Stowarzyszenie Inżynierów i Techników Pożarnictwa
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# Fire ventilation – not any panacea

**Stefan Svensson, Lund, Sweden**

Most of us have vented a fire at some occasion, sometimes fully aware of what we are doing but sometimes without thinking much about it. Just by opening the front door attacking the fire, we have vented the fire: smoke and hot gases are flowing out and fresh air is flowing in. But, in order to fully understand what fire ventilation is about, we need to look at it from different perspectives. And, the use of fans, positive pressure ventilation, has become more and more popular which adds a few more parameters to the problem. Venting a fire is in many cases a good thing, but it may very well create more problems than it solves: to be successful, we need knowledge.

Fire ventilation has to be coordinated with other procedures, especially fire attack and suppression. Also, we have to know the purpose and what will happen when we vent a building. Fire ventilation is not any panacea and we have to be fully aware of what will happen when we vent a building.

Fire ventilation is what we do to vent smoke and hot gases from a space exposed to fire or hot gases, in a controlled fashion. Especially, this last part about doing it in a controlled fashion is very important. Just opening up a structure without any plan or thought at all, is not really fire ventilation. This is just doing something randomly, irrational and even dangerous. Before starting any fire ventilation procedure we should be well aware of what we are about to achieve with it, simply because we have to do other things as well. And, different purposes might need different procedures for venting.

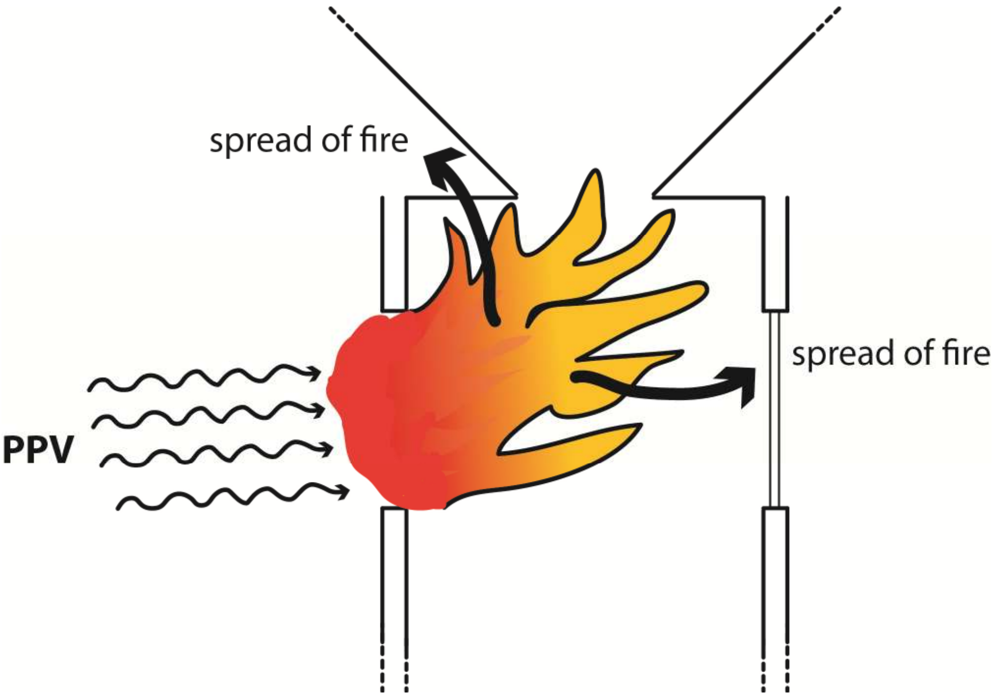


Figure 1: The use of positive pressure ventilation (fans) might increase the risk of spread of fire to an attic or to an adjacent building.

To understand fire ventilation, we have to understand fire behavior. When there is a fire in a room, a few things will happen. Amongst other things, there will be build-up of pressure. This pressure consists of thermal expansion: when air (or smoke/fire gases) is heated up it will expand and thereby creating a pressure. Also, hot air (or smoke/fire gases) is lighter than cold air, causing it to rise. We call this thermal buoyancy.

Thermal expansion and thermal buoyancy creates pressure differentials within the room (or the building) and, especially, pressures differentials relative to the surrounding (the outside of the building or to other parts of the building). These pressure differentials are what we use for fire ventilation and it will cause fire gases to flow. No matter what kind of fluid we a talking about, assuming there's an opening of some kind between areas with different pressures, there will always be a flow from higher pressure to lower pressure. No pressure differential, no flow.

So, if there is a room with an opening, thermal expansion and thermal buoyancy will make fire gases to flow out of the upper part of the opening and fresh air will flow in through the lower part. If there are two openings, of which one is located higher up than the other, hot fire gases will flow out through the upper opening and fresh air will flow in through the lower. This is how a flow path is created, and by doing different fire ventilation procedures we will be able to control the flow path.

To summarize this so far: for the purpose of fire ventilation we create openings, by using doors, windows or cutting holes in roofs. Or, which happens frequently, the fire will burn through a roof which will have exactly the same effect: we have pressure differentials and we have an opening between the different pressures. By creating openings, hot fire gases will flow out of the building and fresh air will flow in. Fresh air is a part of the equation and as hot gases flow out, fresh air will flow in: there will then be a flow path between inlet and outlet, driven by pressure differentials. Also, we have to keep in mind that by creating these openings, we will change the conditions in the building by changing the pressure differentials. If we do right, good things will happen. If we do wrong, bad things will happen.

At this point, we have to bring the concept of fuel controlled fires and ventilation controlled fires into the equation. The development of a fuel controlled fire is mainly driven by characteristics of the fuel (including the building, which usually is part of the fuel). And, the development of a ventilation controlled fire is mainly driven by the amount of air available to the fire.

So, if we vent a building with a fuel controlled fire we will usually not see any dramatic changes to the development of the fire. It already has a sufficient amount of air available. By providing more air, through fire ventilation, nothing much will happen. At least not initially: after some time we might of course see some effect due to the increased amount of available air in combination with a growing fire.

But, venting a ventilation controlled fire might cause some very dangerous things to happen fast. The result might be a very fast progress of the fire causing flashover and, in very rare cases, even a backdraft. The problem is that we rarely know if the fire is fuel controlled or ventilation controlled upon arrival at the fire scene. Consequently, when venting a fire we should assume it is ventilation controlled and we must have water or some other suppression agent readily available. In some cases it might even be better not to open up the building at all.

So, a few basic but very important things to keep in mind about fire ventilation:

- There will be a flow of fire gases between rooms (or between a building and its surrounding) with different pressures, of which one or several pressures are be caused by fire.
- There will be a flow of fire gases within a room if there are pressure differential within that room.
- Flow of fire gases will always be from higher pressure to lower pressure, no exceptions.
- Adding a fan doesn't change this!

Over the past few years, the use of fans has become widely used in the fire service. Especially, positive pressure ventilation is now a well-established method for attacking fire efficiently. It is a procedure where powerful fans are used to push heat and smoke out of the building, creating a flow path of fresh air that can be used for a fast attack on the fire. To give you a simple description of positive pressure ventilation:

- Prepare the crew for interior attack
- Localize the fire room
- Find a suitable inlet opening at the opposite side of the building
- Set up the fan at the inlet, turned off or turned away from the inlet
- Create an outlet opening as close to the fire room as possible, preferably in the fire room
- Turn the fan toward the inlet and run it at full speed
- Attack the fire

Positive pressure ventilation, and there are other terms for it, is suitable for not too complex buildings with "ordinary" ceiling heights and not to large areas. Buildings where it's reasonable easy to create a clear flow path, a flow between inlet and outlet without too much interference, twists or turns: residential buildings, single family houses, multiple family houses with well-defined compartments, small shops or workshops, offices and possibly a hospital ward (a single corridor with a few rooms). Not large warehouses, not a full hospital, not shopping centers.

However, it should be noted that the use of fans on a fire scene may very well create problems. Therefore, it is of outmost importance to be fully aware of what is going on and in-depth knowledge on fire behavior as well as on fire ventilation is critical.

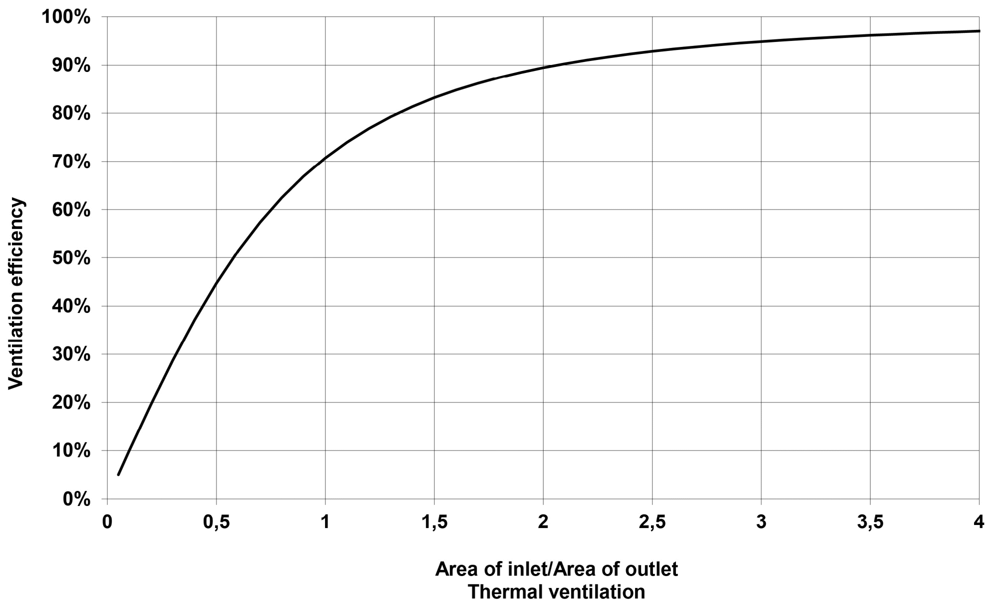


Figure 2: Relation between inlet area and outlet area when using thermal buoyance only.

When looking at fire ventilation from a theoretical point of view, we use the correlation by Bernoulli. This correlation is based on the first law of thermodynamics, and it states that the sum of the atmospheric pressure, the hydrostatic pressure and the dynamic pressure is constant. Based on this, we can calculate the relation between size of inlets and outlets. This can of course also be easily shown through a set of simple experiments.

So, through theory and through a few such simple experiments, we can show that when not using fans or positive pressure ventilation, area of inlets should be at least the same as the area of outlets and preferably twice as large. But, when using fans and positive pressure ventilation it’s the other way around. Then the area of outlets should be at least the same as the area of inlets, preferably twice as large.

However, one must keep in mind that many buildings can be complex with interior doors or objects restricting the flow. So, when we approach a building on fire we only see the outside. We don’t have any clue on what it looks like on the inside. So, when applying some fire ventilation procedures and we don’t get the expected effect, we should stop what we are doing and re-evaluate the situation.

When we are talking about positive pressure ventilation and the relation between inlets and outlets, one can look at it from a more pragmatic point of view. Let us assume a building with two rooms, an inlet in one room, an outlet in the other room, a fire in the room with the outlet and a fan facing the inlet. If the outlet becomes very small, keeping the area of the inlet constant, the pressure loss over the outlet will become very large. The smaller the outlet, the larger the pressure loss. At some very small size of the outlet the pressure loss will be so large that the pressure generated by the fan will not be sufficient to push anything out through the outlet. As a result, there will be a backflow and we will only be feeding the fire with air. No or very little smoke or hot gases will flow out through the outlet.

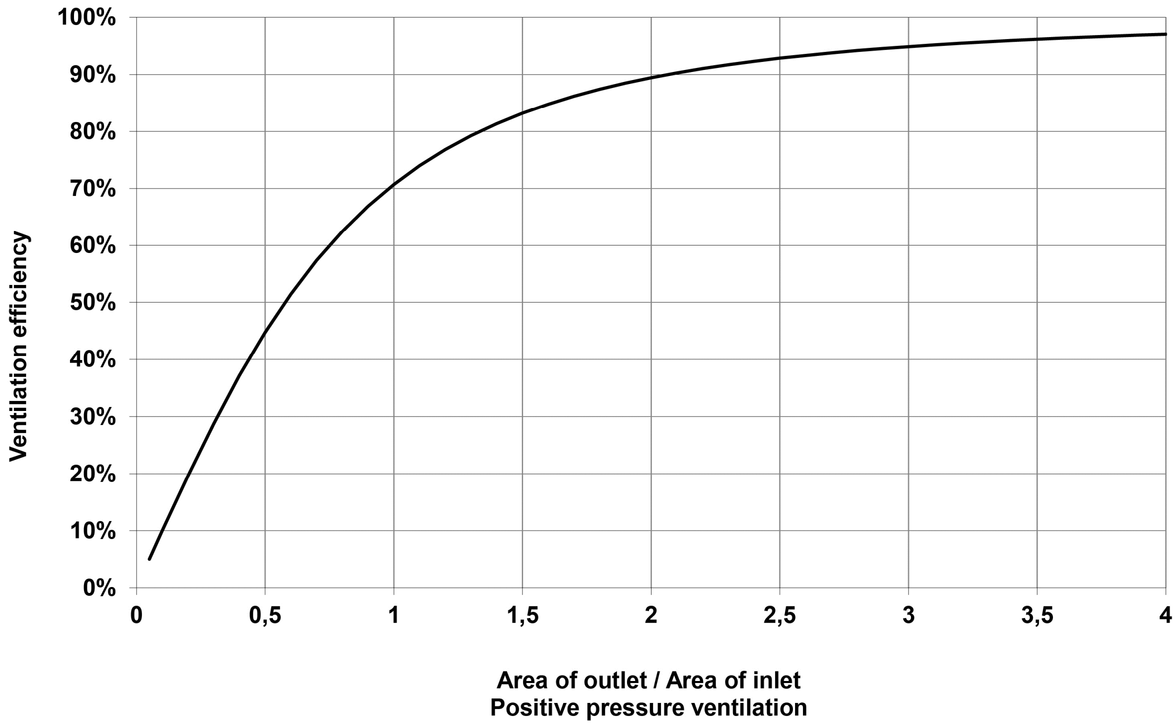


Figure 3: Relation between inlet area and outlet area when using positive pressure ventilation.

If, on the other hand, the outlet becomes very large the pressure loss over the outlet will become very small. At its extreme, removing the outer wall, the pressure in the fire room (which will become a room with an indefinitely large outlet) will be more or less the same as the surrounding. Consequently, no smoke or hot gases will flow back to the first room or through the inlet.

Fans can also be used for pressurization. For stopping or at least reducing smoke and hot gases flowing into a staircase (or some other escape route or even an attack route for firefighters), the fan can be set up to pressurize the staircase. Or, if a part of a building is lost other parts can be pressurized in order to give us some more time to save those parts or their inventories. If fans are used for pressurization, we are not interested in outlets: inlets are of course important, because that's where we set up the fan and push air into the structure, creating a pressure. But we don't really want any flow, so pressurization works best if there is some kind of compartmentation between the space on fire and the space we are going to pressurize.

Another question that comes up every now and then, is about the distance between the fan and the door when using positive pressure ventilation. Unfortunately, there is no answer to that question. The distance depends on a number of things, such as

- size of fan (diameter, power, etc.)
- type of fan (combustion engine, electrical or water-powered)
- construction of the fan
- size and geometry of openings (inlet and outlet)
- design of building

Consequently, one have to test how different fans work under various conditions.

However, the distance between the door and the fan depends on the purpose of using the fan also. If the purpose is to pressurize a staircase or some part of a building, the “cone of air” should be applied so that it covers the inlet opening. This would give an as large pressure in that room as possible. On the other hand, if the purpose is to create a flow through the building, pushing heat and smoke out through an outlet, this distance will become more dependent on the fan. In this case the fan should, generally speaking, be placed as close as practically possible to the inlet. But, some types of fans work better at a distance. For an actual flow of air into a building, sealing of the inlet by the “cone of air” is not of greater importance. Instead we should aim for getting as much air as possible through the building for faster and more significant effect. We achieve this increased quantity of air by directing the whole stream into the inlet and also entraining the air around the stream. Air that hits walls and other surfaces surrounding the inlet is, generally speaking, a loss of flow. On the other hand, larger flow of air might affect the fire more as well so one have to be careful and fully aware of what is going on.

Finally, to summarize all of this the following can be said:

- Pressure differentials creates flow
- Fire ventilation using thermal buoyancy and thermal expansion requires inlets that are at least equal in size, preferably twice the size, as outlets
- Using positive pressure ventilation requires outlets that are at least equal in size, preferably twice the size, as inlets
- No outlet, no fan (except for pressurization)

In addition to this, when doing fire ventilation (with or without fans) the operation must be well-coordinated. Fire ventilation is not any stand-alone procedure and it has to be coordinated with other procedures, especially fire suppression. By venting heat and smoke, with or without fans, we create an environment that is a lot safer and a lot easier to work in for a firefighter. But this improved environment doesn’t last forever and for an efficient operation we must use the flow of gases to attack the fire.

Also, one must always be prepared to do different things depending on the situation. It is not always possible or suitable to do interior firefighting. But when we do, it will make things a lot easier and safer if we first get the smoke and the heat out of the building. And to do so, in a controlled fashion and efficiently, we must have knowledge and understanding on fire behavior, pressure differentials and what will happen when we vent the building.

Fire ventilation is a good thing, with or without fans, but it’s not any panacea. There is no such thing in the fire service!

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