MENU

QUIT

BACK

Backdraught, Flashover & Thermal Layering

Firefighter Phase IV

Section

4

The notes contained in this section are extracts from:

"Recruit Course Training Notes"

5th February 2001

BACKDRAUGHTS

Reducing The Oxygen Supply To A Fire

In general, the hot gases generated in the plume will rise extremely rapidly and will draw air in towards the fire. If there is an adequate air supply, the fire will continue to burn and grow as long as there is fuel available.

If the air supply to the compartment is restricted, the oxygen in the air inside may be used up more quickly than it can be replaced. The net effect will be a progressive lowering of the concentration of oxygen in the gases in the compartment possibly combined with an increase in the temperature in the compartment.

As the oxygen concentration in the compartment reduces, the flames will start to die down, but this will not immediately result in a reduction in the production of flammable gases. Although the radiated heat from the plume reduces, the compartment is still very hot, and nothing has happened to cool the fuel. There may still be flames present, or they may die out altogether. Depending on the relative sizes of the fire and the compartment at this stage, sufficient flammable gases may be generated to spread throughout the compartment. This requires only a new supply of oxygen caused for example by opening a door, for it to form an explosive mixture with potentially lethal consequences – a BACKDRAUGHT.

The Definition Of A Backdraught

Limited ventilation can lead to a fire in a compartment producing fire gases containing significant proportions of partial combustion products and unburnt pyrolysis products. If these accumulate then the admission of air when an opening is made to the compartment can lead to a sudden deflagration. This deflagration moving through the compartment and out of the open is a **backdraught.**

Possible Backdraught Scenarios

There are two different backdraughts scenarios, any one of which could be awaiting the firefighter.

- If the fire is still burning in the compartment when the firefighter opens the door, and especially if the combustion gases are not escaping, the air which enters through the door may mix with the flammable gases, forming an explosive mixture.

If the gases in the compartment are hot enough, they will then ignite on their own (auto-ignite) at the doorway, and the flame will spread back into the compartment along with the fresh air supply. This would result in rapid fire growth, but not necessarily in a backdraught.

If the compartment gases are not that hot, they will be ignited when sufficient oxygen as reached the gases surrounding the fire. Flame will then travel across the compartment towards the door, resulting in flame shooting out of the door (Figure 1), driven by the expanding gases behind it. It is not easy to predict whether this will actually happen, or how long it will take, once the door has been opened. This will depend on where the fire is in the compartment, the rate at which air flows in through the door, and whether the hot gases can escape without mixing with the incoming air.

Figure 1 A backdraught

- A more dangerous situation can occur when the fire in the compartment has almost died out. When the door is opened, the air flows in and an explosive mixture may be generated, but nothing happens because there is now no immediate source of ignition. If the firefighters now enter the compartment, their activities – for example, turning over may expose a source of ignition, initiating a delayed backdraught but now with them inside the compartment and surrounded in flame (Figure 2).

Figure 2 A delayed backdraught

This can still occur even when the fire is apparently out and the compartment has cooled down. Foam rubber, in particular, can smoulder for a long time, producing flammable gases. Whenever flammable gases remain in the compartment, they can be ignited. Cold smoke explosions occur in this way.

The situation can be further complicated if significant amounts of the flammable gases in the compartment have managed to escape into surrounding areas. Areas other than the closed compartment could then contain explosive atmospheres, waiting for a source of ignition. Most at risk is the area directly outside the compartment (Figure 3), exactly where the firefighters are waiting when they open the door. When the door is opened, flammable gases outside the compartment may be ignited by a backdraught within the compartment by embers flying through the open door, or by the hot gases if they are at their auto-ignition temperature. It is even possible, thought unlikely, for other areas of the building to be involved in a backdraught, ignited without there being a backdraught in the original compartment. Flammable gases outside the compartment may be ignited by embers flying through the open door, or if the hot gases in the doorway auto-ignite.

Figure 3 A flammable gas explosion outside the compartment

Signs and Symptoms of a Backdraught

The first clue to the possibility of a backdraught is the history of the fire: if the fire has been burning for some time, has generated lots of smoke which is now leaking out from the building, and has apparently died down without major areas of flame being visible from outside, the possibility is that it has died down from oxygen starvation.

When the building is viewed from outside, it is likely that the windows of the compartment concerned will be blackened with no obvious flames within. If part of a window is broken, it is possible that this will not provide sufficient oxygen to feed the fire. In this case it is likely that smoke will be pulsing out of the hole. Fresh air is drawn in as the fire cools slightly and the hot gases contract. This produces a local explosive mixture which burns, resulting in a mini-backdraught. The expansion of the hot gases in turn drives some smoke out of the compartment.

This cycle repeats itself at a frequency which depends on the size of the hole and the location of the fire relative to it.

If there is a gap under the compartment door, there may be smoke pulsing there due to the mini-backdraught effect already described. There may be a whistling noise if air is being drawn into the compartment through very small gaps around the door, but this could be difficult to hear. The door may be hot on the outside. In particular, the door handle may be hot if there is a metal rod linking it to the door handle on the other side.

If the compartment has been left long enough for it to cool down, air will no longer be drawn in, and the smoke pulsing effect will not be evident. However, if the compartment has not been ventilated and there are still flammable gases present, a backdraught is still possible.

If the decision is taken to open the door, there may be an in-rush of air as soon as the door is ajar, showing either that there is a shortage of oxygen in the compartment, or that the compartment has been much hotter and is starting to cool. Small flames may appear where the gases from the room are meeting the relatively fresh air outside, indicating that there are flammable gases in the room which are sufficiently hot to ignite given a source of fresh air, even without any other source of ignition. In either case, it may still be possible to close the door before sufficient air has entered the compartment to trigger any possible backdraught.

Actions by Firefighters

Once the door has been opened on to a compartment with an oxygen starved fire and fresh air has been allowed in, there is little which can be done to prevent a backdraught happening. It is far better to make appropriate decisions before the door is ever opened.

When firefighters are faced with a closed door, and do not know what is behind it, they should check for any of the signs and symptoms described above before opening it, covering the door with a charged branch, should they decide to open it. If there is a build-up of smoke outside the compartment, the possibility of backdraught can be reduced by spraying these gases before the compartment door is opened. The firefighters should be ready to close the door quickly, if a backdraught appears likely. This may not prevent the backdraught but may direct its force away from the firefighters.

If firefighters believe that opening a compartment door may lead to a backdraught, opening that door must be as a result of a deliberate decision. As long as the compartment door is closed, firefighters have time to think about their actions. Once the door is open, they will only have time to react to events as they occur. Whilst the decision about the timing of opening the door can only rest with the firefighters who form the fire fighting crew at the scene, the consequences of that decision ultimately lie with the Officer-in-Charge of the incident.

However, the compartment will still have to be inspected at some stage. The priority is then to make it safe for the firefighters to enter. As already described, a backdraught can only occur when fresh air is permitted to enter the compartment. It is possible for firefighters to operate in a flammable atmosphere provided there is no opportunity for things to change and for fresh air to enter whilst the firefighters are inside. It is difficult to be sure – a window might shatter, someone might unwittingly open another door to the compartments. The far safer solution is to remove the flammable gases from the compartment – ventilation.

It is important to recognise that ventilation requires that fresh air should be let into the compartment. Thus, there is the possibility that a backdraught may occur during ventilation, so appropriate precautions should be taken.

If it is decided that a compartment needs to be ventilated and once the method of ventilation has been selected by the Officer-in-Charge of the incident:

- Branches must be charged and in position prior to any ventilation being carried out;
- Firefighters must get down low, and well clear of the likely flame path back through the vent opening, should a backdraught occur; and
- It must be remembered that a backdraught could be delayed several minutes and that it might have sufficient energy to break other windows in the compartment.

No compartment can be considered safe from a backdraught until it has been opened to fresh air for some time. However, once the compartment has been properly ventilated, firefighters can tackle the fire knowing that there is no longer any possibility of backdraught.

BACKDRAUGHT SUMMARY

Indicators

- Dense smoke with no obvious sign of flame.
- Smoke blackened windows.
- Smoke pulsing from doors and windows.
- Signs of heat around the door.

Safety

- Ensure you are properly protected.
- Keep door closed and cover with charged branch.

- If possible, keep out of the room and ventilate from outside.
- Check escape routes are secure and, if necessary, protected.
- Cool and ventilate the outer compartment.
- Plan an escape route for the gases before releasing them.
- Stay low and to the side of the door.
- Open the door slightly and spray through, directing the spray upwards.
- Cool as much of the compartment as possible.
- Keep out of the way of the steam and hot gases.
- Only enter the room if you have to – there may still be flammable gases present.

Backdraught Created Using the Fire Experimental Unit Simulator

A sequence of photographs from a backdraught simulator filmed at the Home Office's Fire Experimental Unit Simulation laboratory at Moreton-in-Marsh.

A methane flame has been burning in the compartment for some time, heating the ceiling and consuming the oxygen. The flame has gone out due to a shortage of oxygen, but the methane supply has continued, as though fuel in the compartment were still pyrolising. The door at the left hand end of the compartment is opened after 6 min 0 secs, and an ignition source is turned on at the right hand end 5 seconds later.

MENU

QUIT

BACK

Time 5.92s Fresh air has flowed into the bottom of the compartment and hot gases have flowed out of the top. At the interface between the air and the methane, a flammable mixture has been created. This has ignited. Turbulence is mixing the gases further, and the products of combustion are expanding.

Time 6.12 s The flame travels along the gas/air interface, and searches for anywhere a flammable mixture is available. Unburnt flammable gases are being driven out of the compartment door by the expansion of the gases after combustion.

Time 6.36s The flame now fills most of the compartment, and the jet of unburnt flammable gases is extending outside the compartment.

Time 6.76s The flame drives out of the compartment and ignites the flammable methane/air mixture outside.

Time 6.88s A massive fireball seeks out every available space around the compartment door.

FLASHOVERS

Fire Spread

It has already been described how a smoke layer will build up when smoke cannot escape from a compartment as quickly as it is generated (Figure 4). However, if there is unburnt fuel in the compartment, things will not stay stable for long. Initially, the flame in the plume will not reach the ceiling and fire spread will be limited to flammable materials close to the seat of the fire, ignited by radiated heat from the plume.

MENU
QUIT
BACK

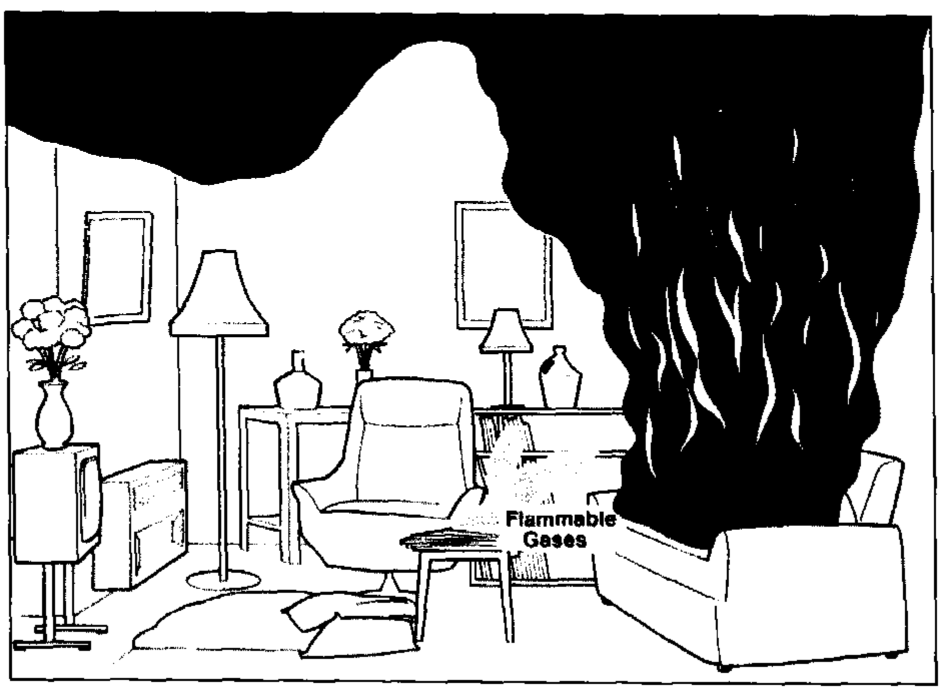

Figure 4 The build up of the smoke layer

The flame height will increase until it reaches the ceiling. The flame will now start to spread across the compartment in the hot gas layer (Figure 5), with the flame appearing both at ceiling level above the plume, where air has been entrained, and at the boundary between the hot gas layer and clear air, as this is where the flammable gas in the ceiling layer can react with the oxygen.

Figure 5 Flame in the smoke layer

Once flame has started to spread across the compartment at the boundary level, this will greatly increase the thermal radiation from the hot products of combustion already built up there. The other flammable materials in the compartment will now start to rise in temperature very rapidly. Not only are they being heated from the side by the plume, they are also being heated from above, where the flames and the hot products of combustion could be much closer, depending on the height of the boundary.

In large compartments with higher ceilings, flame and the hot products of combustion may spread at ceiling level without getting low enough to cause nearby fuel sources to start giving off flammable gases.

However, it may be that, at some distance from the fire, either a discontinuity in the ceiling causes the hot gases to swirl lower, or there is a high pile of flammable material. In either of these cases, the source of thermal radiation has been brought closer to the fuel, and ignition may result. By this mechanism, fire spread can cut firefighters off from their means of escape.

As the hot smoke layer descends, and particularly if there is a low ceiling, all the remaining contents in the compartment will now be heated to the stage when they will themselves start to give off flammable gases (Figure 6). It is then only a matter of time before there is a sudden change in the size of the fire, if no action is taken to prevent it. The smaller the compartment, the sooner these conditions are likely to be encountered.

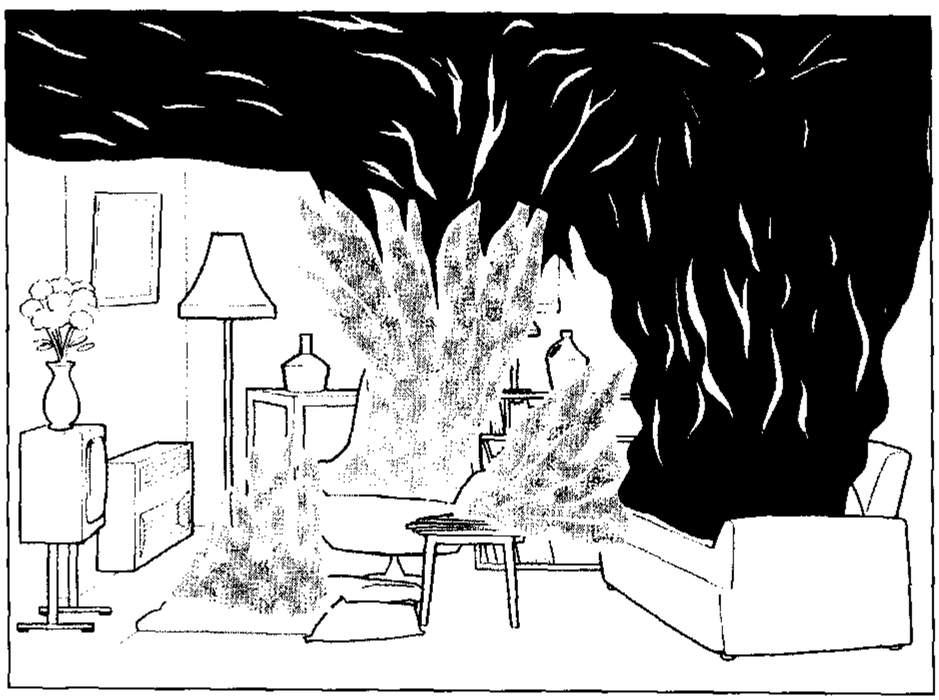

Figure 6 Rapid heating of all combustible materials

Once flammable gases are being given off by the majority of the compartment contents, the transition from a localised fire to total involvement can take a matter of seconds – a FLASHOVER.

Definition of a Flashover

In a compartment fire there can come a stage where the total thermal radiation from the fire plume, hot gases and hot compartment boundaries causes the generation of flammable products of pyrolysis from all exposed combustible surfaces within the compartment. Given a source of ignition, this will result in the sudden and sustained transition of a growing fire to a fully developed fire. This is called **flashover.**

It can be seen that, according to this definition, a backdraught can be a special case of a flashover. If the backdraught results in a sustained fully developed fire, a flashover has occurred. Nevertheless, it is important to be able to draw a distinction between the two because the implications for firefighters are very different.

Signs and Symptoms of a Flashover

The primary requirement for a flashover to occur is that there should be significant thermal radiation from above. This will be felt by the firefighters as a rapid increase in the temperature in the compartment, and in the heat from the hot gases at ceiling level, forcing them down low. If they can see above them, they will be able to see tongues of flame running through the gas layer. In addition, other combustible materials within the compartment will be giving off visible smoke, and flammable gases.

Actions by Firefighters

As the main reason for a flashover is radiation from the hot gases and flames above the, the logical solution is to cool this area. This will have the effect of reducing the flames and radiated heat, and causing the smoke layer to lift. Directing a spray at the ceiling will have this effect. However, too much water will cause the generation of large amounts of steam. Too much cooling will bring the smoke layer down, obscuring everything.

In these circumstances, it will be most effective for the firefighters to attack the hot gases with pulses of spray, observing their effect, and so judging when sufficient water has been applied.

Once the immediate danger of a flashover has been eliminated, the next steps depend on whether flashover conditions could re-develop before the fire can be extinguished. If this is likely, it is important to ventilate the fire as soon as possible.

If the hot gases are released faster than they are generated, the smoke layer will reduce, and the risk of flashover will reduce. Built-in roof vents are designed to do exactly this, either automatically, or when operated by the fire service. However, it is important that the correct vents are opened. The further from the fire that the vent is, the further the hot gases have to travel, and the more the chance of fire spread.

Where there are no built-in vents, firefighters have the option of making their own. It must be remembered, however, that incorrect use of ventilation can result in increased fire-spread at high level as hot gases are channelled into areas they might otherwise have taken longer to reach.

FLASHOVER SUMMARY

Indicators

- A rapid increase in compartment temperature and in heat from hot gases at ceiling level.
- Tongues of flame visible in the smoke layer.
- Other surfaces giving off fumes.

Safety

- Make sure you are properly protected.
- Ensure entrance covered by a charged branch.
- Check escape routes are protected.
- Check the outside of the door for signs of heat.
- Stay low.
- Use spray pulses on hot gases at ceiling level.
- Ventilate only when safe to do so.
- Be aware of the potential for flashover and backdraught.

Build up to Flashover

A sequence of photographs from an enclosed room-fire filmed at the Home Office's Fire Experimental Unit Still-Air laboratory at Little Rissington.

Time 0m 0s	The fire starts in a wastepaper basket.
Time 1m 20s	A smoke layer is starting to build up in the room. The plume has yet to reach the ceiling. Temperatures at ceiling level are rising.
Time 2m 15s	The smoke layer is getting thicker and the fire is starting to spread to nearby furniture. The flames have not yet reached the ceiling.
Time 2m 55s	The smoke layer has descended to one metre above the floor, and there is flame in the smoke. All other furniture in the room is pyrolising.
Time 3m 05s	Flashover has occurred. The flame totally fills the compartment.

THERMAL LAYERING OF GASES

The thermal layering of gases is the tendency of gases to form into layers, according to temperature. Other terms sometimes used to describe this layering of gases by heat are heat stratification and thermal balance. The hottest gases tend to be in the top layer, while the cooler ones form the bottom layer. Smoke is a heated mixture of air, gases, and particles, and it rises. If a hole is made in the roof, the smoke will rise from the building or room to the outside.

Thermal layering is critical to fire fighting activities. As long as the hottest air and gases are allowed to rise, the lower levels will be safer for firefighters. This normal layering of the hottest gases to the top and out the ventilation opening can be disrupted if water is improperly applied.

If water is improperly applied to the fire area and the area is not ventilated, the water will cool and condense the steam generated by the initial fire attack. This reaction causes the smoke and steam to circulate within all levels of the fire area. This swirling of smoke and steam is the result of disrupted normal thermal layering . This process is sometimes referred to a disrupting the thermal balance or creating a thermal imbalance. Many firefighters have been needlessly burned when thermal layering was disrupted. Once the normal layering is disrupted, forced ventilation procedures must be used to clear the area.