Smoke Flow Control and related tactical issues

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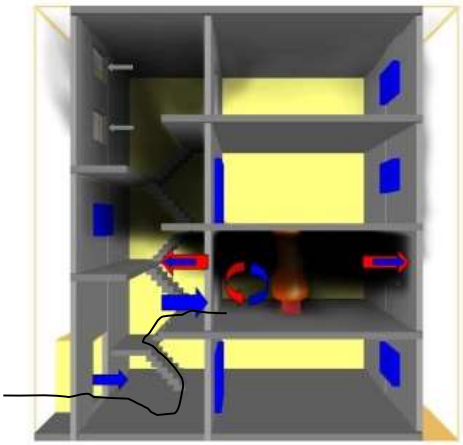
The ability to control smoke flows in building in case of a fire is essential for safe rescue and fire fighting operations. The importance of this task has been discussed by the author in different publications in German fire fighting magazines and books since 2005. Before fire crews are able to solve 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 1000 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) 

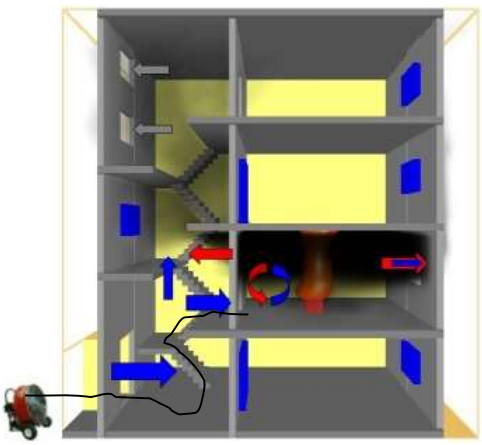
b) 

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.

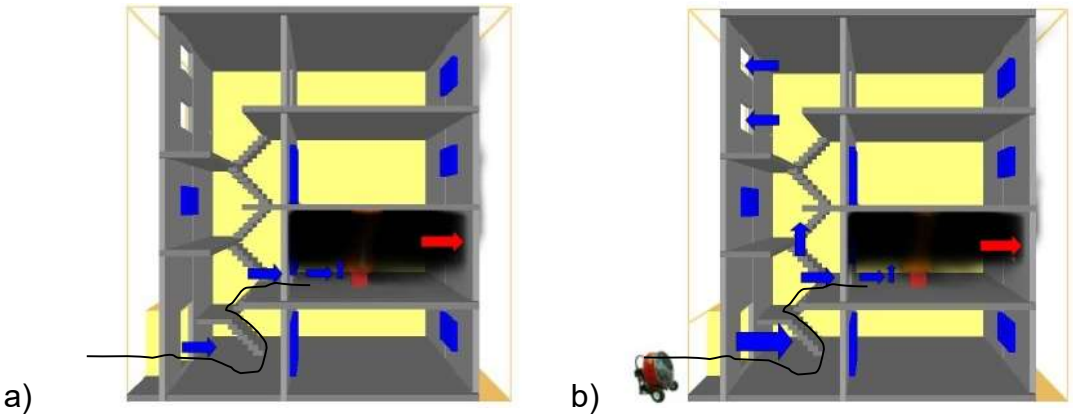
The problem of smoke spreading in a stairway is unfortunately not sufficiently solved by using a positive pressure ventilator in front of the building entrance. It's only when the ventilator is in an optimal position, with all windows and all other doors to the stairway closed, that the complete ventilation 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.rauchverschluss.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.