Fire Gas Ignition – The Hidden Killer
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In the late 1990's, firefighters were being taught to recognise the "signs and symptoms of Flashover" and the "signs and symptoms of Backdraught". While I found these factors helpful, I believed that there were fire phenomena that did not fit into the mould of either Backdraft of Flashover. While analysing case studies, and even my own personal experiences, I realised there was a need to define and recognise potentially dangerous events that have been known to occur some distance from the compartment of origin. Sadly there are many cases where firefighters have been taken off guard because the lack of indicators that precede the event that was defined for the first time as "Fire Gas Ignition" in the book 3D Fire Fighting.

The simplest way to describe a Fire Gas Ignition is "*the ignition of unburnt fuel in smoke that has accumulated in spaces adjacent to, or distant from the room of origin."* Before we go deeper into Fire Gas Ignition let's do a quick refresher of the more universally understood fire phenomena of Flashover and Backdraft. If you read enough text books and articles you will see a few different definitions even for Flashover and Backdraft! I have quoted those that I believe are the simplest and easiest to understand.

FLASHOVER

The International Standards Organisation (ISO) definition is: *The rapid transition to a state of total surface involvement in a fire of combustible materials within an enclosure.*

The simplest way to understand Flashover is that is it a transition from a developing fire to a fully developed fire in a compartment. Prior to this transition we have sufficient unburnt fuel and air in the smoke layer. It is the build-up of heat that leads to the piloted ignition of the fuel and air or a build up to the auto ignition temperature.

Flashover = (Sufficient Unburnt Fuel and Air) + Heat

BACKDRAFT

A fire phenomenon caused when heat and heavy smoke (unburned fuel particles) accumulate inside a compartment, depleting the available air, and then oxygen/air is re-introduced, completing the fire triangle and causing rapid combustion.

So with the Backdraft situation, we have high levels of unburnt fuel and some form of residual heat energy in the form of super-heated smoke and/or smouldering fuel. In this case the missing part of the triangle is air (oxygen).

Backdraft = (Fuel and Heat) + Air

Flashover occurs in the room of fire origin. Backdraft can commence in the compartment of origin or just outside of it and propagate back into the compartment.

There are 2 main "ignition mechanisms" or "triggers".

1. The gases are above the AIT. When they leave the compartment they can auto ignite (like it can be shown in the doll's house) and then the flame outside will move back inside and trigger the backdraft.

2. If the gases are below the AIT then this is impossible. In this case backdraft can only occur if a) the original fire starts up again and the flame meets smoke (fuel) and air that are in a flammable range, OR b) an ember/spark is stirred up when the air flows in and this may have enough energy to ignite any flammable smoke/air mixtures.

Actually it is all a matter of specific conditions. That is why in many cases backdraft potential may be high, but it is only in a small percentage of the cases that it actually will occur. Because when the compartment is opened up the flammable mixture only occurs around the turbulent area in the neutral plane. This is often narrow, so there is a chance the spark/ember/flame may not make it into this narrow zone.

Voids, ducts, shafts, balloon frame construction, large open plan, high ceilings, false or suspended ceilings etc. - allow smoke (and therefore significant quantities of unburnt fuel) to be transported and accumulate in areas adjacent to the compartment of origin, or some distance from it. Modifications can create unexpected openings or voids. Poor or damaged smoke/fire stopping may be present in original or modified buildings. The unburnt fuel in the smoke is often partially mixed with fresh air and can accumulate to flammable concentrations. This premixing may reduce the temperature of the gases, reduce the thickness and lighten the colour. So in this scenario we have the potential to have large quantities of premixed fuel and air just waiting to be ignited by a number of means. This is a trap for the uneducated firefighter because many of the "traditional" warning signs such as high heat conditions and thick dark smoke may be absent!

If this accumulated smoke is ignited, the magnitude of the event will depend upon how well the fuel and air have mixed and how close they are to the ideal mixture. If the percentage of fuel is low the event could result in an mild to intense rollover. If the percentage of fuel is high then the event could be sustained and behave somewhat like a Backdraft. If however the fuel and air is close to the ideal mixture the event could be extremely intense and even explosive in effect.

When the result is explosive it is often referred to as ***Smoke gas explosion***:- *When fire gases are transported into an enclosure adjacent to the fire compartment, these can mix with fresh air. This mixture can in time, occupy the whole volume. If the mixture is ignited the increase in pressure can be extremely high especially if the mixture concentration is close to stoichiometric. This is known as a smoke gas explosion.*

The B SAHF Chart below shows that there may be few fire behaviour indicators present to warn us of the potential for a Fire Gas Ignition. This is one of the reasons that this event has even caught highly experienced fire officers off guard.

	INDICATOR	FIRE GAS IGNITION
BUILDING	The type of building construction will have an enormous impact on how the fire develops and how long the structure will be stable. The use or occupancy of the building may give some indication of the likely fire load and location. Construction features may make some indicators less obvious or difficult to detect.	Voids, ducts, shafts, balloon frame, large open plan, high ceilings, false or suspended ceilings etc. - allow smoke to be transported and accumulate in areas adjacent to the compartment of origin, or some distance from it. Modifications can create unexpected openings or voids. Poor or damaged smoke/fire stopping can be found in original or modified buildings. The unburnt fuel in the smoke is often partially mixed with fresh air and can accumulate to flammable concentrations.
SMOKE	LOCATION AND VOLUME Volume can vary with the size of the fire compartment, available air supply, and combustion process. A small fire burning for a long time can lead to a large volume of smoke.	Smoke can emerge and accumulate some distance from the source. This can give a false indicator of the location of the fire compartment
	COLOUR - Varies with **FUEL**: -Type -Form (gas, liquid, solid, shavings, dust) **COMBUSTION PROCESS:** -fuel controlled or ventilation controlled	Smoke that has travelled some distance from the fire compartment may appear lighter in colour due to partial mixing with cooler air as it moves through the structure.
	HEIGHT OF NEUTRAL PLANE (smoke layer/air interface)	Usually not well defined due to premixing with cool air.
	THICKNESS (Optical/visual density)	Can often appear to be thinner (to some extent) due to pre mixing with cooler, fresh air.
	BUOYANCY (how rapidly/readily the smoke moves upwards)	Generally not very buoyant due to cooling from premixing with cooler air.

	INDICATOR	FIRE GAS IGNITION
AIR	VELOCITY AND DIRECTION (read in conjunction with the velocity and direction of the smoke).	Smoke velocity will slow as it moves further from the source and spreads out (mushrooming). Any air drawn in through openings in adjacent or remote areas is generally slower moving.
	FLOW - TUBRULENT OR SMOOTH (interface of the air/smoke through openings)	The further the smoke moves from the compartment or origin, the more likely the interface will be smooth.
	PULSATIONS	Highly unlikely.
	WHISTLING SOUNDS	Highly unlikely.

	INDICATOR	FIRE GAS IGNITION
HEAT	PAINTWORK BLISTERED OR DISCOLOURED (Heat indicators may be less obvious in structures with heavy insulation)	A lack of heat indicators could be deceptive as cooler smoke is often not perceived as a risk. The further the smoke has travelled the greater the cooling effect in the early stages. If the fuel has pre-mixed with air, and the concentrations are within flammable limits, it is possible for explosive ignition to occur.
	DARKENED OR CRACKED WINDOWS (May be absent with double or triple glazed window construction). (Water application could cause sudden failure)	Darkening may be present as the smoke accumulates. Cracking is less likely in the early stages especially if the smoke has travelled an extended distance.
	SURFACES THAT ARE HOT TO TOUCH (May be absent in structures with heavy insulation)	May not be hot, particularly in the early stages.
	SUDDEN INCREASE IN INTERIOR TEMPERATURE	None until the fire gas ignition. Fire gas ignition can be very sudden and even explosive. The explosive power depends on the amount of fuel and how well it has pre-mixed with the available air.

	INDICATOR	FIRE GAS IGNITION
F	LOCATION AND VOLUME	No flame may be present in the space prior to ignition. Once ignition has occurred it is likely to progress very rapidly (even

L A M E		explosively). Cool the gases and/or remove the accumulated smoke to prevent or delay ignition.
	COLOUR (Can be influenced by a large number of variables).	No flame may be present in the space prior to ignition.
	WAVE SHAPE AND LENGTH (May be difficult to see).	No flame may be present in the space prior to ignition.

Preventing Fire Gas Ignition

There is an old saying that "where there is smoke there is fire". I believe that the modern version of this should be "where there is smoke there is unburnt fuel". Where we have fuel we have the potential for fire. We must treat all smoke as potentially flammable and take actions to remove it or reduce the likelihood of the mixture igniting.

One "fire myth" that must be removed from the mind of every firefighter is the belief that the colour of the smoke gives us an indicator as to how likely it is to ignite. There is a misguided belief by some that white smoke is too lean, grey smoke is within the flammable range and that thick black smoke is too rich. I totally disagree with this approach and believe that it is dangerous and uneducated to make such assumptions. Just take white smoke for example. We know that when most products pyrolyse that the smoke released is white and yet is has a very high concentration of fuel!

The other older "fire myth" is that hot smoke is dangerous and that cooler smoke will not ignite. While I agree that hot smoke is dangerous because we know that the flammability limits of the unburnt fuel component becomes wider. However heat is not the only factor to consider. Some other relevant considerations include the ratio of fuel and air, the amount of premixing that may have occurred and the amount of passive agents in the mixture.

We know that it is not likely that the Heat and Flame indicators will assist in detecting the potential for Fire Gas Ignition. In some cases there may be subtle smoke and air indicators. Having experienced a close call with a Fire Gas Ignition even in 2002 I have become very focussed on assessing the building indicators. Some types of building construction are more prone to allow smoke to flow relatively unobstructed. These are generally easy to identify if you understand the construction and the nature or work in the building. For example some industrial building actually require both horizontal and vertical openings as part of their processes. Voids can be expected in situations where false or suspended ceilings are used for aesthetic reasons. Atriums and large volume structures can also allow smoke to spread and accumulate.

There have been great advances in our knowledge of how to design and build structures that provide increased fire resistance and occupant safety in the last 40 years. However, some jurisdictions have been slow to adopt these standards. There is also the issues of quality assurance during construction, essential maintenance and enforcement of regulations after construction.

It is essential to take this into consideration and not assume that all of the fire safety features will be working as designed. Consequently I make it a habit to check the potential travel paths to ensure there is no hidden smoke spread. Something I have experienced on a number of occasions is smoke and fire spread through common ceiling spaces that should have been separated with a fire wall. On a few occasions the fire walls had not even been constructed. There are many more examples of separation that had been compromised by openings created in the fire wall to allow for additional services to be installed.

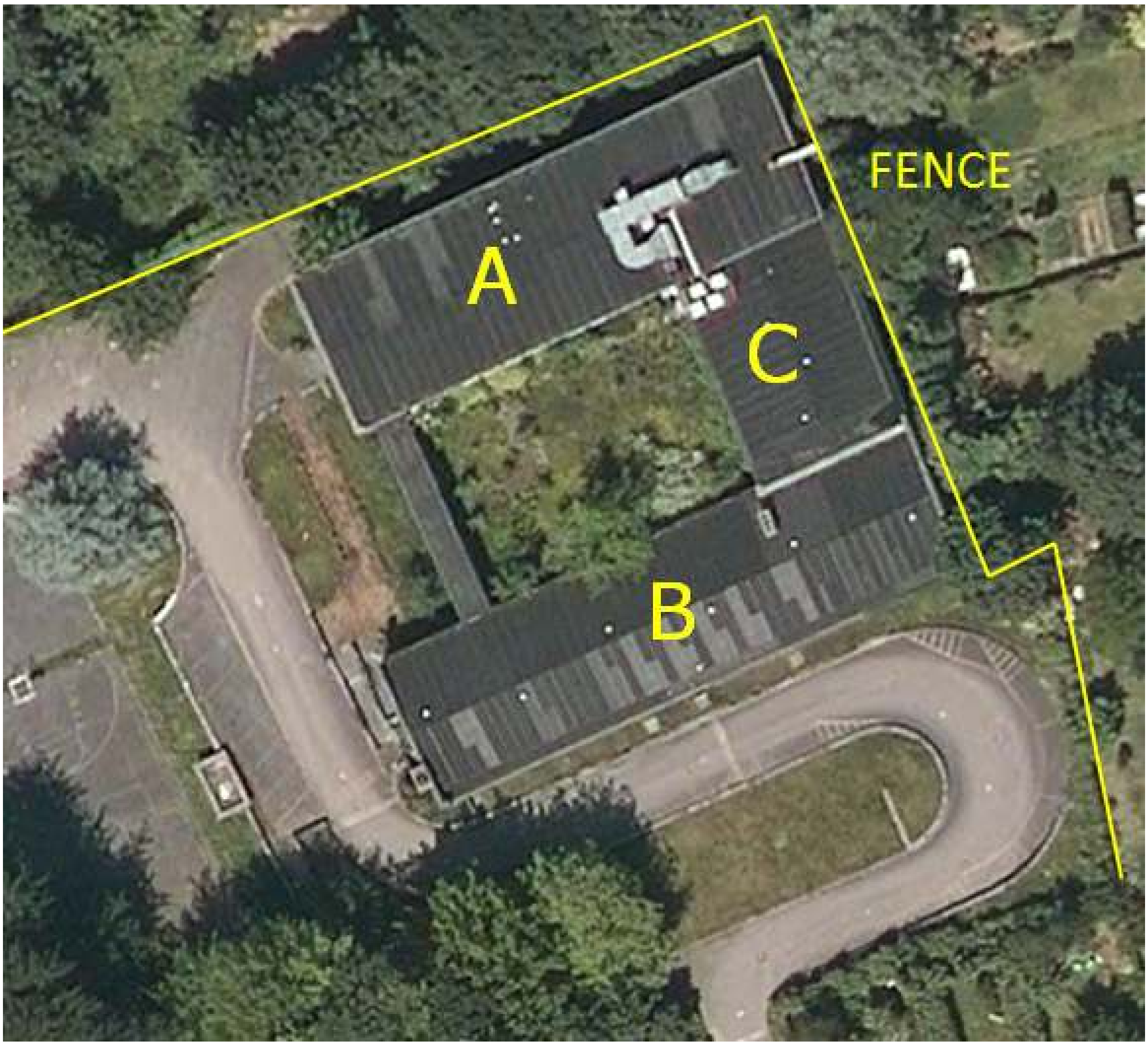
The most difficult building context to assess for Fire Gas Ignition indicators are older buildings and buildings that have undergone renovations and changes in occupancy. A knowledge of the common types of older construction methods in your area can be invaluable. Where renovations and additions have occurred it likely that what you see may not be the whole picture.

Perhaps the 2 best tools for detecting and defeating the hazard of Fire Gas Ignition is a prepared mind and a Thermal Imaging Camera. Always consider the possibility of undetected smoke travel and accumulation. Use your TIC to check the less obvious potential routes of smoke travel. If in doubt, make inspection openings and maintain vigilance even when there seems to be no risk.

Summary

Fire Gas Ignition is a hidden killer. Often there are very few obvious indicators to assist in locating this hazard. Successful detection of Fire Gas Ignition requires a firefighter educated in reading fire that “expects the unexpected” and uses modern technology such as thermal imaging in conjunction with local knowledge of building construction.

On August 30th, 2008 two Brussles firefighters were killed and 7 others seriously inuured when a Fire Gas Ignition occurred in a roof viod. Due to overgrowth of trees, sloping terrain, limted access due to fencing and heavy smoke conditions, the firefighters were not aware that the building (Building B) they were fighting a defensive action from was actually connected to the initial burning structure (Building A) by a 3rd building (Building C) that shared a common roof viod. The smoke that had been accumulating in of the roof void of Building B suddenly and powerfully ignited with sufficient force to blow down part of the ceiling critically injuring one of the firefighters. A second pressure wave was followed by intense heat and rapid fire spread.


FENCE
A
C
B

Poor water supplies, limited access and thick dark smoke hampered the firefighting operations.

Firefighters try desperately to rescue 2 colleagues trapped in Building B. Note that the building was derelict and had been very well secured to prevent the entry of squatters.