Smoke Flow Control during Fire Fighting

Tactical Considerations for the Use of Portable Smoke Blocking Devices

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The ability to control smoke flows in building in case of a fire is essential for safe rescue and fire fighting operations. The importance of this task has been discussed by the author in different publications in German fire fighting magazines and books since 2005. Before fire crews are able to solve the problems on the fireground they often have to stabilize the situation first and prevent it from getting worse. To do this it is very important in multi-storey buildings to prevent smoke flows from entering escape routes and from leading to life hazards for civilians. For the life safety of civilians and fire fighter in a building with a working fire it is also of great importance to control the smoke flow and the flow of fresh air because they have a direct and immediate influence on the development and severity of the fire itself. Since about 10 years fire fighters especially in central Europe use blocking devices to control these flows with great success. This article explains the background and some fields of application and shows some examples for the use in real building fires out of more than 1600 documented incidents.

The most important task for firefighters is to save lives. In the case of fire in multi-story residential buildings, this objective can be best achieved by using the stairways as the preferred route of attack. This method of entering a multi-story dwelling assures that the most important escape route for the inhabitants is immediately controlled as people are often found there on their way out of the building – either in a smoke or in a still-safe and smoke-free environment.

Therefore, one of the most important aims for fire crews is to have a smoke free and safe stairway. However, choosing the stairways as the preferred route of attack to a fire in a building means opening doors. Firefighting operations sometimes enable smoke to travel through a building, entering stairways and can lead to the endangerment of the inhabitants.

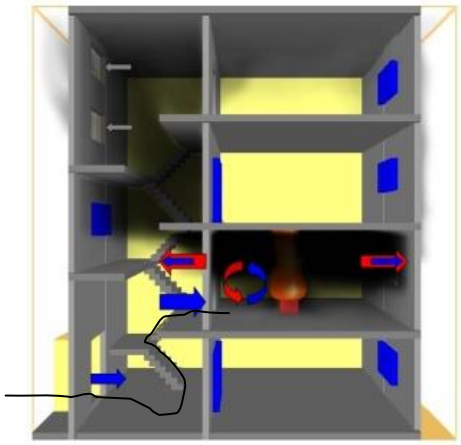
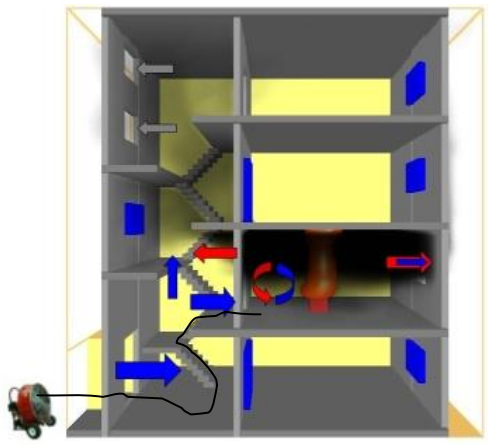
a)  b) 

Figure 1: Smoke and Air flows if the door to the fire compartment is open
Smoke spread in a stairway with open windows and an open door to the fire area;
a) without and b) with a ventilator in front of the main building entrance.

The problem of smoke spreading in a stairway is unfortunately not sufficiently solved by using a positive pressure ventilator in front of the building entrance. It's only when the ventilator is in an optimal position, with all windows and all other doors to the stairway closed, that the complete ventilation process can be ensured. But what can firefighters do when this is not the case? What can be done in larger and more complex buildings where positive pressure ventilation is not possible?

Considering this problem, there is a very simple objective that must be achieved: firefighters need a means of closing an opening quickly and sufficiently sealing it against smoke and air flow, but without hindering firefighting operations.

Fire crews must be able to prevent smoke from spreading with a simple method and be able to purge the building of smoke more easily. This would dramatically improve rescue operations and minimize smoke damage, and would also ensure a smoke free escape route for firefighters thereby leading to more safety even for themselves.

This can be shown very simply by comparing Figures 1 and 2. Both figures are results from a numerical fire simulation and they show the calculated smoke spread in a multi-story building with mainly open windows and doors either a) without, or b) with a positive pressure ventilator in front of the main building entrance. Figure 1 shows the results if the entrance door to the fire compartment is open and not controlled. Using a ventilator, there is a better airflow through the stairway and therefore a reduced density of smoke, but there is still smoke entering the stairway from the fire area through the upper part of the door. This flow will establish to some amount even if the entrance door is somehow controlled (e. g. opened only in a small angle by controlling it with one fire fighter). Considering these flows, the situations 1a) and 1b) are not very efficient. Furthermore, there is also a lot of turbulence around the entrance to the fire compartment because of the bi-directional flow through the door frame.

The utilization of a portable smoke blocking device which blocks the flow at least in the upper part of the entrance door hinders smoke from flowing into the stairway but allows a smaller amount of fresh air to enter the fire compartment at floor level. Both situations in Figure 1 can be transferred and improved upon those situations shown in Figure 2. Figure 2 easily demonstrates that flows in a building are much simpler and easier to control if the upper half of the entrance door is blocked. Ideally the stairway remains smoke free or can be freed from smoke more easily. Turbulences around the entrance to the fire area should be reduced and fresh air enters the fire area in a smaller amount and only at floor level. Therefore, the work of fire fighters in the fire compartment becomes easier and safer, and smoke can leave the fire area through open windows.

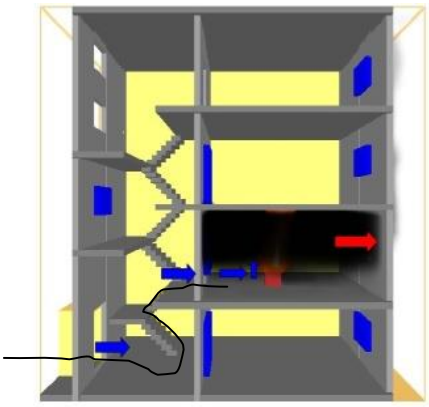
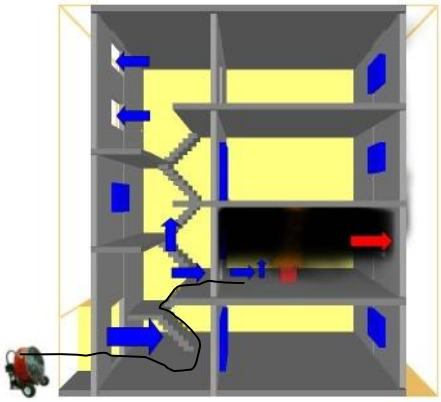
a)  b) 

Figure 2: Smoke and Air flows if the door to the fire compartment is blocked in the upper half
Smoke spread in a stairway with open windows and an open door to the fire area;
a) without and b) with a ventilator in front of the main building entrance.

If the entrance door needs forcible access anyways it might be a possibility to cut the lower half of the entrance door by using a saw or some other tool. This idea was tested in training fires but obviously has some disadvantages and risks. Therefore the need to built an easy device to perform this task fast and easy was described in 2005.

Many various designs for a smoke blocking device were built and tested in 2005. The best results to control all flows have been achieved by using a combination of a metal frame with a spreader and a special textile fibre curtain. Obviously, the curtain had to meet many requirements for safety and practical reasons. In addition it was found to be very favourable if the curtain also influences the characteristics of the fresh air flow into the fire compartment. Looking at the flow of smoke shown in Figure 2, the curtain must prevent smoke from travelling through the upper part of a door, but must still allow fresh air to travel into the fire area through the lower part of the door (this fresh air, however, must flow with much less turbulence in order to prevent excessive mixture of fresh air and smoke). This keeps the volume of smoke to be expelled from the building to a minimum and improves the conditions and safety for firefighters by leading to lower temperatures and better visibility in the lower layer. Keeping the layers of cold smoke in the lower half and smoke in the upper half more distinguished should also result in a smaller smoke layer which is premixed with the necessary amount of oxygen from the fresh air flow.

In the recent years there have been multiple studies in the US from NIST and UL showing the big influence of the fresh air flow to the fire development. In ventilation controlled fires the time between opening a door to a fire compartment and the time a flashover will occur was investigated. Because of the higher heat release rate of modern furnishings it was shown that the time span from starting ventilation (e.g. opening a door!) and a flashover in the fire compartment decreases to about 1 to 2 minutes. For the safety of all life in the fire compartment and the adjacent rooms in the building this development has to be prevented. Therefore it is highly advised to reduce the flow of fresh air. This can be done by keeping the door closed as much as possible even after accessing the fire compartment by the fire crew. This “door control” might be done using a chock to fix the door in a nearly closed position. Because this might hinder the egress of fire fighters it is advised to control the entrance door by another fire fighter. Unfortunately the required staffing to do so is often not available in this stage of fire fighting. Despite the fact that a “door control” with a portable blocking device mounted into the door frame is more effective in the upper half of the door the utilized curtain can also positively influence the flow pattern in the lower half of the door by forcing the flow of fresh air to go low into the fire compartment. This reduces the mixing of smoke and fresh air to reach an ignitable mixture and gives the fire fighters and maybe the victims in the fire room better conditions in a layer close to the floor – and this is where this is needed.

Figure 3: Influence on the characteristic of the fresh air flow into the fire compartment by a smoke blocking device with a curtain nearly covering the whole opening and forcing the fresh air flow to go in low

It must be emphasized at this point that underventilating a fire in a compartment can lead to a higher amount and concentration of combustible gases. Going in a fire compartment even with the mandatory personal protection equipment is still dangerous and smoke layers which

are hot and contain combustible gases should be cooled to further reduce their ability to ignite.

It was experienced in hundreds of real fires in buildings that blocking the upper half of the entrance door and entering the fire compartment together with a limited but still present flow of fresh air (one-directional flow!) actually worked very properly. This limited air flow still improves visibility, reduces the temperature in the lower area and shows outgasing and flaming combustion especially in this area. Fire fighters are therefore adverted to use their hoseline and extinguish the fire, cool the smoke layer and maybe other surfaces as they enter the fire compartment. And the lower amount of the ingoing flow of fresh air should bring up the time between the start of ventilation (opening the door!) and a flashover in the fire compartment a few minutes and this should allow fire fighters to actually get water on the seat of the fire.

In Addition the danger for fire fighters accepting a bi-directional flow (hot smoke out high and fresh air in low) while entering a fire compartment is reduced. With a smoke blocking device as described in this article it should be possible to transform this bi-directional flow into a one-directional flow which has the same direction as the fire fighters entering the compartment.

Further necessary requirements for the curtain are sufficient resistance to high temperatures, flames and mechanical damage. After utilizing a portable smoke blocking device, it should be able to be cleaned very easily and therefore needs to be impregnated against dirt and water accordingly.

This portable smoke blocking device for fire fighting operations is shown in Figure 4.

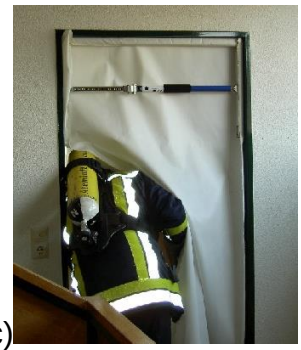
a)  b)  c) 

Figure 4: Portable smoke blocking device
a) Door before installation of the device
b) Installation of a smoke blocking device
c) Easy access for firefighters to the fire area.

There are many various situations and therefore multiple reasons why a portable smoke blocking device should be generally used in most all firefighting operations in buildings:

- In multi-storey buildings: The stairway stays smoke-free and/or smoke which is already in the stairway can be expelled much faster.
- The portable smoke blocking device can serve to close an open or damaged door in order to prevent the spread of smoke in a building.
- A smoke-free stairway enables the rescue team to stay closer to the fire area and therefore communicate more easily with the attack team. This results in a shorter escape route and improved safety for firefighters.
- With a portable blocking device the positive pressure ventilation of a stairway in a building is much easier to achieve, and ventilation operations can be effected section by section.
- The limitation of flows can favourably lead to a reduced air flow to the fire thus leading to a smaller heat release rate and a less severe fire development.
  In case of an underventilated fire the time between the opening of an entrance door

and a flashover in the fire compartment should be increased to an amount that allows to extinguish and control the fire before this development happens.

- In case of unexpected happings (e.g. the failure of a window or the opening of other doors in the building) which might lead to rapid changes in the flow of smoke and hot fire gases and leading to life threatening hazards for fire fighters the installation of portable smoke blocking devices will help to stabilize these situations. Everything should be done that helps prevent the interior attack crew in getting into the flow path between the fire and its outlet.

Also Damage caused by the spread of smoke is often underestimated by firefighters. The use of a portable smoke blocking device has already prevented a lot of smoke damage. Many people affected by a fire have recognized the advantages of utilising such a device. For firefighters, this easy and visible separation of “black” and “white” areas leads to a very different behaviour at the fireground and a more conscious strategy regarding smoke damage.

As one example of many fire incidents thus far, Figure 5 shows a fire in a residential building in Heilbronn (Germany) which occurred on 6th February 2006. The fire area itself (a child's room) was totally damaged by heat and smoke whilst the corridor suffered considerable damage. The portable smoke blocking device placed in the doorway to the apartment efficiently prevented smoke from entering the stairway. The fire fighers entering the fire compartment were able to go in with a one- directional flow in their direction.

Figure 5: Fire in a multi-story dwelling in Heilbronn, Germany (6th Feb. 2006)
The fire room was totally damaged whilst the corridor was considerably damaged by heat and smoke. Meanwhile, the stairway was protected efficiently by utilising a portable smoke blocking device.

The general utilization of a portable smoke blocking device can prevent the spread of smoke caused by fires in buildings, leading to much lower risks for occupants and a massive reduction in actual smoke damage. This is a simple and efficient method for preventing the spread of smoke not only in residential buildings, but also in modern structures with an open architecture. The closing of an opening during building fires is a very basic and important task.

The utilization of a portable smoke blocking device allows fire crews to control the flow of smoke in structural fires much better and more easily. This leads to improved safety for both occupants and firefighters, easier rescue operations and less damage. More Information for more than a thousand of uses in real building fires can be found at www.smokeblockingdevice.eu

Combination of two portable smoke blocking devices

In addition to the basic use of a portable smoke blocking device as shown in Figure 5, a combination of two portable smoke blocking devices is just as simple and easy. Figure 7 shows how this enables the almost total sealing off of an opening to prevent smoke spread. However, access to the room for firefighting operations is also limited.

a)  b) 

Figure 6: Basic use of a portable smoke blocking device

a)  b) 

Figure 7: Combination of two portable smoke blocking devices

a) A second portable smoke blocking device is fastened in the middle of a door. Smoke spread is limited even further, but access to the room is still possible.

b) A second portable smoke blocking device is fastened at the bottom of a door. There is practically no smoke spread possible – however, access to the room is also hindered.

Danger of Backdraft

Opening a door to a fire area is always accompanied by the risk of a backdraft. This does not happen very often, but firefighters must always be aware of this hazard. Figure 8 shows the six stages of the development of a backdraft (according to Gottuk).

To reduce the risk of a backdraft, it is interesting to consider the effect of a portable smoke blocking device upon the movement of smoke and fresh air.

The flow of smoke and fresh air without a portable smoke blocking device is illustrated on the left side of Figure 9. Under the same conditions, but with a portable smoke blocking device fastened in the door, the result is illustrated on the right side.

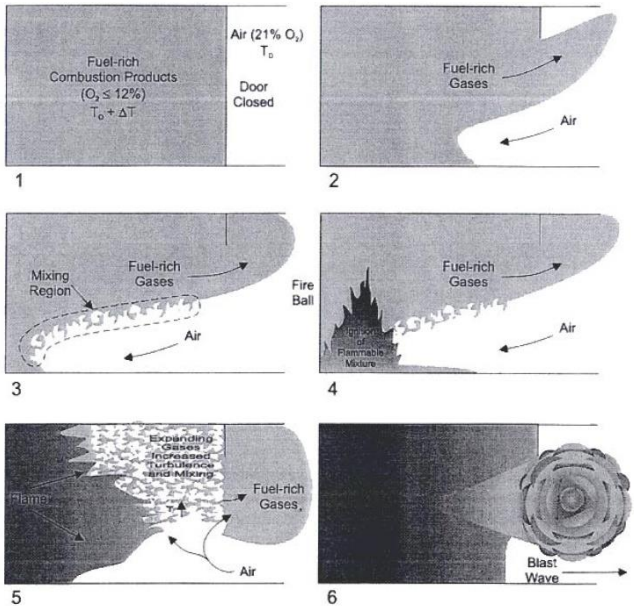


Figure 8: Six stages of a backdraft (according to Gottuk)

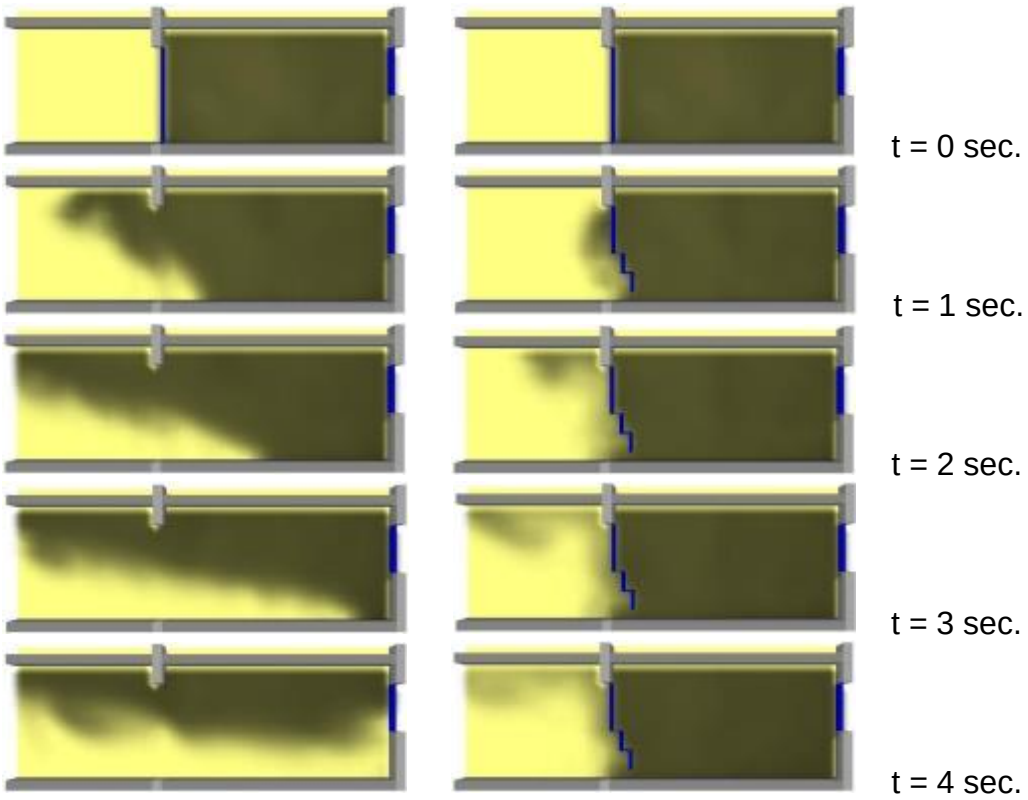


Figure 9: Smoke spread and mixing of smoke and fresh air after opening a door to a fire area

Left side: without a portable smoke blocking device

Right side: with a portable smoke blocking device

(The steps in the flexible material of the portable smoke blocking device are a result of the modelling and are necessary for the numerical calculations.)

When opening a door the movement of fresh air into the fire area can easily be seen when a portable smoke blocking device is installed (Figure 10). If the room “sucks in fresh air” (one indication of an ensuing backdraft), or if the room seems to be very hot (perhaps just before a flashover occurs), the door can be closed again and safe firefighting tactics can be employed as shown in Figure 10 of maybe by using another opening to the fire compartment.

Figure 10: A portable smoke blocking device makes airflows visible

The movement of air into a fire area can be seen and a safe view into the room can be facilitated by using a portable smoke blocking device.

Figure 11: Utilising two portable smoke blocking devices

The second metal frame holds the fire proof curtain of the first portable smoke blocking device in place. A nozzle can be used through the nearly closed opening and a very safe firefighting technique can be employed – without the infiltration of fresh air (and oxygen!) into the fire area itself. This might also be used in wind influenced or wind driven fires.

Black Areas / White Areas

In order to have less damage and pollution in the adjacent rooms to the fire area, it is advisable to use a clear sign to create a barrier against all unnecessary access to the main fire area. Figure 12 shows that a brief look into the fire area is often enough for most investigation purposes.

Figure 12: Indicates black areas

A portable smoke blocking device is a barrier between black and white areas.

Figure 13 shows the creation of a black, a grey and a white area in a building by using two portable smoke blocking devices in two different doors.

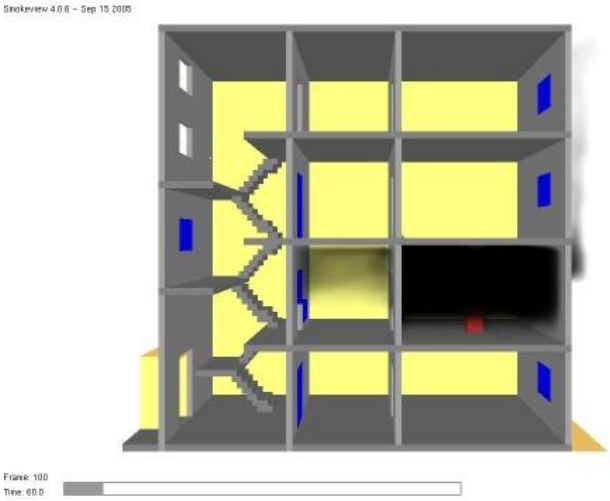


Figure 13: Black/Grey/White Areas

Utilisation of two portable smoke blocking device is an effective method for creating a "grey" area between the "black" and the "white" areas. This helps to prevent the spread of smoke and dirt through the building.

Closure against Dirt and Dust

Fire crews often have to open walls to find the fire. If so, then a lot of dirt and dust will find its way throughout the building. When used, a portable smoke blocking device acts as a barrier that can serve to limit the spread of dirt and dust.

Figure 14: Barrier for dirt and dust

A portable smoke blocking device used as a curtain to prevent the spreading of dirt and dust.

An Additional Tool for Negative Pressure Ventilation

Figure 15 shows the setup for negative pressure ventilation after a small fire in a room at an airport terminal in Stuttgart, Germany.

Figure 15: Room fire at an airport terminal in Stuttgart

To prevent smoke from spreading during the ventilation process, the door can be closed with a portable smoke blocking device.

Figure 16 shows the effect of a portable smoke blocking device used in a hospital. The hazard for the patients could be limited because smoke spread was hindered effectively.

Figure 16: Room fire in a hospital in Würzburg, Germany (26th November 2009)

An Additional Tool for Positive Pressure Ventilation in special geometric situations

For good positive pressure ventilation (PPV) it is often recommended to cover the entire opening of a door with the flow of air. At least it should be the aim to achieve a best fit between the flow pattern and the opening. Depending on the geometry of the entrance, this could require placing the ventilator far away from the door which is ineffective and sometimes unfeasible. By closing the upper part of the door, the entrance area for PPV is reduced in height whilst the entrance area is transformed into the shape of a square. This increases the effectivity of using PPV because the ventilator can then be placed closer to the entrance thus covering the entire opening.

Figure 17: Stairs in front of the entrance
By utilising a portable smoke blocking device in the upper part of the door (the lower part of the fire proof curtain is hung over the spreader bar of the metal frame), the PPV-method becomes more effective.

Figure 18: Stairs in front of the entrance
The ventilator may be placed directly in front of the entrance when employing a portable smoke blocking device.

The figure shows that a large ventilator can even be placed very close to the door when a portable smoke blocking device is utilised. The PPV-method then becomes even more effective.

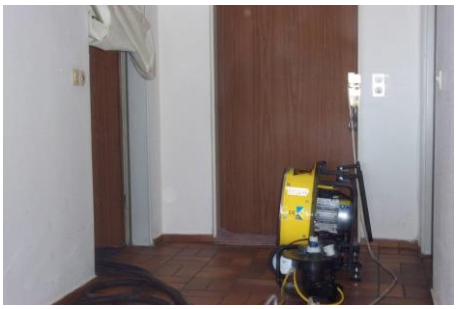


Figure 19: Corridor situation in a multi-storey or high rise building

The ventilator can be placed in an effective position in a small corridor in a building when the upper part of the entrance door is blocked with a smoke blocking device.

An Additional Tool for Positive Pressure Ventilation to increase the differential pressure in the stairway

Regarding the fact, that the shape of the air flow is nearly a circle, the shape of the entrance should be changed from a rectangle to a square. This will reduce the losses of air flow at the entrance door of a building.

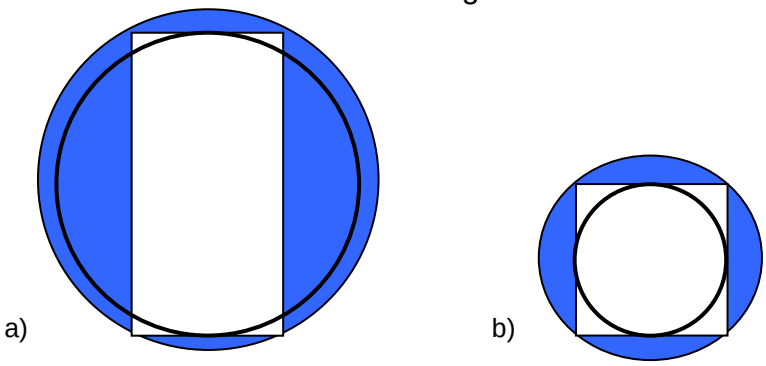
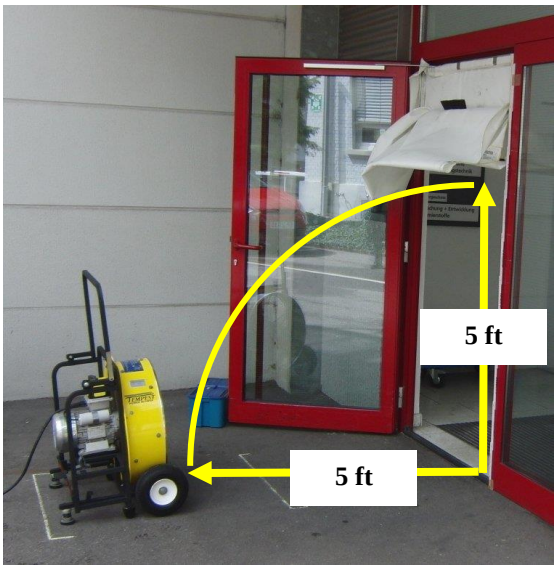


Figure 20: Comparison a) between a rectangular door and a circle and b) between a square and a cirle.

Tests in a building with four floors showed that the differential pressure in the stairway could be increased with one blocking device by 50 % and with two blocking devices by 100%. This is a very easy method to increase the power of a smaller blower – or used together with a stronger blower this can ensure a sufficient differential even in higher buildings.

In addition the use of a blocking device in an entrance door is a good way to show all other people on a fire scene that nobody should access the building in this stage. The blocking device together with a ventilator directly in front of the building is a very easy and efficient method to achieve limited access



The pressure difference can be increased by 50 % by using one blocking device installed in the entrance door of a building. The distance from the blower to the entrance door should be about the open height of the door.

The pressure difference can be increased by 100 % by using two blocking devices installed in the entrance door of a building. The distance from the blower to the entrance door should be about the open height of the door.

Figure 21: Using a blocking device in an entrance door of a building increases the differential pressure and shows to other people that this access is blocked by the fire department.

Usage and spread of the portable smoke blocking devices

Developed in 2005 the first portable smoke blocking devices were first used Germany by several innovative fire departments. After a lot of experience in real fires and some improvements – and because of their very good acceptance and impressive reports from real fires – 10 years later more than 17 000 portable smoke blocking devices are actually in use.

One of the most common booklets in Germany for Firefighters is “Die Roten Hefte”. The book Nr. 212, published in its fourth edition in 2015, explains the basic theory and shows a lot of pictures for the safe and powerful use of a portable smoke blocking device.

Die Roten Hefte / Ausbildung kompakt Band 212
ISBN 978-3-17-026264-5