

SMOKE REMOVAL

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INTRODUCTION

The primary goal of effective ventilation operations is the reduction or removal of smoke, heat, and fire gases (contaminants) from a structure or enclosed area in a timely manner. Proper blower placement will assist in achieving this goal. This process will result in the following:

- Assist in search and rescue, extinguishment, overhaul, and other suppression operations.
- Reduce or eliminate the numerous products of combustion.
- Reduce the interior temperature within a structure.
- Improve visibility for occupants and fire suppression personnel.
- Increased safety for occupants and fire suppression personnel.
- Reduce fire loss.

VENTILATION METHODS

Plans for ventilation operations should begin by identifying the direction (horizontal or vertical) contaminants must travel to exit the contaminated area. Once the direction of travel is established, the method for moving the contaminated contents must be determined.

There are two basic methods that are utilized to pressurize a contaminated area to enhance or direct the travel of contaminants to the exterior. These are natural and mechanical positive pressure ventilation.

Natural Ventilation

As a fire burns within a confined building, the fire floor is filled with products of combustion that rise and fill all available spaces within a building. A simple method to ventilate products of combustion consists of utilizing natural convection currents. This is easily accomplished by opening doors, windows, skylights, and other similar openings. Although this method may perform satisfactorily, it is dependent on the following factors:

- Proximity of the ventilation opening to the contaminants to be removed.
- Ability of the contaminants to travel unobstructed to a ventilation opening.
- Number and size of ventilation openings.

- Direction of wind.
- Humidity.
- Temperature differential between the interior and exterior of a building.

Pressure Ventilation

Natural ventilation is a viable method that is effective within certain limitations. However, by utilizing portable blowers, the natural ventilation process can be dramatically assisted or replaced by FORCING the movement of contaminants to:

- Exit through pre-selected and/or controlled openings.
- Allow the use of ventilation openings that are remote from the contaminants to be removed.
- Overcome interior - exterior temperature differentials.
- Move contaminants to the exterior of a building through areas or openings not normally utilized by natural ventilation.
- Reduce the time necessary to ventilate a building when compared to natural ventilation operations.

PRESSURIZED VENTILATION

The current methods that are utilized to provide pressurized ventilation with portable blowers are negative and positive pressure ventilation. To examine these two methods, the building in Figure 1 will be ventilated. In this example, the building is filled with various products of combustion from a fire. The warmer gases have risen to the top of the building, and the cooler gases have settled at the bottom of the building. The door and windows are closed.

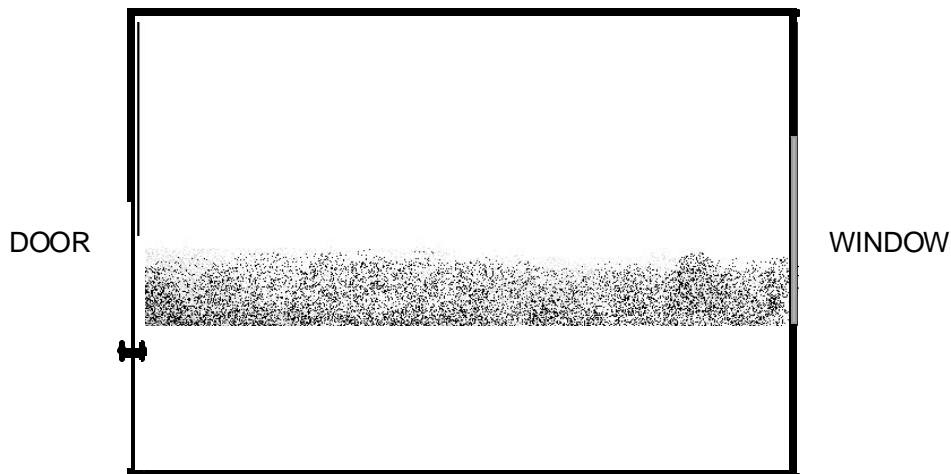


FIGURE 1

Negative Pressure Ventilation

To ventilate the building, the door is opened and a blower is placed INSIDE the building to exhaust the contaminants as in Figure 2. This method will draw the contaminants within the building through the blower and exhaust the contaminants to the exterior of the building by creating a negative pressure within the building. By opening the window, the exhausting contaminants will be replaced with fresh incoming air. Although this method performs satisfactorily, negative pressure ventilation has the following disadvantages:

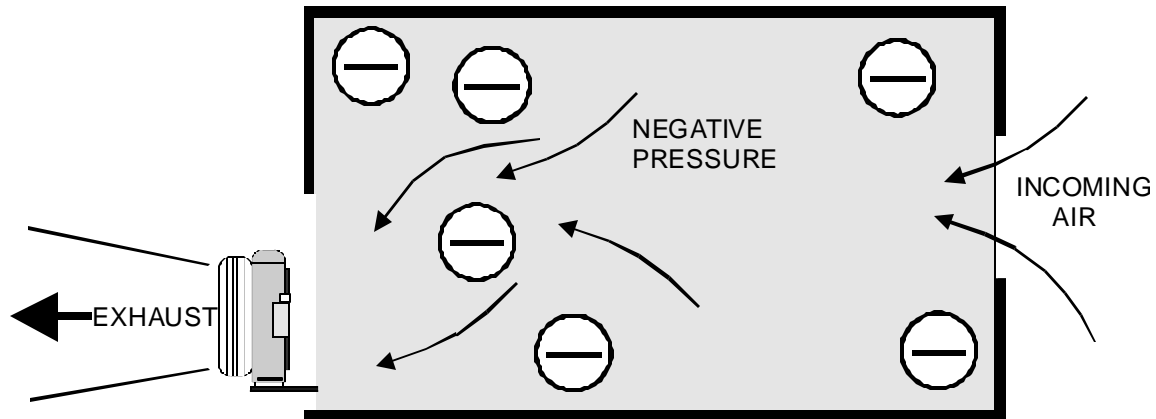


FIGURE 2

- Personnel must be exposed to hazardous contaminants to position a blower.
- Contaminants are drawn through the blower, creating additional equipment cleanup and maintenance.
- Blowers placed in doorways or hallways can block entry or exit to the building.
- To be effectively positioned, blowers suspended in doorways or windows must utilize straps, ladders, or other accessories.
- Interior blowers are not efficient in removing contaminants at the top of a room or building. Air will follow the path of least resistance, which is normally a straight line from the fresh air inlet to the blower. This limits the flow of air at the top of the area to be ventilated.

Positive Pressure Ventilation

To ventilate the building, the door is opened and a blower is positioned OUTSIDE the building as in Figure 3. This method will force clean, fresh, pressurized air inside the building and create a positive pressure (similar to blowing up a balloon) inside the building.

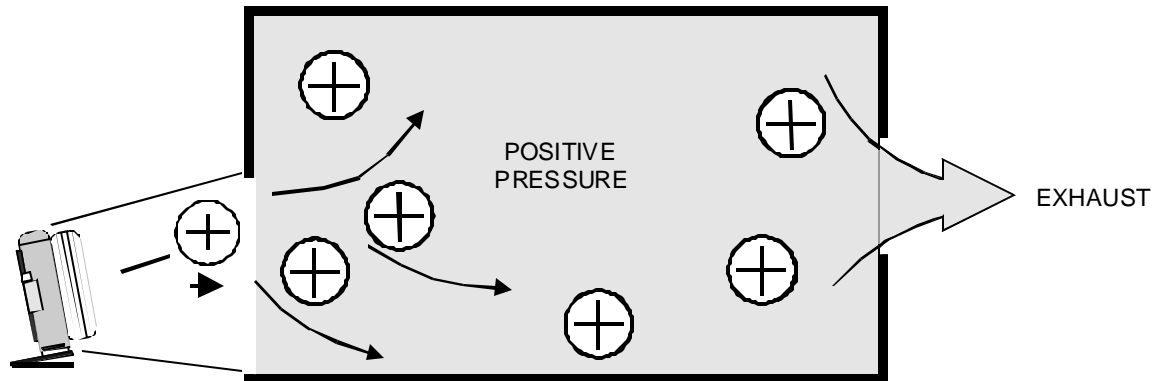


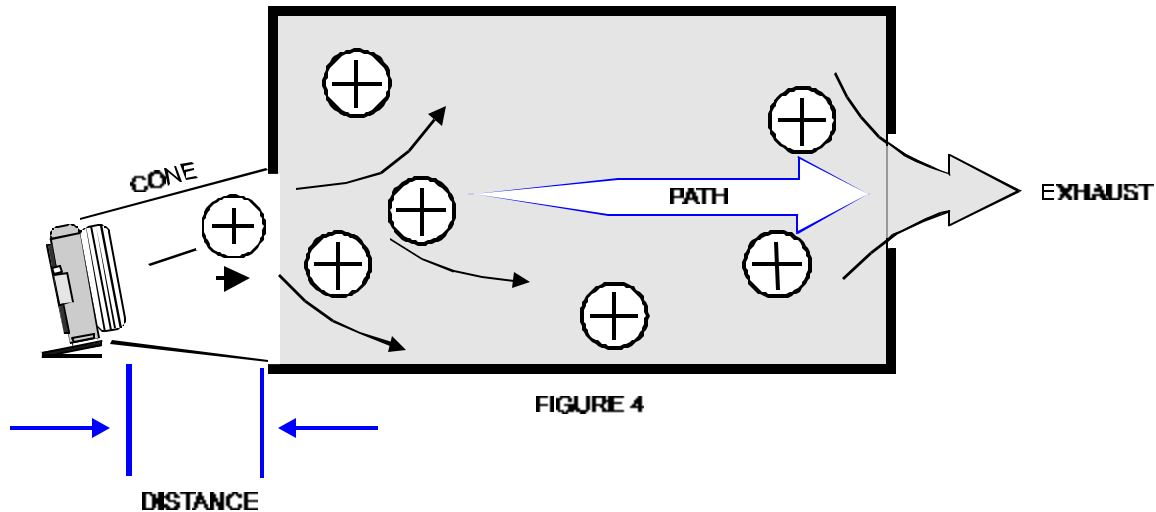
FIGURE 3

The positive pressure will be equal at the top, bottom, and corners of the building common to the pressurized air. When the window is opened, the contaminants from ALL parts of the pressurized building will exhaust to the exterior (similar to piercing a hole in a blown-up balloon). Compared to negative pressure ventilation, positive pressure ventilation has the following advantages:

- Personnel are not exposed to hazardous interior contaminants while positioning exterior blowers.
- Contaminants are not drawn through blowers, resulting in minimal cleanup and maintenance.
- Doorways, windows, and halls do not need to be blocked by blowers.
- Exterior blowers are not dependent on additional equipment or accessories for setup and operation. Additionally, less time, and in some instances, less personnel are required to put exterior blowers into operation as no other equipment or accessories are necessary.
- Reduced noise level.
- Exterior blowers are efficient in removing contaminants at the top, bottom, and corners of a room or building.
- Compared to negative pressure ventilation, positive pressure ventilation is approximately twice as effective at removing contaminants from a building.

IMPLEMENTATION OF POSITIVE PRESSURE VENTILATION

The effective implementation of positive pressure, as in Figure 4, is dependent on the entrance opening, airflow between openings, exhaust opening, weather, training and communication.



Entrance Opening

Blowers must be positioned so the cone of air issued from a blower will completely cover the entrance opening to eliminate contaminants being forced back through the "unsealed portions" of the entrance opening and being reintroduced into the pressurized building. This is accomplished by varying the distance from the blower to the entrance opening.

Air Flow Between Openings

It is imperative that the path of pressurized air between an entrance and exhaust opening be controlled to achieve maximum ventilation. If pressurized air is directed from an entrance opening to an appropriate exhaust opening (without being diverted to other openings), contaminants will be removed with the pressurized air in a minimal amount of time. Simultaneously opening multiple windows and/or doors will not facilitate a successful positive pressure ventilation operation.

Exhaust Opening

Exhaust openings can be selected to provide horizontal or vertical ventilation of contaminants. The location of the exhaust opening is dependent on the location of heat and smoke, and the prioritization of suppression operations (overhaul, search and rescue, extinguishment, etc.). The size of the exhaust opening is dependent on the size of the entrance opening, and capacity and number of blowers being utilized.

Positive pressure is most efficient when the exhaust opening (heat hole, window, door, etc.) is between three-fourths (3/4) to one and three-fourths (1 3/4) the size of the entrance opening. This variance is due to the number and cubic feet per minute rating (CFM) of blowers that are utilized. An 18 inch blower utilizes a smaller exhaust opening than a 24 inch blower. A single blower utilizes a smaller exhaust opening than multiple blowers in parallel or series configurations. Optimum efficiency is easily obtained by a combination of training and practical experience.

If a gasoline powered blower is being utilized and an exhaust odor is noticeable inside the building or area to be ventilated, this is an indicator that the exhaust opening is not large enough. The exhaust odor should disappear by increasing the size of the exhaust opening (opening another window, door, etc.)

Weather

Temperature, humidity, and rain do not have any appreciable effect on positive pressure ventilation. Although cold-damp weather conditions may limit the ability of smoke to rise, these atmospheric conditions will not limit the ability of blowers to move contaminants horizontally, and in most cases, vertically.

Wind can have an adverse effect on positive pressure ventilation, but its effect is dependent on direction and velocity. As in any ventilation operation, maximum efficiency can be obtained by utilizing the prevailing wind direction to an advantage (windward to leeward). It is most advantageous to pressurize the structure on the windward side and exhaust contaminants on the leeward side of the building. If it is not possible to utilize the prevailing wind as an advantage, positive pressure has proven effective AGAINST winds (leeward to windward) of up to 25 mph; efficiency will be reduced accordingly.

Training and Communication

The key to effective positive pressure ventilation is dependent on controlling the entrance opening, the path of the interior air flow, and the exhaust opening. These

factors can only be maintained in their proper relationship if all personnel engaged in the ventilation operation have been properly trained and are aware of the goal of the intended operation. If personnel are not assigned specific tasks, they should not arbitrarily move and/or reposition blowers or alter exhaust openings.

BLOWER PLACEMENT

SINGLE BLOWER

A single blower should be positioned so the cone of pressurized air JUST covers the entrance opening as in Figure 5. If the blower is too close to the opening, the opening will not be completely covered by pressurized air. If the blower is too far from the opening, pressurized air will strike the area around the opening, reducing the amount of pressurized air being forced inside the building. Optimum placement is dependent on the size of the entrance opening and the CFM of the blower. These two factors will regulate the distance between the blower and the entrance opening.

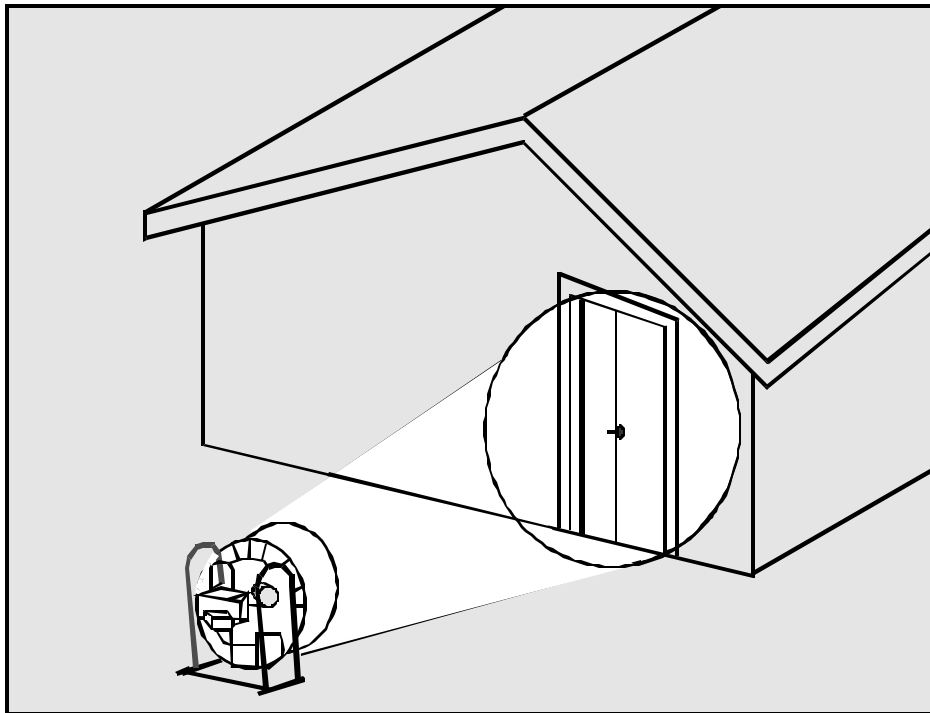


FIGURE 5

Small blowers (18") need to be moved back from entrance openings while larger blowers (24") can be placed closer to entrance openings to properly cover the opening with pressurized air. This is due to the size of the "pressurized cone" of air issued from a blower. This operation can be enhanced by "tilting" a blower. Tilting blowers at angles more than the manufacturer designed will result in a lack of lubrication to the crank shaft.

MULTIPLE BLOWERS

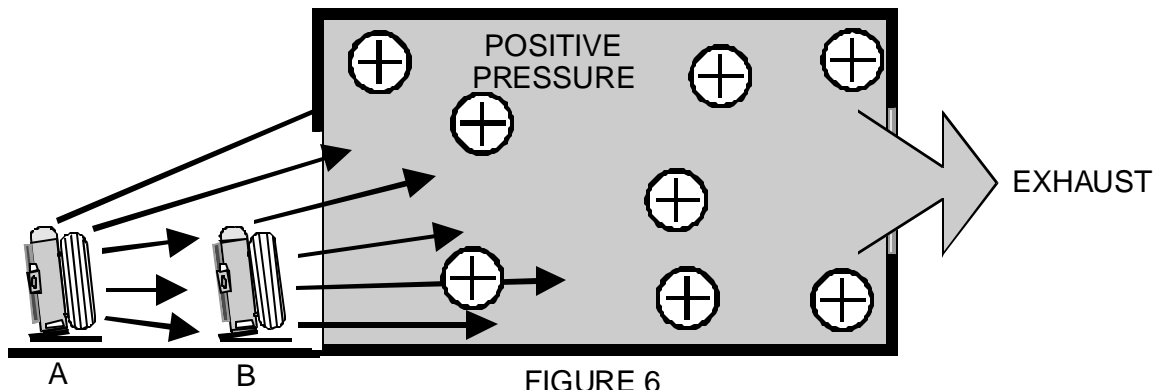
Multiple blowers can dramatically increase CFM when used in series or provide proper coverage of the opening when used in parallel. Multiple blowers can also reduce the time necessary to complete a ventilation operation.

In Series

For standard entrance openings maximum effectiveness is achieved by placing two blowers in series (in-line) with each other.

In Figure 6, Blower A is positioned about two-feet from the entrance opening. This ensures that all of the pressurized air from the blower enters the building, yet allows sufficient room for ingress/egress of personnel. Blower B is positioned behind Blower A. The proper location for Blower B is determined by the distance necessary to cover the entrance opening with pressurized air.

Blower B is utilized to cover the entrance opening with pressurized air, force pressurized air into the building, and increase the capacity of blower A by approximately 10%.



If two blowers of unequal CFM are utilized in the series position, place the large blower about two feet back from the entrance opening and utilize the smaller blower behind the larger blower to cover the entrance opening with pressurized air. This configuration will utilize the larger blower to provide most of the pressurized air for the ventilation operation while the small blower covers the entrance opening, and increases the efficiency of the larger blower.

If the area in front of an entrance opening is limited to three feet or four feet (i.e., raised porch), place the smaller blower in the entrance opening and the larger blower three to four feet back from the door. Use the larger cone of pressurized air to seal the entrance opening.

Parallel

For standard entrance openings, multiple blowers in a parallel (side-by-side) configuration are less effective than multiple blowers in a series configuration. However, for large entrance openings, multiple blowers in a parallel configuration (Figure 7), should be utilized due to their combined ability to cover the larger opening with pressurized air. The size of the opening will dictate the number of blowers that will be necessary to cover the opening with combined cones of pressurized air. Remember that some openings (i.e., loading-dock doors) can be reduced in size by partially closing the door which will reduce the size of the entrance opening that must be covered by pressurized air. Depending on the number of blowers that are available, large areas may be effectively ventilated by utilizing a combination of parallel (proper coverage of the opening) and series (increased CFM) blowers.

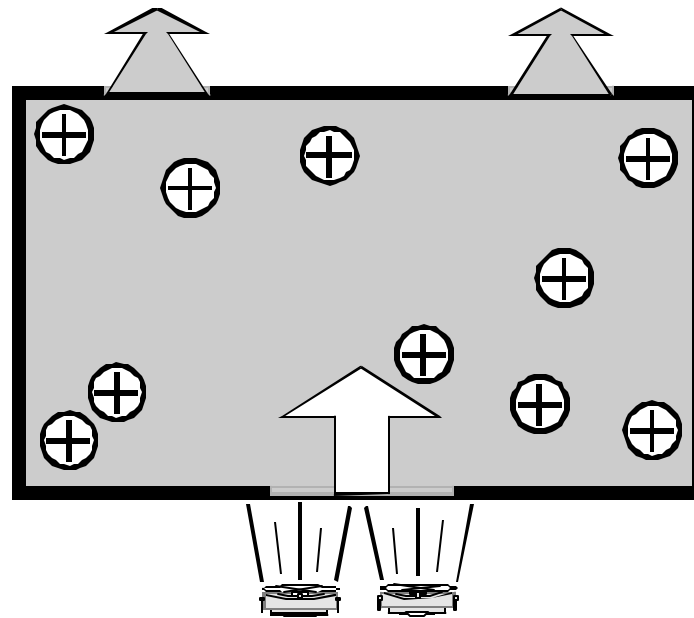


FIGURE 7

Areas Without Exhaust Openings

Areas or locations that do not have an exhaust opening (storage rooms, offices, enclosed work areas, etc.) can be effectively ventilated by using multiple blowers.

In figure 8, Blower A is positioned to provide a flow of air past the opening. This blower can be located outside the building to provide pressurized air to the interior of the building and past the area to be ventilated. Blower B is positioned in the bottom portion of the opening and will provide pressurized air that will create a positive pressure within the area to be ventilated and force the contaminants out of

the upper portion of the entrance opening. The air flowing past the entrance opening will force the exhausting contaminants to follow its direction to the exterior of the building.

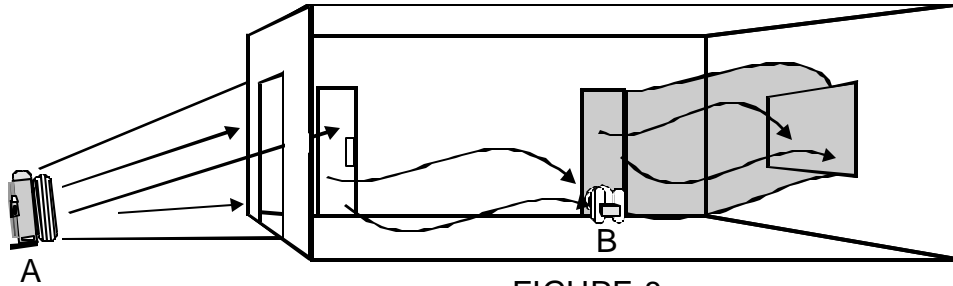


FIGURE 8

If the flow of air past the opening is not sufficient, the exhausting contaminants from the area to be ventilated can circulate back into the blower in the bottom portion of the opening. To alleviate this condition, use an additional blower (Blower C in Figure 9) to provide a sufficient flow of air past the exhausting contaminants and Blower B.

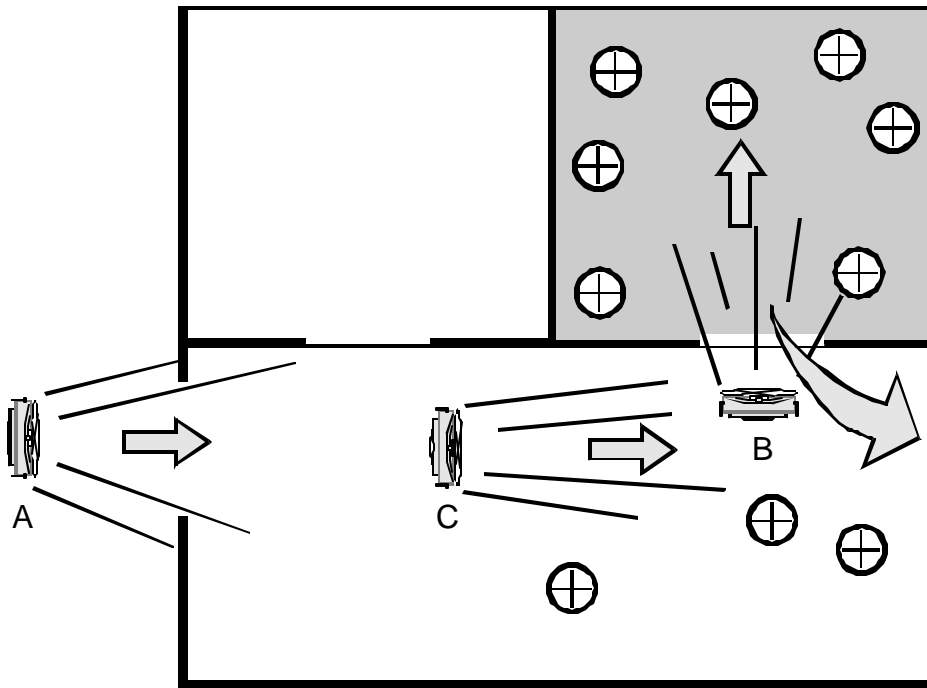


FIGURE 9

STRUCTURAL CONSIDERATIONS

Below ground areas should be treated as any other smoke removal problem with the following added considerations:

1. Use of creative methods may be required to channel the smoke i.e., use of salvage covers, additional blowers, etc.
2. The smoke that is exhausted from the below ground area in many cases will accumulate in the ground level floor (or higher) and will require evacuation from its new location.
3. Management of this smoke in the above ground area is vital.
4. Removal of the smoke at or above ground level will be accomplished using standard positive pressure ventilation techniques.

DWELLINGS

Single Story

Effective ventilation requires SYSTEMATIC VENTILATION of contaminated areas within a building. This process will provide the maximum amount of pressurized air from a blower to ventilate each contaminated area within a building. This results in maximum efficiency and minimal time for ventilation. During positive pressure operations, do not "open the structure up" as is common practice. This will reduce the flow of air through each room and increase the time for ventilation.

Additionally, remember that removing screens on windows prior to using these openings for ventilation purposes will increase the efficiency of these openings by at least 50%.

Assume that a kitchen fire, in Figure 10, has charged the dwelling with smoke. All doors and windows are closed, a blower has been positioned to cover the front door with pressurized air, positive pressure would be utilized as follows:

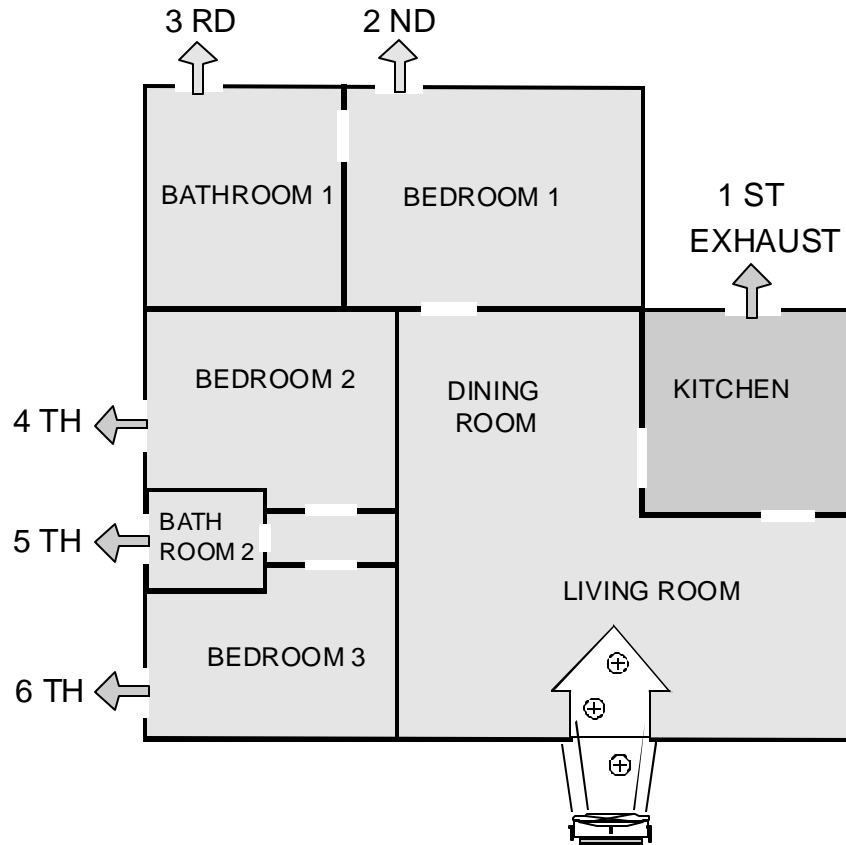


FIGURE 10

- To clear the kitchen, living room, and dining room, open the exterior door in the kitchen and both interior doors to the kitchen. When these rooms have cleared, close the exterior kitchen door.
- To clear bedroom one, open the bedroom door and window. When cleared, close the window or door.
- To clear bathroom one, open the bathroom window. When cleared, close the window or door.
- To clear bedroom two, open the bedroom door and window. When cleared, close the window or door.
- To clear bathroom two, open the bathroom door and window. When cleared, close the window or door.
- To clear bedroom three, open the bedroom door and window. When cleared, close the window or door.

Closing a door or window of an area will yield the same results.

Additionally, an area that has open walls or ceilings (from a fire), or other large openings, can be isolated from a ventilation operation by closing an appropriate door if applicable. Remember that it is possible to ventilate several rooms at one

time with multiple blowers.

Multiple Story

Assume a first floor fire, in Figure 11, has charged the multiple story dwelling with smoke.

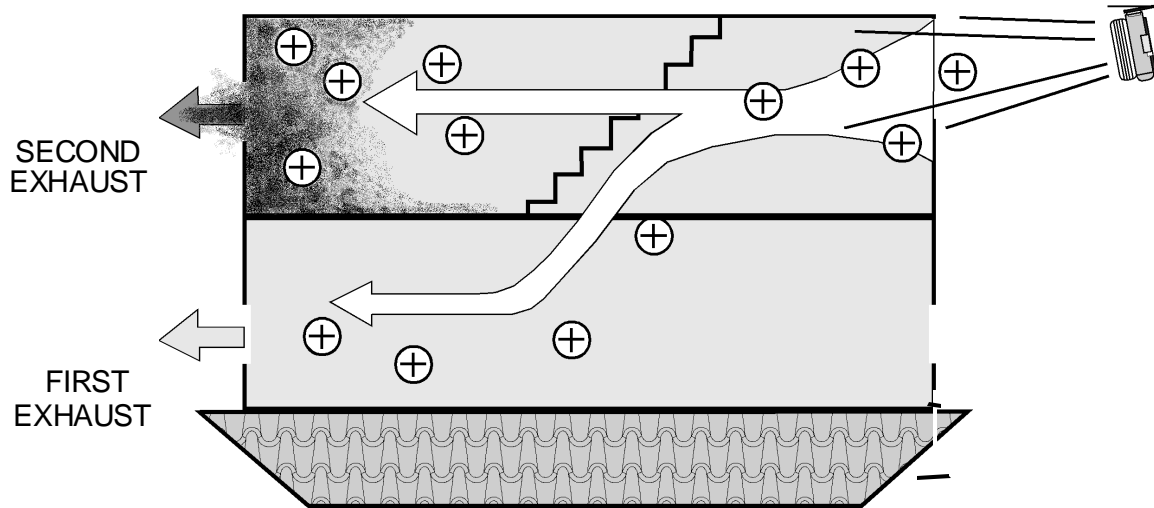


FIGURE 11

To ventilate the first floor, ensure that all exterior windows on the upper floor are closed, or a stairshaft door to the upper floor is closed (whichever is appropriate). Position a blower at an appropriate entrance opening, and systematically ventilate the contaminated areas on the first floor of the structure. This will provide maximum pressurized air for ventilation on the first floor, and no flow of air on the second floor due to the lack of an exhaust opening.

To ventilate the second floor, leave the blower in the same position and ensure that all exterior windows and doors are closed on the first floor. If a stairshaft door has been closed, open the door and systematically ventilate the contaminated areas on the second floor.

Due to the lack of an exhaust opening on the first floor, pressurized air from the blower will pressurize the first and second floor, but will only create a flow of air on the second floor due to its exhaust openings.

MULTI-HABITATIONAL BUILDINGS

These types of buildings generally have multiple floors, and enclosed central hallways that provide access to numerous rooms within the building. The hallways may be of considerable length (depending on the size of the building) and may incorporate Ponet Doors at various intervals within the hallways. If Ponet Doors are present, they may be opened to allow pressurized air to travel to a specific location, or they may be closed to "compartmentalize" specific sections of a building. This may be useful to keep contaminants from spreading to uncontaminated areas, or to divert pressurized air to a specific area.

Multi-habitational occupancies can be effectively ventilated with positive pressure by:

- First, pressurizing appropriate stairways and hallways.
- Second, ventilating contaminated rooms or other areas that are common to a pressurized hallway dependent on the location of the most heat and smoke, and the prioritization of suppression operations (overhaul, search and rescue, extinguishment, etc.).

Assume a third floor, rear apartment fire, in Figure 12, has charged the third floor with smoke. The building has an enclosed stairshaft that is common to each floor, and Ponet Doors separating each floor from the stairshaft.

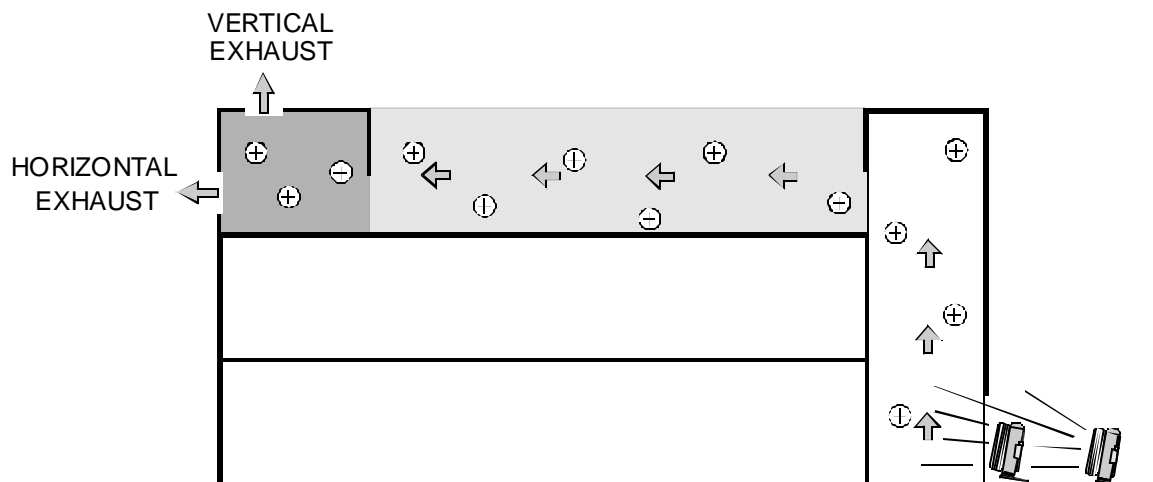


FIGURE 12

Position blowers outside the building to cover the entrance of the stairshaft to be pressurized. Open the third floor hallway door to the stairshaft that is being pressurized with air from the blowers, and ensure that the ponet doors to the first and second floors are closed. By opening the door to the involved apartment, the stairshaft, the third floor hallway, and the involved apartment will be pressurized.

Horizontal and/or vertical exhaust openings can be used in the involved apartment.

The hallway and apartment will be cleared of all contaminants. This is most effectively accomplished by opening a patio sliding glass door, large window, or using a room with the greatest number of windows as the initial exhaust opening. When the hallway and that portion of the apartment utilized as an exhaust opening is cleared, systematically ventilate the other portions of the apartment.

Depending on the floor plan of a building and the location of the fire, opposing blowers as illustrated in Figure 13 can be effectively utilized to remove the contaminants in a hallway and an apartment. Blowers of unequal ratings or equal ratings can be effectively utilized for this ventilation operation.

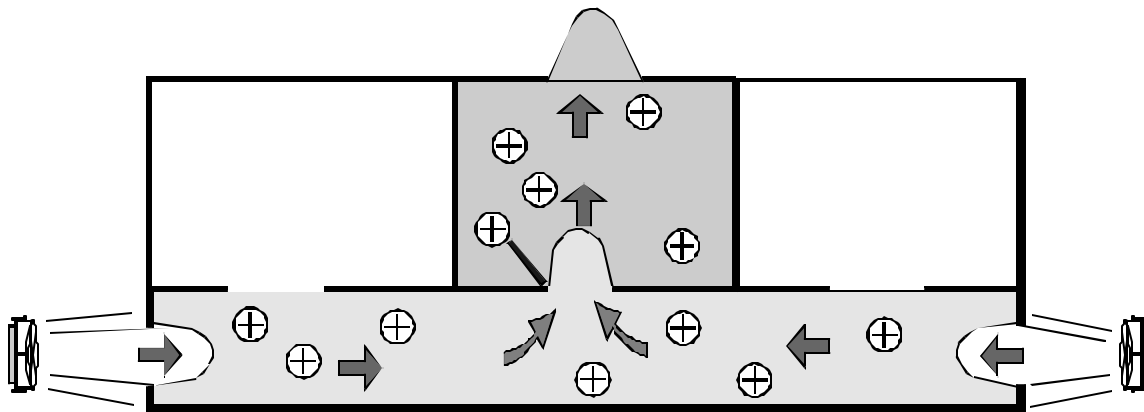


FIGURE 13

A multi-habitation occupancy that may need creative techniques are two story center hallway apartments. These buildings do not utilize pocket doors which result in vertical openings between the first and second floor hallways. Depending on the location of smoke in the hallways, normal positive pressure operations may cause the smoke to circulate between the first and second floor hallways before exiting the building.

To alleviate this condition, use two blowers as illustrated in Figure 14. This placement of multiple blowers will enhance the pressurization and EQUAL flow of air

on each floor. The removal of smoke can be accomplished as follows:

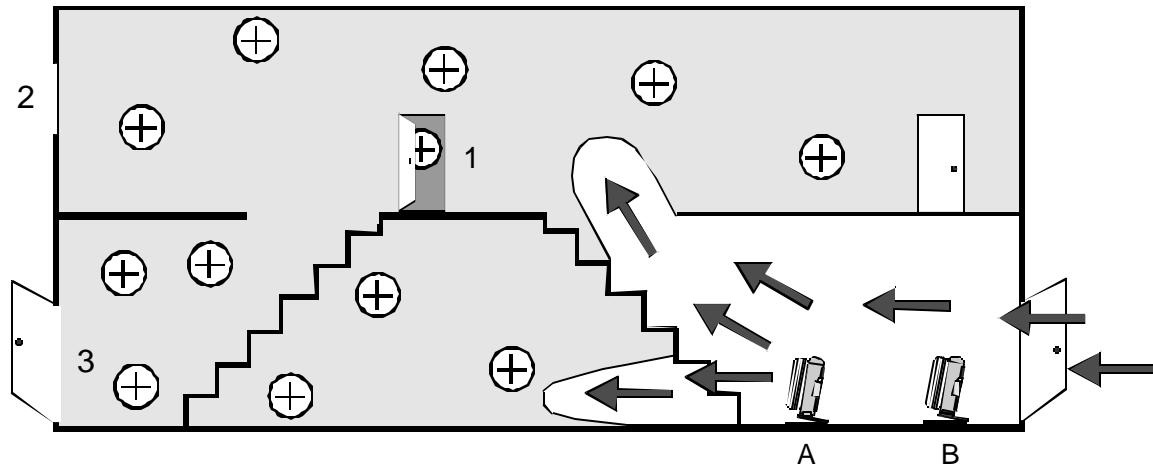


FIGURE 14

NOTE: For this operation Blower B can be placed just inside the door (as illustrated) or outside the door (as per standard practice).

- Involved apartment (Door 1) used as an exhaust opening.
- Second floor window (Window 2) used as an exhaust opening.
- First floor hallway door (Door 3) used as an exhaust opening.

COMMERCIAL BUILDINGS

Commercial buildings vary in their size, height, and use. However, the following factors should be applied when considering ventilation operations for these types of buildings.

Depending on the size of the structure, some commercial occupancies such as warehouses and manufacturing occupancies offer large open areas that are normally difficult to ventilate. These occupancies require a combination of blowers that are capable of providing adequate CFM for the area to be ventilated and an understanding of positive pressure principles.

When possible, large areas of a building should be divided into smaller areas by closing partition doors, rolling or sliding fire doors, etc., and then systematically ventilating each contaminated area. Large structures that are comprised of smaller areas such as stock rooms, work stations, offices, etc., should be ventilated by using systematic ventilation techniques in a pre-planned, coordinated operation.

When large ventilators, removed skylights, or ventilation openings in a roof (heat holes and strips) will negatively effect positive pressure operations, use these openings as vertical exhaust openings. Openings such as doors and windows that

are below these exhaust openings must be closed to ensure the flow of pressurized air is maximized and directed to vertical exhaust openings.

OPERATIONAL GUIDELINES

Depending on the type of building, determine the effectiveness of removing contaminants horizontally or vertically. Include heat holes and strips when evaluating exhaust openings. Additionally, determine the path that pressurized air must travel to remove contaminants within the building. Consider where the most heat and smoke is in relationship to the location of the exhaust opening.

GENERAL

It may be necessary to pressurize vertical stairshafts to horizontally ventilate upper floors of a multi-story building. If possible, reduce large areas into smaller areas and ventilate systematically.

Large structures or large areas within structures require increased CFM to remove large quantities of contaminants. Consider the use of larger blowers for these applications. Multiple blowers in series will also provide additional CFM and enhance the removal of contaminants. Multiple blowers in parallel will provide proper coverage for large entrance openings. Various types of large doors can be partially closed to facilitate the pressurization of an entrance opening.

MULTIPLE FLOORS

Buildings with multiple floors can be ventilated by systematically ventilating each floor, as in Figure 15. Start where there is the most heat and smoke. This will most

likely be the fire floor due to Ponet Doors, it could also be the top floor where heat and smoke will have mushroomed because the Ponet Doors did not close. Stairshafts can be used to channel pressurized air to each floor as necessary. Position blower(s) on the exterior of the building and pressurize the opening to the stairshaft that is common to the contaminated floors. Systematically ventilate each floor by opening a door to the pressurized stairshaft and an appropriate window as an exhaust opening. For information concerning cross ventilation by utilizing opposing stairshafts in sealed buildings, reference Book 100, High Rise Incident Command System, Chapter 6.

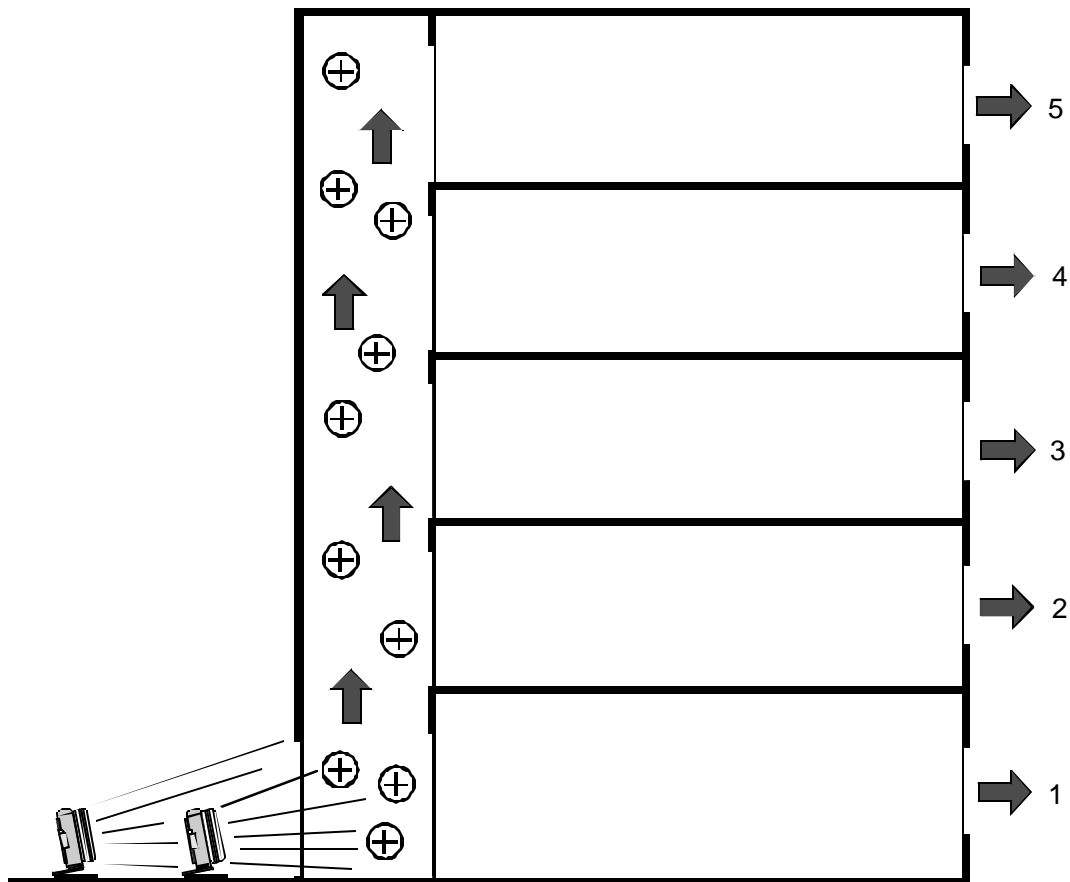


FIGURE 15

WATER POWERED BLOWERS

Water powered blowers will produce considerably more CFM than the same size

gasoline blowers and should be considered for metro rail tunnels, high rise buildings, large underground parking structures, and very large commercial buildings. They also pressurize air without carbon monoxide as a by-product and should be considered in rest homes, hospitals, and other types of structures where respiratory concerns should be considered. Water powered blowers are intrinsically safe and can be utilized at hazardous materials incidents.

OVERHAUL

Overhaul operations are conducted for the purpose of ensuring a fire is completely out, determining the probable fire cause, and leaving the owner or insurance adjusters some means of determining the loss. However, overhaul operations are often conducted in conditions that may be tenable yet hazardous to personnel.

Unless a fire has been **TOTALLY** extinguished and the contaminated structure **COMPLETELY** ventilated, overhaul operations may be conducted within varying concentrations of smoke, heat, carbon monoxide, and other toxic gases.

Remember that any carbon monoxide that has been collected at the top of a room or building (as a result of a fire) may have cooled and settled within the area of overhaul personnel. Additionally, common building materials retain and radiate heat that has been generated by a fire. This can result in elevated temperatures during overhaul operations.

Typically, most blowers are utilized for ventilation operations after the initial knock down of a fire and prior to overhaul operations. This will allow heat, smoke, and carbon monoxide to **ACCUMULATE** during overhaul operations. Positive pressure can be utilized during overhaul operations to provide a flow of fresh-cool air through the overhaul area, as in Figure 16.

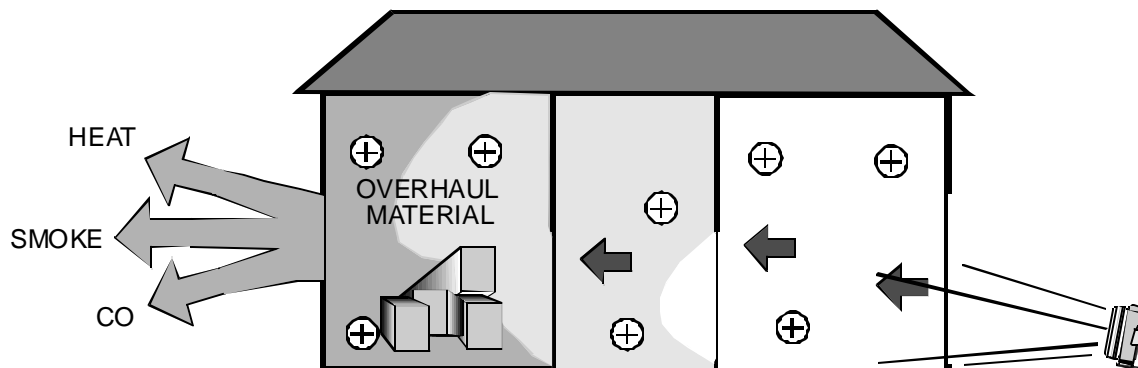


FIGURE 16

This will result in the following conditions being improved:

- Radiated heat within the overhaul area will be reduced. Additionally, humidity is

reduced.

- Smoke within the overhaul area can be substantially reduced depending on the degree of extinguishment within the overhaul area.
- Similar to heat and smoke, concentrations of carbon monoxide and other toxic gases can be significantly reduced.

Carbon Monoxide Guidelines

Depending on the type of fire, concentrations of carbon monoxide within the range of 500 parts-per-million (ppm) to 1200 ppm are easily obtainable during overhaul operations.

NOTE: For comparative purposes, the following guidelines are regarded as acceptable carbon monoxide concentration standards:

- to 500 ppm of carbon monoxide can be inhaled for one hour without appreciable effects.
- to 700 ppm of carbon monoxide inhaled for one hour will cause some appreciable effects.
- to 1200 ppm of carbon monoxide inhaled for one hour is dangerous.
- Concentrations of 4000 ppm of carbon monoxide and over are fatal in less than one hour.

Measurements during actual overhaul operations have indicated that positive pressure can easily reduce carbon monoxide concentrations of 1000 ppm to approximately 130 ppm to 220 ppm.

Overhaul Guidelines

The effectiveness of using positive pressure during overhaul operations is determined by the overhaul area (size and overhaul materials) and the blowers that

are utilized for positive pressure. A single 18" blower is adequate for an average (2000 square feet) single family dwelling. Remember that as the CFM is increased, so is the effectiveness. A MODERATE movement of air is sufficient to cause smoke, heat, and carbon monoxide within the overhaul area to move in the direction of an exhaust opening. Positive pressure does not have a tendency to accelerate or spread fire that may still be in the overhaul area. However, caution should be exercised when using positive pressure with smoldering type fires (i.e., mattress, overstuff, etc.) If any fire does begin to accelerate or spread, it can easily be controlled by:

- Extinguishing the fire.
- Turning the blower 90 degrees away from opening.
- Reducing the RPM of the blower.
- Increasing the distance between the overhaul area and the blower.
- Shutting the blower off.

NOTE: Positive pressure should never be utilized in place of a Self-Contained Breathing Apparatus (SCBA). SCBA should ALWAYS be used when personnel encounter hazardous atmospheres.

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