obstruction of either inlet or outlet vents could have serious consequences.

The decision to initiate PPV will only be made by the Incident Commander following a dynamic risk assessment, which should include the availability of sufficient resources. Ideally the unit should be deployed in readiness, but should only be got to work on the instructions of the Incident Commander who will consider:

- Size of compartment to be ventilated.
- The location of the fire/fires.
- If persons reported, establish location of casualty.
- Check for backdraught/flashover conditions.
- Wind direction.
- The location for of the outlet vent to be created.
- Jets to cover outlet vent/adjacent structures.
- The appropriate tactic.
- The location of the Entry Control Board may need to be away from petrol driven fans due to their operating noise.

Having conducted the dynamic risk assessment the Incident commander should recognise those situations when PPV should not be used for example:

- If there is a potential for backdraught.
- If there is a potential for flashover
- If communications are not established between internal crews and the Incident Commander.
- If the wind strength and direction will overcome the effects of the fan.

A fire that has produced potential backdraught conditions should discourage the use of PPV as the air movement may potentially mix the unburned gases causing ignition. This situation is further exacerbated as the air movement may also create an ignition source from remaining smouldering material.

Ventilating a compartment will reduce the temperature and remove the products of combustion, therefore the onset of flashover will be prevented.

Where flashover is imminent there is a transitional stage from a fuel controlled fire (growing fire) to a ventilation controlled fire (fully developed fire). Maintaining the supply of air to the compartment may allow the transition to continue, supporting the ignition of flammable gases.

Where the compartment is small and the relative inlet/outlet sizes are favourable the use of PPV may not cause any difficulties. However, where the compartment is large, or the above circumstances are not favourable, the use of PPV is less likely to be effective.

A thorough dynamic risk assessment is important to ensure the correct decision is made as to whether or not to use PPV.

Once PPV has commenced, entry to the structure will have to be carefully controlled and usually only through the inlet opening. (Obstruction of either inlet or outlet vents could have serious consequences.)

At larger incidents it may be appropriate to appoint an officer to co-ordinate ventilation operations, however the Incident Commander must retain overall responsibility for ventilation throughout the incident. (The appointed officer will liaise directly with BA crews in the building to control opening and closing of windows and doors. The need to co-ordinate the activities between fire attack and ventilation crews is paramount).

3.4 Fireground communications

Good fireground communications are essential where PPV is deployed as part of firefighting procedures.

There should be communications between the IC, PPV operator and any personnel within the building. This will allow the IC to monitor the effectiveness of the PPV and the fire conditions within the building.

Informing oncoming appliances and all fireground personnel that PPV is in operation. All personnel to be made aware of any changes regarding inlet or outlet vent locations.

3.5 Application Techniques

3.5.1 Fan Placement

The number and placement of fans is crucial to the successful application of PPV techniques. There are two basic types of fan available in the UK at present. One produces a cone of air to seal the opening; the other produces a narrower flow of high-speed air which entrains further air.

Single Fan

A single fan must be placed so that the airstream is aimed at the centre of the door and the cone of pressurised air just covers the entrance opening, too close and it will not fully cover the opening, too far away and the air in-flow will be drastically reduced. (Placing the fan the same distance away from the opening as the door height is a good general rule of thumb (See Fig.2)).

If the inlet vent is not sealed it is possible for heated gases and smoke to move towards incoming firefighters.

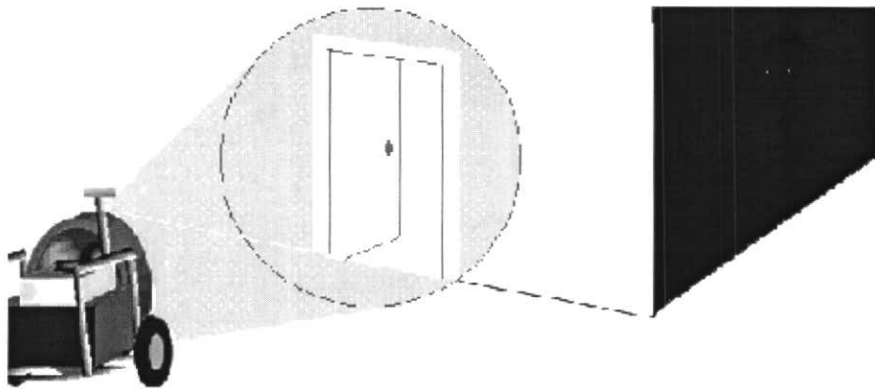


Fig 2: Siting the fan.

Multiple Fans

To increase airflow into a structure more than one fan can be used. The ideal position is to place two units in series, with the largest 1m from the opening, and using the second fan to seal the opening. (See Fig. 3)

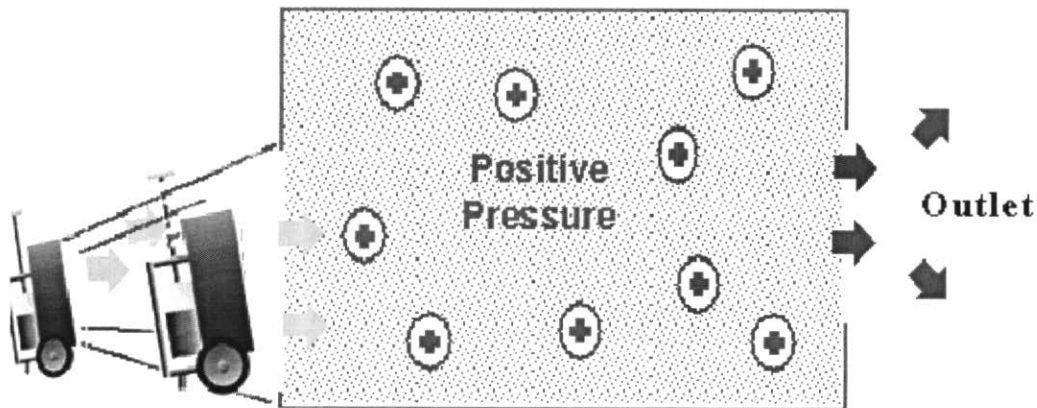


Fig3:Using fans of different size in series.

If fans of different size are used, the largest fan should be placed nearest the inlet to give increased airflow, the smaller one at the rear creating the seal.

Where entrance openings are larger, the units can be arranged in parallel, although it is more effective to reduce the size of the opening, if possible. (See Fig. 4)

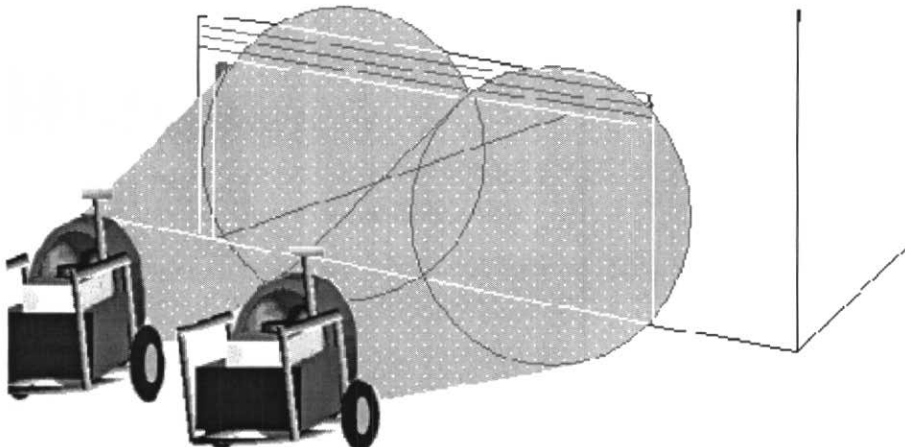


Fig 4: Using two fans in parallel on a large opening.

3.5.2 Outlet Vents

The outlet vent must always be created first, ideally within the affected compartment. The positioning of the outlet vent will be dependent on the availability of natural openings, plus the prevailing wind direction and force.

The latter can have an adverse influence, so as in any ventilation operation, maximum efficiency will be achieved by utilising the prevailing wind to advantage.

The size of the opening should be slightly less than the size of the inlet as this facilitates the build up of positive pressure, the size may be increased if more than one fan is in use.

Before the outlet vent is opened, the vent should be covered with a charged branch. The branch can be used to cool the smoke and gases as they come out to prevent secondary ignition but **UNDER NO CIRCUMSTANCES SHOULD THE WATER BE DIRECTED IN THROUGH THE VENT** when ventilation is taking place. This will interfere with the ventilation process and could place firefighters inside the building at risk.

Control of the outlet vent size and location is critical to the success of PPV and indiscriminate ventilation, e.g. random breaking of windows other than the outlet vent should be avoided.

Sequential Ventilation

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

The doors to all rooms should be closed initially, then starting with the room nearest the fan, 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.

For large volume buildings it may be possible to use sequential ventilation if the area can be divided into smaller compartments. This will dramatically improve the effect of PPV.

3.5.3 Airflow management

It is important to control the flow of air between the inlet opening and the outlet vent. This may require closing windows and doors that are already open. All personnel should be kept aware of the position of the fan and the outlet 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, hence the need to co-ordinate the activities between fire attack and ventilation crews.

A common mistake is for BA wearers to stand in doorways and dramatically reduce the airflow through the building.

When planning the airflow through a building it is vital that

- the outlet vents are used/created in the right place
- the outlet vents are of a size and number that air flows efficiently
- the airflow route is effectively managed

3.6 A phased approach to introduction

PPV can be applied at any point in time from first arrival of crews (see Fig 5 below), to just before the last appliance leaves the scene.

The safe and effective use of PPV require training and a dynamic risk assessment prior to use. There are situations when the use of PPV will be inappropriate, or counter productive. The emphasis on safety must prevail at all times when the decision to use PPV is made, just as with any other fireground tactic.

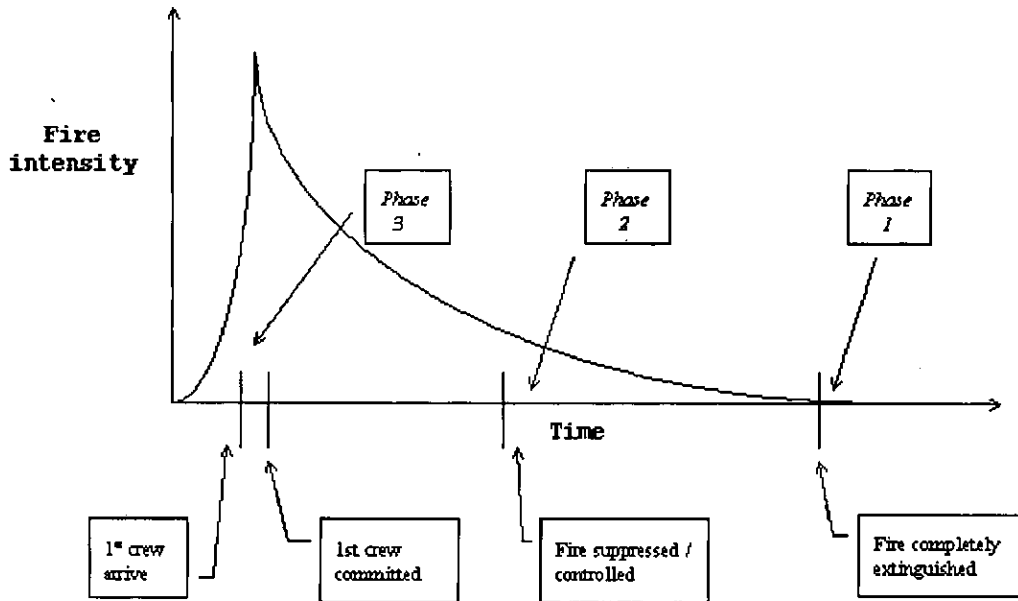


Fig:5 Incident Phases

It is strongly recommended that all brigades consider a phased approach to the introduction of PPV as a firefighting tactic. The diagram above illustrates the growth of a fire and the three phases in which PPV should be introduced.

3.6.1 Phase 1

Brigades should first use PPV during the closing stages of an incident. This will normally be after the fire is extinguished. This is often referred to as smoke clearance or post fire ventilation. The use of PPV will substantially reduce the time taken to remove the heat and smoke from a building where the fire has been extinguished.

3.6.2 Phase 2

Once crews are competent in the application of PPV during the closing stages of an incident, PPV can then be introduced while the fire is still burning, but is controlled.

Examples of this phase include when the crew has located the fire and suppressed it, but not necessarily completely extinguished it to the point where there is nothing but cold ashes remaining. Provided that the internal crew and the Incident Commander are confident that the application of PPV cannot worsen the situation, then commencing

PPV at this point is a very useful part of the learning process for both BA wearers and Incident Commanders.

Internal crews can immediately report the success (or otherwise) of ventilation, and external crews and Incident Commander gain valuable experience in reading the effectiveness of PPV from outside the building.

This is an invaluable stage in preparation for Stage 3. (Crew safety is increased by ensuring that BA wearers are not between the outlet vent and the fire prior to commencing PPV.)

3.6.3 Phase 3

Once crews are competent in the application of PPV while the fire is still burning but under control, Brigades can consider the introduction of PPV in the initial stages of an incident, on first arrival, prior to committing BA crews. This will create the best possible environment for crews and casualties.

This phase requires a greater degree of experience from the Incident Commander, as they must be able to estimate the effects of PPV with little knowledge of the internal layout, and no crews inside the building to provide them with feedback. It is also the point at which the greatest benefits to BA wearers is realised.

4 Fire service risk assessment summary sheet

TASK	HAZARD/RISK	LEVEL OF RISK	RISK GROUPS*	CONTROL MEASURES
Transporting fan into position	Manual handling	Med	A,B,C	- Provision and use of equipment to PUWER 1992
	Slips, trips and falls on uneven ground	Med	A,B,C	- All Personnel to wear correct PPE minimum of full firefighting kit
	Broken glass, sharp edges	Med	A,B,C	- All personnel under full supervision
Creating inlet/outlet vents	Backdraught	Med	A,B,C	- As above plus - All personnel to receive information, instruction and training in: -Correct methods of entry -Positive Pressure Ventilation -Recognition of flashover and backdraughts
	Flashover	Med	A,B,C	- All personnel to wear full protective clothing including flashhood, HO Specification (A28) and BA - BA crews to be provided with spray jet - All personnel under full supervision - Communications between I.C., BA Crews and PPV Operator
	Normal hazards associated with firefighting	Med	A,B,C	
Commence PPV	Backdraught	Med	A,B,C,D	- Establish and maintain continuous path - Personnel aware of hazards received "passive training" - Correct level of PPE - Effective communications and cordon control - Inform all personnel that PPV is about to commence - Covering jets - BA crews protected by spray jet - All personnel to wear appropriate level of PPE full fire kit as minimum including flashhood
	Increased fire intensity	Med	A,B,C,D	
Sequential Ventilation	Backdraught	Med	A,B,C,D	- Communications -All personnel under full supervision
	Flashover	Med	A,B,C,D	
	Normal hazards associated with firefighting	Med	A,B,C	

* A = Wholetime, B = Retained, C =Volunteers/Auxiliary, D = Non service personnel, E = Public

5 Further Information

Manual of Firemanship Volume 2 and HomeOffice Video Series Flashover, Backdraught & Tactical Ventilation.

DFM & DCO Letter 8/97, management of Physiological Stress.

Study of the Physiological Effects of Wearing BA (Institute of Occupational Medicine).

Fire research and development group.

- Assessment of the use of P.P.V. in Domestic Properties FRDG (Fire Research Report & Memorandum 17/96).

- Research into Venting FRDG (Research Report 68/96).

- P.P.V. a study of overseas experiences FRI3G (Fire Research Reports & Memorandum 8/96).

PPV fan manufacturers.

Members of the PPV working group.

6 Technical References

1 Fire Service manual Volume 2 Fire Service Operations, Compartment Fires and Tactical Ventilation. [^](#)

2 Table of Contents, Volume 3 Guide to Operational Risk Assessment [^](#)

3 Research into Venting FRDG (Research Report 68/96) PPV a study of overseas experiences FRDG (Fire Research Reports and Memorandum 8/96) [^](#)

4 Assessment of the use of PPV in Domestic Properties FRDG (Fire Research Report and Memorandum 17/96) [^](#)

5 Research into Venting, News of Home Office Fire Research for the Fire Service Issue 16 Home Office, Winter 1993 [^](#)

6 Chapter 7, Fire Service Manual, Volume 2 Fire Service Operations, Compartment Fires and Tactical Ventilation [^](#)

7 Measurements of the firefighting environment made during Tyne & Wear Metropolitan Fire Brigade's PPV trials at The Fire Service College (FRDG Research Report 8/98). Tyne & Wear Metropolitan Fire Brigade's PPV trials at Chiltern Fire. [^](#)

8 Chapter 8, Fire Service Manual, Volume 2 Fire Service Operations, Compartment Fires and Tactical Ventilation [^](#)

9 The Provision and Use of Work Equipment Regulations and Guidance 1992 [^](#)

10 Page 43, Fire Service Manual Volume 2 Fire Service Operations, Compartment Fires and Tactical Ventilation [^](#)

11 The Manual Handling Operations Regulations and Guidance 1992 [^](#)

12 Guidance on the Noise at work regulations HSE 1998. ISBN 1 7176 1511 1 [^](#)

13 The Fire Experimental Unit's backdraught simulator, Fire Research News : News of Home Office Fire Research for the Fire Service, Issue 21, Home Office, Winter 1997. [^](#)

14 Video reference [^](#)

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