Fire Gas Ignition

In the Belgian fire service the phenomena of flashover and backdraft are pretty well known. The fourth article of this series elaborated on the subject of backdraft. The sixth article covered flashover. The existence of a third family of fire phenomena is less known however. This family is called Fire Gas Ignitions (FGI). FGI is a term to describe all the events that don't really fit the definition of flashover, nor that of backdraft. The most common occurrences of FGI are discussed below.

1 Flashfire

During a fire, a lot of smoke gas is being produced. This smoke is hot and it's mobile. It will spread through openings and cracks. Possibly smoke will amass in a space somewhere near the fire. The example that obviously comes to mind is that of a false ceiling. It's also possible that the smoke gas exits the room through cracks at the door and enters the neighboring compartment where it will form a layer up against the ceiling. It may even happen that smoke amasses in a built in closet or a false wall. Houses made up of a wooden frame often have shafts built into the structure. After entering these shafts, the smoke will spread out into the building. This will cause flammable smoke gas to appear in places where it is least expected.

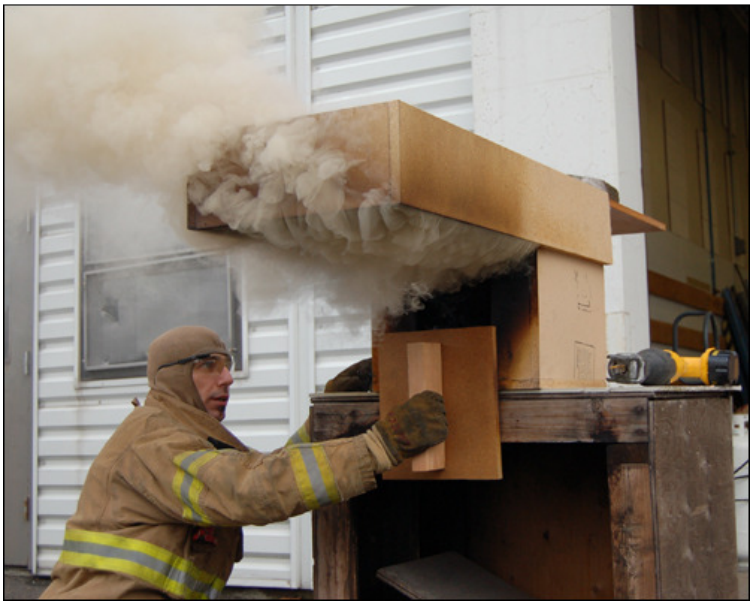

Fig 1.1 The compartment at the back is burning. Smoke gas has leaked from the closed off door and has formed an explosive mixture up against the ceiling *(Photo: Ed Hartin)*

When sufficient smoke gas has been added into a room, a mixture of gas and air will be formed that's inside flammability limits (see Fig. 1.1).

At that point, two sides of the fire triangle are present. The smoke that has entered the room contains enough flammable components (white, grayish pyrolyzates and/or black unburned smoke gas). Inside the room there's also sufficient oxygen still present in the air.

When the mixture is inside the flammable range, the only thing needed for ignition is an energy source.

This energy source can be provided by exiting flames or by the fire crew adding energy into the mixture. The latter can happen when sparks fly up during the overhaul. The impact of water when using a solid jet at multiple small fires, can cause fiery particles to fly up into the smoke layer. The insertion of an ignition source can even occur at the overhaul by moving a piece of furniture and thus exposing a small fire.

When an ignition source with enough energy is brought into the mixture, it will catch fire. A flame front will spread out through the mixture.

A situation that regularly arises on the fire ground is when smoke is leaking massively through the cracks around doors. In the compartment in front of the door a smoke layer will form up against the ceiling. A smoke layer within the flammability range creates a high risk situation for an attack crew.

When the fire crew opens the door, exiting flames may ignite the mixture (see Fig. 1.2). The entire smoke layer inside the room where the attack crew is in, will catch fire. The heat radiation will rise enormously and pose a severe threat for firefighters.

Aside from this, the occurring flashfire will make sure the fire development in the second room will accelerate.

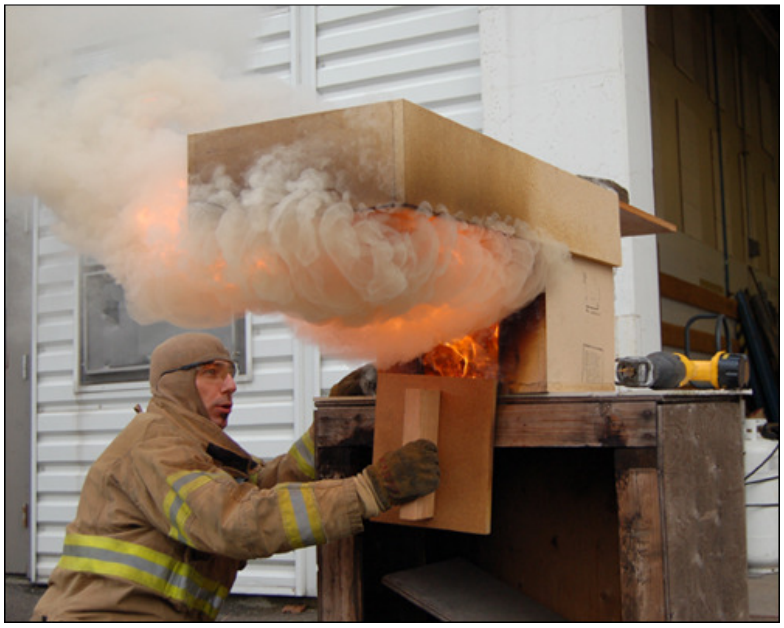

Fig. 1.2 Opening the door will allow for flames to exit and ignite the mixture. *(Photo: Ed Hartin)*

Any available furniture in the second room will almost immediately start to pyrolyze. The fire in the second room will progress very quickly into flashover (see Fig. 1.3). Either way the risk is very high for firefighters opening the door. A proper door entry procedure will try to minimize this risk by the application of two pulses before opening the door. The mist of water droplets formed above the door will prevent the exiting flames from igniting the mixture in the second room.

Fig 1.3 Fully developed fire after a flash fire. *(Photo: Ed Hartin)*

Case: The fire in "De Punt"

On May 8th of 2008 a flashfire occurred in "De Punt" (NL) in a hangar where boats were being repaired. In the back of the hangar were several smaller rooms. In one of these rooms a fire had started. The fire was under ventilated and a large amount of smoke was leaking into the hangar through an open door. Underneath the mildly angled saddle roof a lot of smoke was being amassed. The smoke mixed with the available air and formed a flammable mixture.

At one point flames exited through the door of the room containing the seat of the fire and created an ignition. The consequences of the flashfire were devastating. In a short period of time the entire hangar caught fire. The fire inside the hangar progressed to fully developed state almost instantly. Three out of four firefighters inside were unable to get out in time and perished.

An important characteristic of a flashfire is the lack of a large pressure buildup. Because of the flame front a natural rise in pressure will occur. This rise in pressure will not cause damage by itself.

2 Smoke Explosion

A smoke explosion works the same way as a flashfire. Likewise we are dealing with a mixture made up of smoke gases, pyrolyzates and air which is ignited by inserting an ignition source. Just as a flashfire, it's possible for a smoke explosion to occur during a fire in a neighboring compartment or even after a fire in a sealed of space (closet, false ceiling, …).

The big difference between a flashfire and a smoke explosion is that the latter does have a substantial pressure buildup. This pressure buildup creates a peak of overpressure. The overpressure depends on the mixture of smoke and air. A mixture forming a smoke explosion will be closer to the stoichiometric mixture than the one forming a flashfire. A mixture forming a flashfire will therefore be closer towards either limit of the flammability

Fig 1.4 Concequences of a smoke explosion. *(Photo: Roland Stregfelt, www.msb.se)*

range.

The peak of overpressure will cause damage to structures. Ceilings will drop down, windows will shatter, doors will break down, false walls will collapse, and so on.

3 Warning signs and preventive measures

3.1 Warning signs for flashfire & smoke explosion

Contrary to flashover and backdraft, flash fire and smoke explosion don't have clear warning signs. Any room where air and smoke gas have mixed sufficiently can produce the phenomena.

The phenomena are however most common in sealed off spaces. False ceilings, shafts and false walls form hidden voids where smoke gases can amass. Therefore the presence of hidden voids and sealed spaces should be seen as a warning sign. Some buildings will allow for a size up that includes the presence of false ceilings and false walls. The B-SAHF model can be a great asset for this.

3.2 Decreasing the risk of flashfire and smoke explosion

Flash fire and smoke explosion are two phenomena that work the same way as a regular gas explosion. They most often occur in spaces that are sealed off from the fire. By (partially) evacuating smoke by use of ventilation, it is possible to drop the concentration of smoke gases down to below the lower flammability limit. Once this has been achieved, an ignition is no longer possible and the danger has passed.

In practice it may happen for smoke gas to gather up against the ceiling. In this case they are clearly visible. More often it happens that the smoke gathers in shafts or false ceilings. Detection will no longer be as easy. When dealing with hot smoke gas, a thermal imaging camera can sometimes provide the answer. Then again it may well be that it's impossible to detect the smoke.

Even when the smoke gases have been detected, it won't always be easy to vent them. If venting is viable, it's a solid tactic for the situation.

Often when dealing with small (decaying) fires of which the seat is hard to localize, a situation arises in which smoke amasses in false ceilings. An example of this is a smoldering fire inside a wooden floor. If the fire stays small, it's advisable to assess the risk for flashfire in the false ceiling during a thorough size up. "Where is the smoke going?" By opening up or partially removing the false ceiling it may become possible to remove the smoke by use of ventilation. While one crew searches for the seat of the fire, another can concentrate on dealing with the gathered smoke in hidden spaces.

The new (Belgian) door entry procedure also contains an element to provide some level of protection in the event of a flash fire. When the attack crew has advanced through a room in which smoke has gathered up against the ceiling, chances are they will find a sizeable fire in the adjacent room. Suppose now that the smoke in the first room against the ceiling has mixed sufficiently with air. This mixture could easily be ignited by a flame. Before opening up the door to the next room, one pulse is directed above the head of the

hose man and one pulse is directed above the nozzle man. The goal is to create a mist of water droplets at the top side of the door. In the event of flames exiting the room upon opening of the door, they will be caught in the mist of water droplets. This will make it impossible for exiting flames to act as an ignition source for the smoke gathered in the room with the attack crew.

4 Auto-ignition

Auto-ignition is a phenomenon which occurs when smoke gases reach a high enough temperature. Every mixture of smoke has a temperature at which it will spontaneously combust. This temperature is called the auto-ignition temperature (AIT). This temperature also exists for flammable liquids.

It goes without saying that there's an important condition that has to be met for auto-ignition to occur. Just as with every other form of combustion, sufficient oxygen has to be available in the room in which the smoke has exceeded the temperature threshold. During a compartment fire, the fire uses up the oxygen inside the room. It may well be that the oxygen needed for auto-ignition is no longer available the moment the smoke reaches the AIT. Such fires sometimes have a limited air track at floor level. This current of air keeps feeding the fire. At the top of the room, a layer of super-hot smoke exists which has the potential to auto-ignite. Because of the lack of oxygen, this smoke mixture is above the upper flammability limit.

When a window fails or is opened during such a fire, hot smoke will exit. Upon exiting, the smoke gas will quickly become mixed with air. The smoke gas will be diluted. The mixture will enter the flammable range and will ignite. The smokes own temperature will provide the energy needed for ignition.

The biggest hazard of auto-ignition is the massive heat source it creates at the exit point. This heat source is capable of causing a secondary fire. Auto-ignition can just as easily happen when opening an inner door. If not reacted to properly, the exiting smoke gases will surely cause the fire to progress into the adjacent room.

Auto-ignition can also lead to an incorrect assessment of the fire. When upon arrival, the officer is confronted with a fire exiting through a window, he could easily conclude that the fire is fully developed. Most of the times this assessment will be the correct one. Tactics will be altered according to the size up. An interior attack in the burning compartment is no longer a viable option. There are however situations in which "exiting" flames provide an incorrect view. The flames aren't coming from the inside, it's the smoke that's igniting upon exit. In this case the fire is still pre-flashover and in the growth stage. These fires do allow for a more aggressive interior attack. To distinguish exiting flames from auto-ignition, several offensive 3D pulses should be directed into the opening. The water will provide a minor cooling effect on the exiting smoke gas. In the case of auto-ignition the flames will disappear and the crew will recognize they're dealing with smoke flowing out of the window. In the case of a fully developed fire, 3D pulses will not suffice to knock down the flames. Here the flames will continue and the fire will need to be tackled differently.

5 Roll-over

For the sake of completeness, it's mentioned here that rollover is assigned to the category of fire gas ignitions. Rollover is known as the phenomenon that precedes flashover. It's the ignition of the smoke layer. The flames originate in the smoke layer close to the seat of the fire. A flame front then moves through the smoke layer. This usually happens fastest towards the ventilation opening.

6 Bibliography

[1] *Lambert Karel & Baaij Siemco, Brandverloop: technisch bekeken, tactisch toegepast, 2011*
[2] *McDonough John, personal talks, 2009-2011*
[3] *Hartin Ed, personal talks and www.cfbt-us.com, 2010-2011*
[4] *Bengtsson Lars-Göran, Enclosure Fires,2001*
[5] *Grimwood Paul, Hartin Ed, Mcdonough John & Raffel Shan, 3D Firefighting, Training, Techniques & Tactics, 2005*
[6] *Lambert Karel & Desmet Koen, Binnenbrandbestrijding, versie 2008 & versie 2009*
[7] *Hartin Ed, www.cfbt-us.com*
[8] *Raffel Shan, www.cfbt-au.com*

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