Realistic Live Fire Training To Deal Safely With Flashover and Backdraught

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Plastics and other synthetic materials that are used extensively in the construction of and contents of all buildings, do not burn cleanly but generate large volumes of smoke. International research has revealed that the amount of unburnt fuel in this smoke is much greater than previously thought. These unburnt energy-rich vapours congregate in the ceiling area and gradually heat up towards their auto ignition temperature (AIT). When this temperature is reached, the result can be a rapid ignition of the vapours, creating a wave of flame that radiates down onto the contents of the room. Not only does this lead to rapid fire spread, but it poses a major occupational hazard to firefighters which may result in death, or serious injury to persons caught in this heat wave.

Sometimes this effect is delayed and may occur after firefighters have entered. When they direct a stream of water onto the base of the fire, fresh air is introduced, and the embers are stirred up. This may cause the vapours to be ignited. A number of the serious injuries and firefighter fatalities across the world can be attributed to this phenomenon.

In contrast, Sweden has not suffered death or serious injury from flashover since the introduction of live fire behaviour training involving the use of fire flashover simulators over 13 years ago.

This paper discusses the need for realistic training methods to teach firefighters how to safely reduce the likelihood of flashover and backdraft.

INTRODUCTION

Throughout the world there is agreement that firefighting is a potentially dangerous profession. Yet in some parts of the world, firefighters are expected to carry out firefighting operations in life threatening emergency situations without ever having the opportunity to observe the development of a fire in a compartment, in a safe, low stress environment.

It has long been realised by the military that soldiers had to operate in a wide range of extremely hostile environments. These can range from jungle, alpine, desert, swamp terrain, etc. If they are to operate effectively in these environments then they must not only have a sound theoretical understanding of what to expect and how to survive, but they must be exposed to these environments and carry out realistic training exercises. The end result of live, realistic training is not only an increase in efficiency, but a reduction in battlefield casualties.

The Firefighters are also required to carry out their duties in very hostile environments. The environment in a typical structural fire can change suddenly from what appears to be relatively stable to an inferno with temperatures over 1000 degrees Celsius at ceiling height and over 300 degrees Celsius at floor level.

Whilst sudden, such changes can be anticipated if the indicators are recognised. Unless the firefighters are able to "read" the signals that the fire is sending, they could become a victim instead of a rescuer. Therefore it is essential that firefighters have a solid understanding of the fundamentals of fire behaviour. This can only be achieved by allowing firefighters the opportunity to witness the development phases of a fire in a realistic, safe, controlled and predictable environment. The Firefighter can then see the results of the different firefighting techniques on the dynamics of the environment. This leads to an understanding of the implications of their actions not only on the fire but also entrapped occupants, other firefighters, and possible effects on fire spread to surrounding areas. Only then is it possible to obtain full benefit from the next phase of "Realistic Training", ie Tactical Live Fire Training.

In this paper I focus primarily on realistic training methods designed to teach fire behaviour in compartments. The purpose is to teach firefighters how a fire develops in a compartment, and how to recognise and safely deal with Flashover/Backdraught and other emergent fire phenomena. These training methods originated in Sweden where they have been incorporated into basic firefighter training since the mid eighties.

BACKGROUND

There have been enormous changes in construction materials and the typical contents of buildings and vessels in the last forty years. One of the most significant for firefighters is the wide-spread use of synthetic materials. These materials do not burn cleanly but generate large volumes of thick, dark, energy, rich ,smoke. The unburnt vapours in the smoke congregate in the ceiling area and gradually heat up towards their (AIT). The result can be a rapid ignition of the vapours creating a wave of flame that radiates down onto the firefighters, and the contents of the room.

There have been improvements in the equipment and protective clothing available to firefighters. One of the most significant of these is the wide-spread use of self-contained breathing apparatus (SCBA). There have also been advances in the design of protective clothing, branch design and communications. The combined effect is that firefighters are able to go further into structures and stay in for longer than ever before. Overall, this has allowed firefighters to carry out their tasks with greater safety and efficiency. However, it has also created other problems.

Recently, attention has been given to firefighters killed or injured due to sudden and unexpected fire phenomenon such as flashover and backdraught. In many parts of the world there has been a tendency to blame this on the fact that the combination of improved protective clothing and SCBA use allows firefighters to go further into a structure. At the same time the insulative properties of the protective clothing reduce the ability to sense the greater heat. There is no doubt that this is part of the picture. What has been fatally overlooked by firefighters and planners is the combustible nature of smoke in modern buildings.

Urban firefighters are often arriving at structural fires at the 'pre flashover' phase. They can easily find themselves in a situation where the failure to recognise the signs of imminent flashover, and to take appropriate precautions, can lead to life- threatening situations. Often the situations that look the most hazardous are not, and sometimes the 'routine fire' may turn out to be the most dangerous. Realistic live fire training gives firefighters the chance to observe and understand the development of a fire in a compartment and teaches them how to avoid becoming a victim of flashover and backdraught.

It is vitally important to realise that this smoke can be ignited after congregating outside the room of origin.

This cold grey smoke, which we have hardly considered in the past as a hazard, can be ignited if the conditions are right, with disastrous consequences. This "Delayed Flashover" can be very unexpected and powerful, and has been the cause of a large number of firefighter deaths.

There is pressure on Fire Authorities world wide to reduce costs. In some cases this has lead to reduced crew sizes and to situations where junior firefighters do not have the same opportunities that were available in the past to learn the skills required to safely carry out 'aggressive interior attack' and 'search and rescue' in burning buildings, under the direction of an experienced firefighter.

DEVELOPMENT

SWEDEN

In Sweden, the theory of the combustibility of smoke has been long understood and practical training methods applied that teach firefighters to recognise, anticipate and deal with the flashover phenomenon have been in use since the mid 1980s. This has reduced the number of firefighter fatalities from flashover and backdraught from an average of three every two years, to zero since the introduction of realistic fire behaviour training. (Cederholm 1997)

One of the factors that caused a major rethink in Sweden, was a tragic fire in 1985 which resulted in two firefighters losing their lives when an apparently subdued fire inexplicably erupted into a fireball. This was only a few months after two other firefighters lost their lives to flashover. These events changed the Swedish Fire Service. There was a national inquiry into the problem and a number of recommendations became law. Breathing Apparatus (BA) control procedures were reviewed and regulations were introduced to ensure that all brigades were able to support BA teams by the formation of a "Smoke Diving Team" consisting of two firefighters (smokedivers), and a BA Leader, who carries out BA control at the point of entry while wearing BA. This officer is also equipped with a charged hose line and maintains radio contact, the primary purpose of this officer is to ensure the safety of the crew. Fitness standards and annual tests were introduced. There was also a recognition of the need for firefighters to have a sound understanding of fire behaviour and development in compartments. (Svenssen 1997)

For several years before these events, two Swedish Fire Engineers had been teaching some radical theories on the combustibility of smoke. In their efforts to prove their theories they challenged the existing knowledge and science of fire behaviour in compartments. Krister Giselsson and Mats Rosander provided a new angle to fire behaviour, reasons for the tragic occurrences in fires and, most importantly, extinguishing techniques that would improve firefighter safety. Giselsson and Rosander focussed their extinguishing research at a molecular level. From a re-examination of the fundamental of fire the Swedes started to develop practical techniques and procedures for structural firefighting. From the close cooperation of the fire engineers and firefighters, the Swedes then developed a total package for structural firefighting.

Around the same time, Anders Lauren, a Station Officer in the Stockholm Fire Service, had been putting into practice the theories of Giselsson's and Rosander's by carrying out live burns in derelict houses. These of course were in limited supply and Lauren turned to Giselsson for assistance to develop an idea he had for modifying shipping containers to produce a compartment fire simulator. These simulators also proved the theory combustibility of smoke. It can be clearly seen that when there is only a pile of wood burning in the rear corner of a container, the only other available fuel source is the smoke. The smoke can be seen burning as it rolls across the non combustible ceiling. As the temperature approaches the (AIT), small

tongues of flame can be seen to ignite well away from the burning combustibles. Seconds later the smoke layer can be seen to ignite. This is known as Lean Gas Combustion (LGC) and the resultant radiant heat may lead to ignition of other combustibles in the room (Flashover) (Giselsson 1997).

Today, with more than 13 years of experience in this type of training, the Swedes are regarded as experts in firefighting worldwide. Many of the world's fire services are today trying to fast track the Swedish methods.

United Kingdom

The UK Fire Service operates under three main pieces of legislation that provide the foundation for the provision of operational training;

1. Section 1(1)b of the Fire Services Act 1947,
2. The Management of Health and Safety at Work Regulations, 1992,
3. Section 2(1) of the Health and Safety at Work Act, 1974.

This legislation recognises that firefighters are often called upon to work in extremely hazardous environments and that there is a need for realistic training to ensure that they are able to react in the most appropriate manner to ensure their safety and the safety of their colleagues.

The Home Office Health and Safety publication "Training for Hazardous Occupations", HSE OP8 has this to say about firefighting:

> *The activities which firefighters are required to perform can be frightening. They frequently must work at heights, they are exposed to heat and smoke and they may have to enter dark confined spaces for rescue work. Unless the firefighter has experienced the fears to which these conditions give rise and has learnt to control them, there is a risk that he will get into difficulties in the hazardous circumstances of the fireground and will himself need to be rescued. He must also rely greatly upon his colleagues and his officers to look after him in hazardous situations. He needs to be confident in their ability to do so. He needs to know that if he is given an order by an officer that an officer will have considered the firefighters safety before asking him to do the task. He must also be confident that the task is within his own capabilities if he is to approach it in the right frame of mind. Each of these aspects, control of fear, and confidence in himself and his colleagues and his officers can be developed in training, but only if the training is undertaken under realistic conditions which may well expose the firefighter to risk.*

There is strong recognition that the employer, in the UK has a legal obligation to train staff to meet the hazardous situations to which they may encounter. Sensible, risk-based, realistic training is essential to ensure that firefighters are able to react appropriately and safely to the extreme environments and situations they are often exposed to.

British Research

In 1993 the Home Office Fire Experimental Unit was asked to investigate the whole field of the science of firefighting and suppression. The goal of the unit was to determine whether the Fire Service was sufficiently informed about what was known about fire behaviour, and whether there were any areas that

required future research. The Fire Research Station was commissioned to examine flashover and backdraft. They concluded that the Fire Scientists had a clear understanding of both phenomena, but that this information was not being effectively communicated to the Fire Service. The Home office reacted by producing two supplements to the Manuals of Firemanship; "The Behaviour of Fire - Compartment Fires", and "The Behaviour of Fire - Tactical Ventilation of Buildings and Structures". The ongoing research is causing a major rethink on firefighting tactics and training. The Institution of Fire Engineers (IFE) has been actively stimulating discussion and research into this area (Thomas 1996).

Blaina Tragedy

On the 1st February 1996 a fire occurred that sent shock waves through the British Fire Service and reinforced the fact that the employer has an obligation to ensure that employees are adequately trained to meet any safety hazards they are likely to encounter during the performance of their duties.

Two firefighters in Wales (Blaina, Gwent) were killed when they were searching a smoke-filled house for a person reported missing. The firefighting crew attended what appeared to be a routine job - no obvious flame visible, just smoke, and in the back kitchen an orange glow. A child was rescued from the top floor, and after a report that there may be a second child still inside, the team made entry a second time. Moments later a powerful whoosh was heard and the entire building erupted into a fireball. The entry door slammed shut onto the hose reel line, trapping the two firefighters in the inferno. Such was the intensity of the fire that it forced back the desperate attempts of the rescuers. It took nearly eleven minutes to subdue the fire to the point where the firefighters could be removed from the building. (Baglin 1996)

A Health and Safety Executive investigation was launched and the findings indicated that the training given to the firefighters did not adequately prepare them to deal with the situation they had encountered. As a result of the findings an Improvement Notice was served on the South Wales Fire Brigade.

The following is a quote from part of the findings;

2. *The training provided did not adequately equip firefighters to recognise and deal with the situation encountered at Blaina.*
3. *Monitoring of watch based training was not sufficiently rigorous to spot areas which had not been covered adequately. Resources for Officers delivering training were not sufficient to ensure quality training (e.g.. comprehensive bibliographies, lecture packs, overhead slides).*
4. *Few firefighters in Gwent had received useful hot fire training."* (Baglin 1996)

This incident occurred only months after the Home Office Review Team published its preliminary recommendations. The review team recommended that the training of firefighters must equip them with tools and knowledge necessary to carry out firefighting tasks safely. Basically if firefighters are to be exposed to risks in the duties of their employment, they should be prepared for this by being exposed to a degree of risk in controlled training scenarios.

It can be clearly seen that the UK Fire Service has recognised the need for realistic training and in particular, fire behaviour training. Many brigades in the UK are in the process of developing or delivering flashover training to their firefighters. Moreton-in-Marsh is nearing completion of its facility and has commenced delivering its training. As well as the supplements to the Manuals of Firemanship, an effective audio-visual training aid has been developed.

AUSTRALIA

In Australia legislative requirements in each jurisdiction outline the "Duty of Care" of employers and define duties for employees and define their responsibilities to contribute to workplace safety. The employer has responsibility to ensure that hazards are identified, risk is assessed, and appropriate actions are put in place to remove or reduce the hazard. This involves, not only the appropriate protective clothing, but safe systems of work and adequate training. Many Fire Services have seen realistic training as necessary to prepare and develop firefighters for their operational tasks.

Typically, training is carried out using props to simulate the conditions experienced during petrochemical and gas firefighting operations. These are mostly "outdoor" setups. Tactical live fire training is carried out in purpose-built buildings to simulate the conditions experienced during structural firefighting, ship firefighting, aircraft etc. These are mostly fuelled by LPG, because it is relatively inexpensive and burns cleanly. The problem with using these facilities to teach compartment fire behaviour is that LPG does not allow the firefighter to witness and experience the development of an ordinary combustible fire from incipient to the "lean gas combustion" phase (the phase immediately preceding flashover), or to experiment with the effects of the introduction of water spray into the smoke, flame zone or the combustible linings that are producing the energy rich vapours.

The Queensland Fire and Rescue Authority (QFRA) has recognised the need for firefighters to have the opportunity to witness fire development and learn extinguishing techniques in a controlled environment. Fire behaviour training is seen as the foundation for the understanding of fire behaviour in compartments. This can be achieved by the use of Flashover Fire Simulators (FFS). These are modified shipping containers designed to allow for the burning of six sheets of particle board. This is based on the tried and proven methods pioneered by Station Officer Anders Lauren (Stockholm Fire Service) and Fire Engineers Krister Giselssen and Mats Rosander, which was endorsed by the Swedish National Rescue Board and has formed the basis of all "Indoor Firefighting" training. The QFRA has carried out extensive research and is currently developing a Compartment Firefighting course in cooperation with the United Firefighters Union of Australia, Queensland Branch.

Current Understanding of Flashover, Backdraught and other emergent Fire Phenomena

Combustibility of Smoke

Traditionally, firefighters have been taught to attack the 'seat' or base of the fire. In a compartment this can lead to the entrainment of air which supplies oxygen to the super-heated, unburnt fuel in the ceiling. This could lead to a flashover or backdraught. The Swedish methods are more holistic and focus on cooling, shrinking, and diluting the smoke to prevent sudden flashover or backdraught, and aid in locating victims and the seat of the fire with greater safety and efficiency. It is essential that the firefighter realises that this combustible smoke layer can ignite spontaneously when the AIT is reached (provided there is sufficient oxygen present). This can occur in the room of origin, or from the ignition of smoke that has drifted into other parts of the structure.

Terminology

There is still a great deal of confusion regarding terminology. The Swedes refer basically to four types of "flashover".

1. Lean Flashover
This is the ignition of the vapour layer in the ceiling leading to total involvement of the compartment.

2. Rich Flashover
This occurs when the combustible vapours are ignited at the upper region of the flammability range. This can occur when opening up a compartment in which the fire has subsided to a lack of oxygen. The ignition source can be the re-ignition of the smouldering objects, or the stirring up of embers by the air track.

3. Delayed Flashover
This occurs when the ignition of the smoke layer has been delayed. Ignition can occur at any point within the flammability range and the result can be very unpredictable. If ignition occurs at the Ideal Mixture (IM) then the result can be a very violent ignition (Smoke Vapour Explosion).

4. Hot Rich Flashover
his occurs when super heated, rich smoke leaves a compartment at or above the AIT. Upon mixing with the air the smoke is diluted down to the UEL and ignition occurs spontaneously. The resultant flame can propagate back into the compartment resulting in an event similar to the rich flashover.

There is currently a great deal of debate on terminology. There is reluctance on the part of the part of some British fire scientists to accept the Swedish terminology. Some of them may feel that it is not scientific enough. This is a shame because the Swedish terminology was created to describe the events that firefighters had been experiencing for many years. It was created in an attempt to give firefighters a practical understanding of the different events and how they occurred.

The British Standard definition for flashover is:

> *Sudden transition to a state of total surface involvement in a fire of combustible materials within a compartment.* (BS 4422, 1987)

Backdraft, or backdraught (English spelling) is a term commonly used in America. The NFPA definition for Backdraft is:

> *The explosive or rapid burning of heated gases that occurs when oxygen is introduced into a building that has not been properly ventilated and has a depleted supply of oxygen due to fire.* (Burklin, NFPA 1980)

A video produced for the Home Office in 1997, entitled "Compartment Fires and Tactical Ventilation" talks of "Delayed Backdraught". This is the event that the Swedes are calling Delayed Flashover.

As you can seen there are currently a number of ways of describing the same event. It may be quite some time before terminology is standardised. Until then firefighters will have to be aware of the variations and make their own determination as to what definition is the most meaningful. The most important point is that firefighters are aware of the different events, how they occur, how to recognise the conditions that could lead to them, and most importantly, how to safely deal with these phenomena.

CONCLUSIONS

In order for firefighters to competently and safety function in the dangerous situations and environments that they are often placed in, they must experience in training the conditions that may be encountered, in a safe, low-stress environment. This builds confidence and allows for the recognition of conditions that could endanger their lives.

To obtain maximum benefit from Tactical Live Fire Training exercises, it is essential that the firefighter has a sound understanding of fire behaviour in compartments. This can be achieved through the combination of theory, small scale demonstrations, and then live training in a facility designed to allow firefighters to safely experience all stages of fire development in a compartment. The firefighter is then ready to undergo Tactical Live Fire Training. The next logical step is the use of derelict buildings for controlled fire suppression training.

Review of realistic training sessions can greatly assist in identifying and rectifying deficiencies in training, equipment, protective clothing and operational procedures. The final step is the review of actual fire incidents through debriefing. During my firefighting career it has been my experience that everyone tries to do their very best at an emergency incident. Rarely, however, is our performance "perfect", there is always something to be learned from every incident. Firstly we must encourage people to appraise their own performance honstly. Then to appraise the performance of others in the team in a positive manner to ensure that people are not discouraged, strengths should be reinforced, and areas of improvement should be identified. Strategies can then be developed to ensure increased efficiency and safety.

The result of the holistic approach to training is a firefighting team that is able to respond to actual fire situations in a calm, confident manner and accurately "read" the conditions, reacting instinctively, efficiently and safely.

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