The most familiar form of Rapid Fire Progress: Flashover

In a previous article we discussed ventilated as well as under-ventilated fire behavior. We noticed that with access to sufficient fuel and oxygen, a compartment fire will evolve to a state wherein the entire room is engulfed in flames. This transition is called flashover. Flashover has been responsible for the loss of life of dozens of fire fighters in recent history. These incidents with Line Of Duty Deaths (LODD) often exhibit a similar turn of events. Fire fighters arrive on scene with the fire still in the growth stage. Entry into the building is made in order to perform search and rescue, or to initiate fire attack. During the search for victims and/or seat of the fire, little heed is being paid to the increasing risk presented by the evolving fire. When flashover occurs in these situations, fire fighters are often caught unaware, suffering serious injury or perishing on the fire ground as a result.

Flashover is the sudden and continuing transition of a fire from the growth stage to a fully developed fire.

1. Different kinds of flashover

1.1 "Common" flashover

Flashover is a normal part of the ventilated fire development (see fig 1.1). It marks the transition of the fire from growth stage to the fully developed fire. During the growth stage, a hot layer of smoke forms against the ceiling. This layer passes heat to all objects in contact with the smoke: cabinets, combustible wall linings, … This is called convective heat transfer. Aside from this, the smoke also radiates heat downward onto objects underneath the layer such as chairs, tables, … This is called radiative heat transfer. Both processes of heat transfer cause all the objects inside the room to heat up. At a certain point in time, the temperature will reach the pyrolysis threshold, meaning that the temperature of the object is so high that it will start to pyrolyse. Flashover is preceded by roll-over. Roll-over consists of a flame front moving throughout the smoke layer. This will cause a substantial rise in the temperature of the smoke, which in turn increases radiation towards objects beneath the smoke layer. If pyrolysis of the objects hadn't already started, it now soon will. Following swiftly after, the ignition of newly formed pyrolyzates will cause the entire room to become engulfed in flames.

During flashover, the temperature inside the room will rise extremely. In just a matter of seconds, it will rise to 600°C. The radiated heat flux will increase as well. Survival becomes impossible. Fire fighters who find themselves in a room in which flashover occurs, only have a few seconds to get out alive. Even then they often will have suffered severe burn injuries. It is therefore imperative to exit a room before flashover occurs.

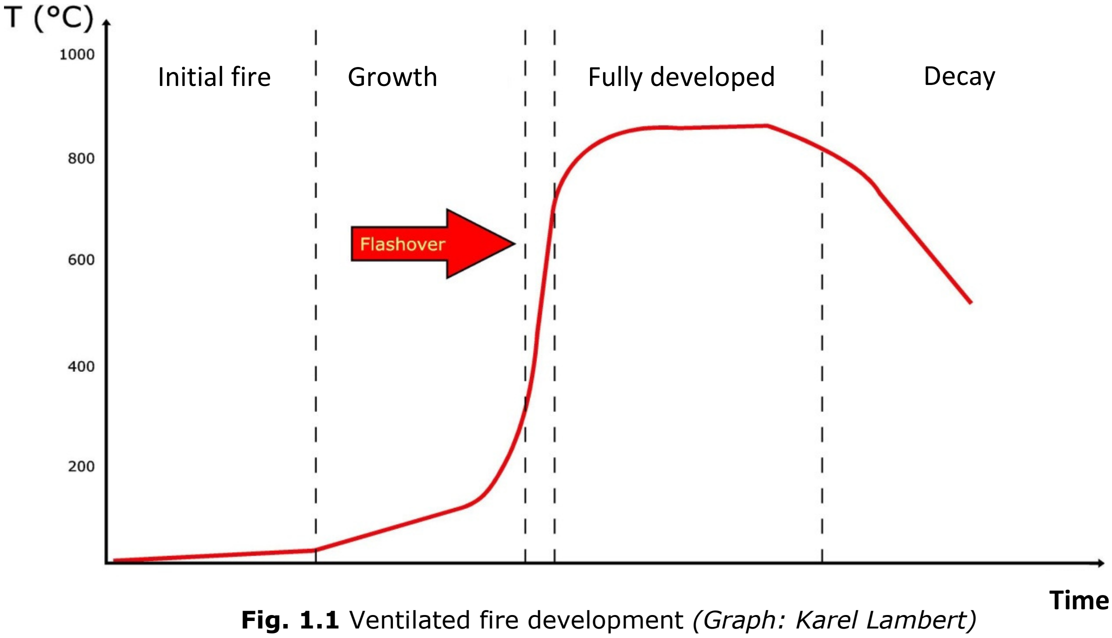

Fig. 1.1 Ventilated fire development *(Graph: Karel Lambert)*

1.2 Ventilation induced flashover

A ventilation induced flashover only occurs after a fire has become underventilated and enough heat has been built up at the time of the FC/VC point. This means that a lack of oxygen inhibited the growth of the fire in the early stages of fire development. If there are no changes happening in the fire's ventilation profile, the fire will stop burning by itself. The yellow line in figure 1.2 depicts the phenomenon. At first the yellow line rises less fast and subsequently starts to decline. Numerous parameters will determine the amount of heat buildup in the room during the underventilated phase. With sufficient heat, a lot of objects in the room will continue to pyrolyse. Again we will be confronted with a supply of gaseous fuel. Obviously this will be a frequently recurring problem in modern, well insulated housing.

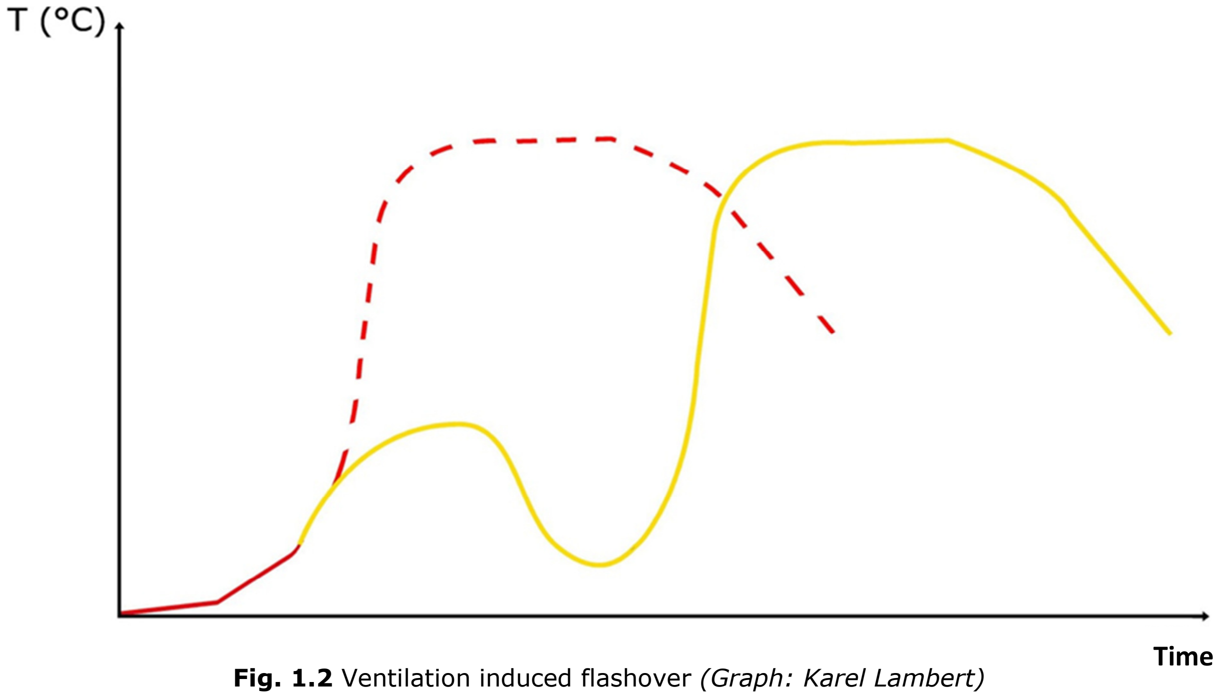

Fig. 1.2 Ventilation induced flashover *(Graph: Karel Lambert)*

Herein lies a great danger for firefighting crews. Simply by opening the door, an opening for ventilation is created. **Entering a room is venting it!** Fire fighters will therefore always exert a change in the ventilation profile. This extra ventilation will in turn fan the fire. Figure 1.2 shows us an inclination of the yellow line upward. The temperature inside the room will rise. The smoke inside of the room will ignite and in a matter of seconds the fire will have reached a fully developed state. The effects of this phenomenon are similar to those of common flashover.

The amount of ventilation added, will determine the speed by which ventilation induced flashover will occur. When a door has been opened, air will rush into the room. Suppose a PPV fan is put in front of the door. In this case ventilation induced flashover will occur much sooner.

Other terms used to describe this phenomenon are "delayed flashover" and "thermal runaway". At an international level, the term "ventilation induced flashover" is preferred.

1.3 Comparison of both kinds of flashover

Next we will compare both kinds of flashover and examine the similarities and differences. The main difference is the source of the phenomenon. Common flashover happens in the ventilated fire development while ventilation induced flashover occurs in the underventilated fire development. Figure 1.3 maps the percentage (gaseous) fuel against the temperature.

The left hand side of the graph shows us the beginning of a fire. Here the fire is fuel controlled and limited to a certain surface area. The materials involved in the combustion process will determine whether the fire evolves to flashover. Parameters like Heat Release Rate (HRR), the rate at which energy is released by a certain object, and flame spread, the rate at which flames expand across fuel surfaces, will determine the fire's evolution. With sufficient HRR and flame spread, the fire will grow and the temperature in the room will rise. Sufficient fuel has to be available for this to happen. Heat will build up inside the room and when sufficient energy has been released, flashover will occur. Some sources of information use the terms "heat induced flashover" or "radiation induced flashover".

The right hand side of the graph depicts the under-ventilated fire. In such a case, the fire has been burning for some time already. Sufficient fuel is available, but the necessary air is lacking. The fire will extinguish by itself, unless ventilation is increased. If that happens, fire development will again accelerate. The temperature will rise again inside the room. As with common flashover, buildup of heat will occur. Just as before, enough heat has to be built up for flashover to occur. This kind of flashover is therefore just as heat induced, as a common flashover. The start of heat buildup is caused by the change in the ventilation profile. Thus the phenomenon is defined as "ventilation induced flashover".

In summary a common flashover originates from a fuel controlled fire, whereas ventilation induced flashover originates from an underventilated state.

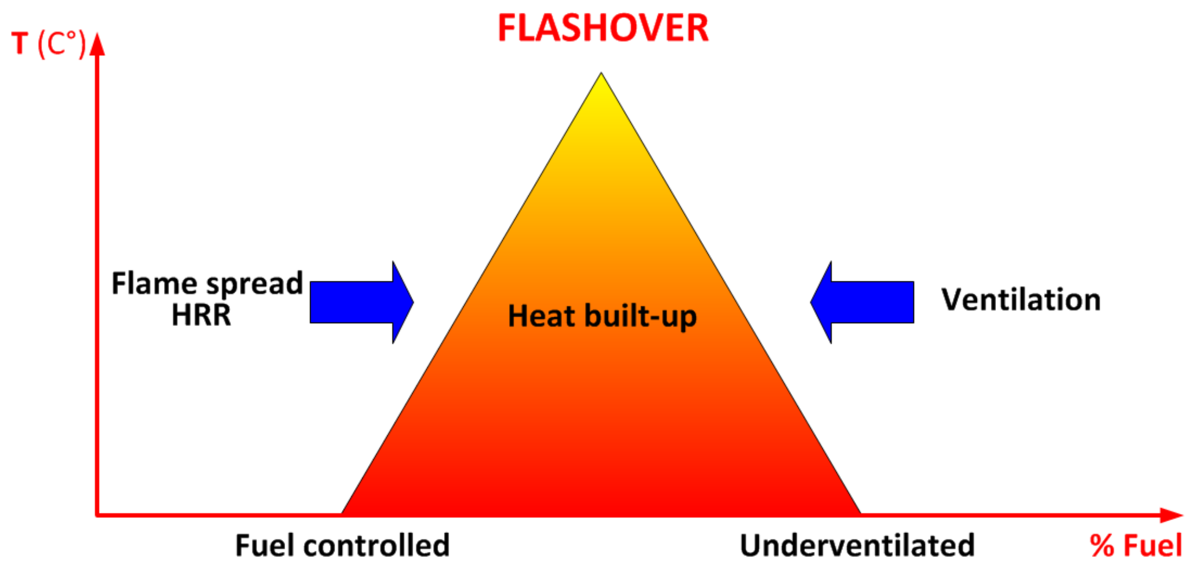

Fig 1.3 Both types of flashover *(Graph: Karel Lambert)*

2. Strategy for safe interventions

Often in the past, fire fighters were caught unaware by the sudden increase in fire intensity. The moment flashover occurs, fire fighters rarely stand a chance of surviving. In several countries a thorough investigation is done after a severe accident involving fire fighters as to learn from it and also to perform safer interventions in the future. This shows that a fire fighter is without chance at the moment flashover occurs in a room, and he/she is farther than 1,5m from the exit of the room. This means that in post flashover circumstances, one has only enough time to cover the distance of 1,5m before perishing. Naturally speaking, this distance is covered right after the room has changed into an inferno. The temperature is close to or exceeding 600°C and there's practically no visibility. This leads us to the conclusion that there's only a limited number of safe actions at hand.

2.1 Don't be there

The most important strategy is: "Don't be there". Fire fighters who have exited the building in case of imminent flashover, will not perish because of the flashover occurring. This strategy underlines the importance of correct fire assessment. Because of the fire's dynamics, various warning signs are visible from which can be deduced whether flashover is imminent. Ever (chief) officier should be able to recognize those signs and order an immediate evacuation of the building when necessary. It is clear that the present form of education is severely lacking in this area.

2.1.1 Warning signs for flashover

For fire fighters it's crucial to read a fire correctly and the assess whether flashover is possible. The B-SAHF model, designed by Shan Raffel and further developed by Ed Hartin, can be a helpful tool for this job. There are a number of signs that indicate flashover is close to happening and evacuation of the fire fighters needs to be started:

- A smoke layer that's rapidly dropping or that is already very close to the floor
- A smoke layer containing dark, black smoke or evolving from white greyish to dark black.
- A smoke layer that is very turbulent or that is becoming very turbulent.
- The heat of the smoke layer that is becoming intense and unbearable.
- The violently pyrolysing of objects that until then were seemingly unaffected by the fire. Suddenly pyrolyzates will appear from those objects.

2.2 Preventing flashover

The cause of flashover is well known. Both "common" and ventilation induced flashover build up heat in the smoke layer. In the case of common flashover this is done by adding more fuel to the fire. In the case of ventilation induced flashover this is done by increasing the fire's oxygen supply.

2.2.1 Cooling of smoke gases (gascooling)

The tactic that's bound to be the most successful for fires in the growth stage, is gascooling. This is done by using the 3D firefighting technique. The goals of this technique are cooling and inerting the smoke layer. To achieve these goals, the spray cone of the nozzle has to be set to about 60°. A pulse, as short as possible, is then directed into the smoke layer. By doing this, a large number of water droplets will enter the smoke layer. Evaporation of these water droplets will extract energy from the smoke, which causes it's temperature to drop. When numerous pulses are directed into the smoke layer, one can possibly keep the temperature of the smoke low enough as to make flashover impossible. An additional advantage of this technique is the mixing of steam into the smoke layer. Steam is a non-flammable gas. An eventual roll-over will be hindered by the steam present in the smoke. Making a smoke layer non-flammable is called inerting.

2.2.2 Anti-ventilation

In the case of ventilation induced flashover, the use of anti-ventilation can offer a solution. Anti-ventilation means that one will try to contain and close down the room in which the fire is burning. A fire that is underventilated will eventually die out by lack of oxygen. In reality it is not always possible to apply an anti-ventilation tactic. One of the windows in the room might break because of the difference in temperature. In the USA and in Canada, experiments have been conducted to ascertain the possibilities for eliminating ventilation and in particular the effect of wind. At high wind speed the use of Wind Control Devices (WCD's) can be an option. Simply put this means a form of fire retardant canvas is placed in front of the window.

3. Case: the Stardust disco fire

On January 14th, 1981 a fire started in the Stardust nightclub in Dublin. At the time of the fire there were 841 people present at the disco. The fire initiated in a closed in section of the great room and developed extremely fast into flashover. Because of this the fire spread out into the rest of the nightclub. Forty eight people died that night and another 214 were injured. The flashover was an important contributor to the heavy casualty toll. Aside from this, very little had been done in terms of fire prevention. The wall linings and benches were very flammable, there were hardly any fire extinguishers and several emergency exits had been locked.

3.1 The building

The disco was housed in a complex made up out of several buildings. Inside the nightclub there was a central dance floor area surrounded by several niches. These niches were furnished with upholstered benches. A layout is shown in figure 3.1. The niche where the fire originated is highlighted. The niche was measuring approximately 17m wide and 10m deep. The benches were mounted on a slope and were made up of 50mm of polyurethane foam with a PVC wrapping. Figure 3.2 shows that some kind of curtain made it possible to close off the niche from the central area. This curtain made it possible to adapt the size of the disco to the number of people present. The curtain was made up of a flammable material, in this case polyester with a PVC lining.

The rear and side walls were covered with flammable linings made of polyester tiles. The ceiling of the niche had been insulated. The presence of insulation in the ceiling forced (some of) the heat to be directed towards the central dance floor area.

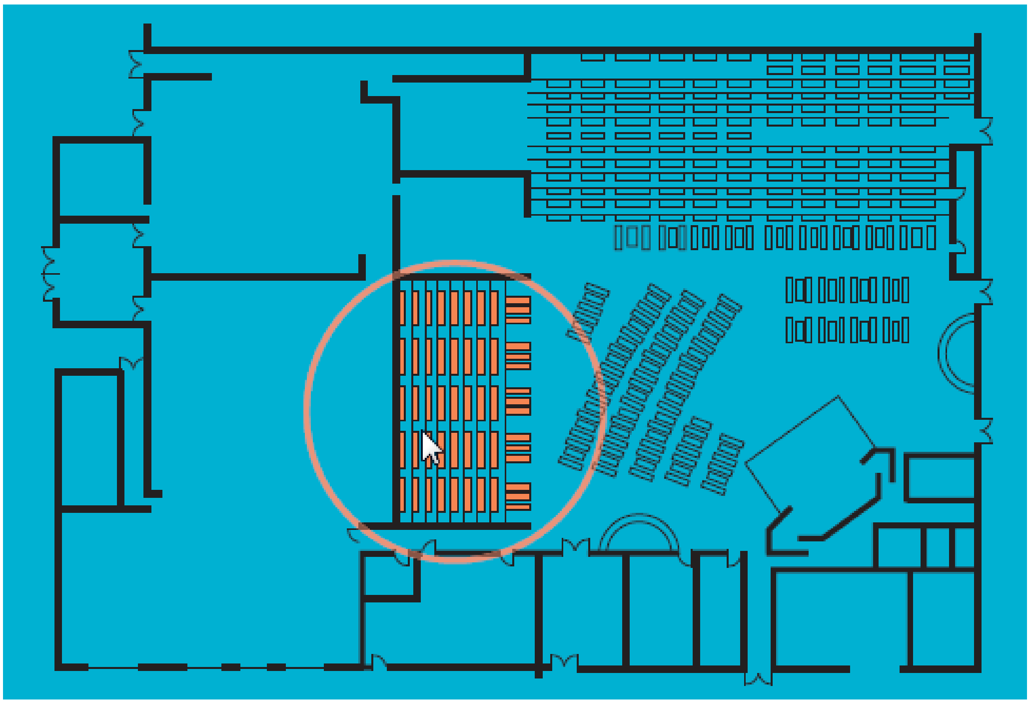

Fig 3.1 Floor layout of the disco *(Image: Bo Andersson)*

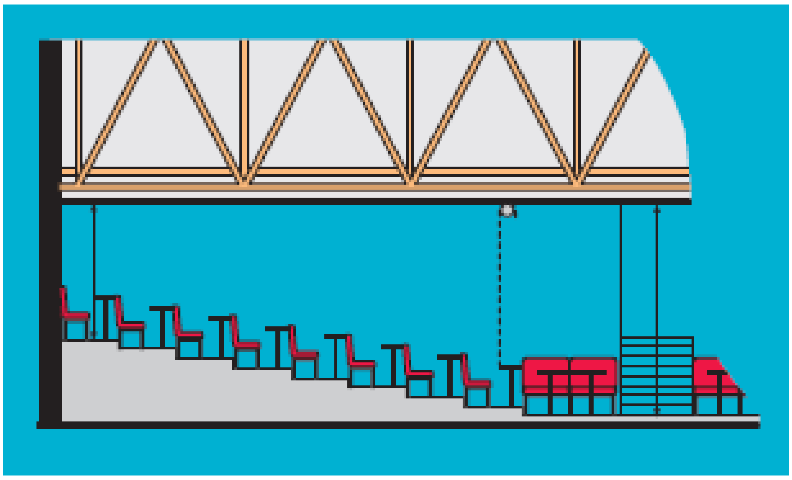

Fig 3.2 Sectional view of the niche. The dotted vertical line indicates the position of the curtain. *(Image: Bo Andersson)*

3.2 The fire

The fire started at the back of the niche. None of the people present was alarmed by the initial small fire. The nightclub's employees decided on trying to extinguish the fire themselves. Only after failing this, the fire department was called. Even the partygoers initially chose to stay and watch. Evacuation of the building began too late.

At some point in time an employee opened up the curtain which was separating the niche from the central area. The flow of smoke had been limited up to that point. After opening the curtain the fire grew rapidly. After flashover occurred inside the niche hot smoke was flowing into the central area. Panic erupted soon after.

3.3 The flashover

A thorough investigation of the fire was ordered because of the high death toll. BRE (Building Research Establishment) performed a thorough job by doing a full scale test. The niche in which the fire had started was rebuilt with identical benches and tables as those that had been placed in the nightclub. The necessary equipment was installed and a fire was instigated. The entire test process was filmed and a shortened version of the film is available on youtube. The film shows the fire development inside the niche quite well. Especially the phase of flashover is clearly visible. Originally I had hoped to provide this article with images from the film, but permission was denied by BRE. Readers that feel like searching for extra material can visit www.youtube.com and type in "stardust disco fire". The results will usually have a short film of about 50 seconds in the top entries. It's worth the effort to view and review the film fragment several times to gain awareness of the intense nature of flashover. The film also shows that flashover is a phenomenon that lasts several seconds.

At 5 seconds into the film, four out of five rows of benches are still clearly visible. The fifth row of benches is burning. This fire is limited to a surface area. Already a dark grey smoke layer has formed. About 9 seconds into the film it is shown that the seat of the third row of benches is starting to pyrolyse. Eight seconds later the second row of benches is starting to pyrolyse and another two seconds later the first row starts to pyrolyse. By second 24 the ashtray on the foremost table has caught fire. Flashover has clearly occurred inside the compartment. During the 19 seconds that have passed, a flame front has been moving from the back wall toward the opening of the niche. Coloring of the smoke has transformed from dark grey to pitch black. From second 29 and onwards, it is shown how hot smoke gases are flowing out and are igniting upon exiting the niche. During the actual fire this flow was being directed into the central dance floor area. The amazing speed at which the phenomenon had occurred and the enormous amounts of hot smoke that entered the central area, resulted in a very large number of casualties.

4. Bibliography

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5. Author's note

Personally I think it would be good idea to also discuss Belgian cases in the future. I have a feeling that the amount of Rapid Fire Progress cases is ever increasing in our country as well. If you have experienced a fire intervention which exhibited extreme fire behavior, you are always welcome to e-mail me a report containing the facts (preferably with images) at karel.lambert@skynet.be.

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