Solutions for Rapid Fire Progress

1 Introduction

In the past years, more and more focus has been put onto fire behavior. This change was long overdue because the knowledge and understanding of fire behavior in the fire service were very limited. For instance in the chief officer's course which I attended in 2002, the phenomenon of fire gas ignition was not discussed. Even the basic fireman training dealt rather poorly with fire behavior. Fortunately this trend has been countered over the last few years. There's still a long road ahead of us, but at least we're moving in the right direction.

Every discipline (engineering, medicine, …) first teaches its students to understand a certain problem. Next it teaches them how to solve it. Medical science is continually evolving. Several illnesses for which there was no cure 50 years ago, can now be successfully treated. But against some illnesses doctors still remain powerless.

There are similarities in firefighting. Firefighters (no matter their rank or level) need to understand the problem first. They need to study the fire behavior so they'll know what might go wrong. Next there's a number of solutions available to avoid things from going wrong. Then again, there are some situations to which we don't have the answer yet. This article tries to list the different solutions available.

2 Technique vs tactics

2.1 Technique

Since 2010 the basic firefighter training course has included nozzle techniques. The phrase is rather obvious, we're talking about techniques here. A technique is an action performed by a single firefighter. Often this firefighter is supported by a colleague but he or she is capable of performing the technique by him- or herself.

One or two persons applying a technique at a single location, is a simple way of dealing with a problem. It's similar to a football player performing a penalty kick. There's one person to determine the problem, select the solution and apply it. For instance: *I see a small fire. I decide to knock down the fire using penciling. I perform the nozzle technique.*

Figure 1 Simple techniques are also used when gas cooling. Like the long pulse in this picture. *(Photo: John McDonough)*

For firefighters to be able to use techniques to deal with problems arising from rapid fire progress, they need to be trained sufficiently. They first require knowledge on fire behavior. Otherwise they won't have enough understanding of the

problem. Next they need certain skills (e.g. nozzle techniques). These skills can be taught individually. When they have the knowledge to identify the problem and to select the right technique and then have skill to perform the technique, there's a good chance firefighters will be able to prevent rapid fire progress from happening during a fire intervention.

2.2 Tactics

It becomes more difficult when tactics are needed to solve a particular problem. Tactics usually require (at least) one person to analyze the situation. Next he has to choose between a number of different options. He also has to inform others, who need to help solve the problem, of his choice. Then everyone has to understand his or her job and perform it correctly. Often timing plays a crucial role in this. During a football match, teams will use different tactics to get the ball in the opposing teams goal. It's very normal in football to discuss tactics beforehand and train them with the team. Only then will everyone in the team know what's expected of them.

The same is happening in the fire service. Tactics that are trained in advance are called Standard Operating Procedures (SOP's). The systematical deployment of hose lines for fire is an excellent example of this.

In order for a tactic to produce a positive result, several different things are required. As it is with techniques, firefighters need to be trained in both fire behavior and techniques. The same goes for (chief) officers. The harder the problem, the more knowledge will be needed to solve it. It may be expected that with a higher rank, there needs to be a deeper understanding of fire behavior. Ideally for each tactic there's an SOP written down and approved by the fire departments high command. Aside from this, (chief) officers and firefighters will have to have trained together in executing the tactic. Otherwise chances are that something will go wrong on the fire scene.

A simple technique often won't be enough to solve problems involving rapid fire progress. The incident commander (the coach) will then need to turn to tactics. These tactics will only be successful when they have been sufficiently trained.

3 Avoiding Rapid Fire Progress = smoke management

3.1 Smoke is the problem

Each and every form of Rapid Fire Progress basically comes down to smoke igniting. Smoke equals a lot of potential energy. This means that a high amount of energy is stored inside the smoke. When the smoke is transformed into flames, this energy is transferred onto the surroundings. This may happen very fast. Those cases are addressed as an explosion. Phenomena such as backdraft and smoke explosion are examples of this. Here, energy is released from the smoke in less than a second. This causes a violent phenomenon that's often accompanied by a pressure wave.

In a normal fire development, the smoke layer will ignite at some point. This is called roll-over. The smoke then transfers its energy onto the surroundings. This is done in the form of radiative heat. Any objects that are in direct contact with the smoke will also

become heated by convection. Because of this enormous amount of heat, objects in and underneath the smoke layer will heat up quickly and start to pyrolyze. The pyrolysis gases contain a lot of (chemical) energy and can cause temperatures to rise drastically when they ignite. This will lead to the fire spreading, until the entire room is engulfed in flames. The transition of a 2D fire to a 3D fire is called flashover and is less violent than backdraft. The process of a fire in room turning into a room totally on fire, takes several seconds. Because of this, the pressure build up remains limited.

3.2 Cooling the smoke

The Swedish approach to such problems is cooling the smoke. Smoke is considered to be an energy storage. Our Swedish colleagues developed this method of operating during the '80s. Their ways have now been adopted in Europe, Australia and parts of Asia, South and North America.

When (smoke) gas cooling, water is inserted into the smoke layer. Energy will then be transferred from the smoke into the water. The temperature (amount of energy) of smoke drops while the temperature of the water rises. The reasoning behind this approach is that cooled smoke is harder to ignite. More energy has to be added to the smoke for rapid fire progress to happen. After all a critical level of energy has to be exceeded before a phenomenon can occur. Aside from that, steam will be formed in the smoke layer as well. Because the smoke is mixed up with steam, a kind of buffer is formed. This is called thermal ballast. When roll over occurs, part of the energy released will be absorbed by the steam in the smoke layer. All of the energy absorbed by the steam, can't be used to heat objects underneath the smoke layer. Cooling the smoke layer will therefore either make it impossible for rapid fire progress to occur, or will slow down its development.

3.3 Removal of the smoke

Our American colleagues have a different approach to this problem. They primarily look at smoke as fuel. They figure that the best way to deal with the problem is to remove the smoke.

Traditionally, holes are cut into the roof to allow smoke to escape by means of natural ventilation. In the US, housing is often constructed using wood which means that making holes is a lot easier than in our parts of the world. When dealing with situations where creating an opening in the roof isn't a viable option, windows are broken out. This tactic is a lot older and dates from the 19th century.

Ventilation is always made up of two flows: Smoke is flowing out and air is flowing in. This fresh air can/will cause the heat release rate of the fire to grow. American fire crews counter this by taking a sufficiently large hose line into the building. An interior attack using a 70mm hose line flowing at 2000 liters per minute is considered a normal thing. By taking this approach they make sure there's a balance between extinguishing capacity and the heat release rate of the fire.

In the past decade however, there has been a growing number of problems with this method of operating. As it has been in here, firefighters in the US have increasingly been confronted with under ventilated fires. Recent studies by UL have shown that the heat

release rate of an under ventilated fire increases rapidly when natural ventilation is done in even the smallest way possible (e.g. opening a door). Researchers concluded that the risk for ventilation induced flashover had become very large. Often this phenomenon happens before attack crews can locate the seat of the fire.

In certain areas in the US this new problem is countered by the aggressive use of ventilation. Positive pressure fans are used to clear smoke before attack crews enter the building. This tactic is called positive pressure attack (PPA). It's clear that the use of positive pressure ventilation offers advantages in a number of situations. However it has to be used with extreme caution. In Belgium there aren't a lot of fire services that have adequate experience when it comes to using positive pressure ventilation during fire attack. Only time will tell whether PPA can offer the solution for under ventilated fires.

4 Approach from the fire triangle perspective: anti-ventilation

In the section above, smoke was first described as a means to store energy and subsequently as a fuel. These are in fact two sides of the fire triangle. The third side of the triangle is formed by oxygen. There is a way to interact with this side in order to prevent certain phenomena from happening.

The tactic in which the fire is denied oxygen as much as possible is called anti-ventilation. Anti-ventilation can be applied in different ways. It is best suited for situations where fire crews arrive at closed buildings in which under ventilated fires are raging. Here the fire is controlled by the lack of oxygen and will stay that way as long as no new openings are made. By keeping everything closed down, the fire crews buy themselves time to prepare everything for the actual attack. During the attack, the entry door can be closed as far as possible so there's only a small opening for the hose line to go through. This way, what is left will be a small fire to put out.

A second way to apply anti-ventilation, is closing an open door to the fire compartment. Doing this while the fire is in growth stage, can be enough to prevent flashover. This tactic may prove useful when fire spread is imminent or when there is more time needed to build up the attack line. By closing the door in these cases, a lot of trouble can be avoided.

5 Concrete application

5.1 Flashover

Flashover is a phenomenon that occurs during the ventilated fire development. It's the transition from a fire in growth stage to a fully developed fire. In the end, the goal of every fire crew is to extinguish the fire. While the attack crew advances towards the seat of the fire, the smoke can be cooled with water. This will decrease the chance for flashover. Kriss Garcia, the father of PPA, provides training that teaches how to attack a fire with the wind at your back. This method has yielded good results in the US. For now it's unclear whether this method is viable when applied to housing as built in our region.

5.2 Ventilation induced flashover

This variation of flashover happens during the under ventilated fire development. It is the transition of an under ventilated fire to a fully developed fire. In this kind of fire development, there no longer is a smoke layer. The smoke is filling up the entire room. This means that fire fighters have to advance without a view on their surroundings. The rushing in of air is very turbulent which causes a swift mixing of air and smoke. Firefighters are with their heads in the smoke and often don't see the phenomenon happening until it is too late.

Gas cooling is a way to prevent the phenomenon or at the least delay it. Each and every crew advancing in such conditions should perform gas cooling. However it is also possible to gas cool prior to entry. The cobra offers the possibility to quickly cool smoke gas at several different places before an interior attack. Another option is to use a power drill combined with piercing nozzles.

Figure 2 Cobra in use at an under ventilated fire *(Photo: Patrick Persson, © Cold Cut Systems Svenska AB 2012)*

Again, positive pressure ventilation might offer help as well. When large exhaust openings are created, a lot of energy is transported outwards through the exiting smoke. At the same time, the heat release rate of the fire will rise due to extra oxygen being made available. Therefore, more energy will be produced as well. Research will have to be done to examine whether the venting out of energy is powerful enough to compensate for the extra energy production.

Aside from that it's important to be able to reach the seat of the fire. In Figure 2 there is a fire in the attic area above the garages. If the entire building is filled up with smoke, ventilation might cause smoke to be cleared from the ground floor. It is also possible however that there are small cracks allowing fresh air into the attic. The intensity of the fire will then increase. If there is no stairs leading into the attic for fire crews, fighting the fire will become impossible. In such a case the fire crew might lose the building because of the use of ventilation.

In Sweden, a combination is made of positive pressure ventilation and the cobra. First smoke is cooled using the cobra, next ventilation is executed and lastly the interior attack is started. During the entire operation the thermal imaging camera is used to assess the situation. This tactic seems to be giving good results.

A final option is the use of anti-ventilation. This means the room will remain closed as much as possible. The lack of oxygen will put the fire on hold, so to speak. An attack crew can the use a 45mm hose line to search for the seat of the fire. Naturally this is only possible when the smoke gas temperature isn't too high. It's also advisable to adopt a structured approach to the tactic. The fire crew preferably has a good idea of the

building layout and the location of the fire. Aside from that, there have to be (several) back up teams.

5.3 (Hot) Backdraft

This phenomenon causes a pressure wave. The human body does not withstand overpressure well. This is why it's absolutely inadvisable to send firefighters into a pre-backdraft situation.

Gas cooling can offer a solution. The cooling will have to be done from the outside in. This can be done using a cobra or with piercing nozzles. In both cases it will be necessary to flow water in for a long time. After all the flow rates of both tools are very limited. Another option is using a 45mm hose line to flow water in through a small opening or through a door that can be opened and closed repeatedly.

Figure 3 Applying a piercing nozzle in a pre-backdraft situation. The water being flowed in will create a cooling effect. Large amounts of steam are also formed that inert the room. *(Photo: Lars Ågerstrand)*

As a last resort fire crews can decide to trigger the backdraft. This tactic chooses to remove the risk completely. Often after a backdraft a small fire will remain. The pressure wave has "blown out" the fire so to speak. After backdraft has occurred, the interior attack can be started to extinguish the fire. If this approach is selected, fire crews have to take into account that things might turn out differently than expected.

5.4 Fire gas ignition

In the event of a fire gas ignition like flashfire or smoke explosion, a certain amount of smoke that has sufficiently mixed with air is ignited by an ignition source. Sometimes these smoke gases are clearly visible because they have accumulated up against the ceiling. The logical way to avoid an FGI in such cases is to prevent ignition sources from getting into the smoke layer. However this is a difficult thing to ensure. After all flames might come through a doorway or another opening unexpectedly and ignite the mixture.

It also happens that the smoke gases accumulate in void spaces (false ceiling, false wall, …) Then the smoke gas often can't be seen by fire crews in the room. This is a potentially very dangerous situation because one is simply unaware of the danger.

In the past, FGI often occurred in situations that seemed to have stabilized. The seat of the fire was hard to find or seemed to have been put out already. In other words there was enough time to implement measures which could have prevented the FGI. In such cases venting the smoke from the building is a good option. If smoke can be vented from a room before walls and ceilings are opened up, the risk for trouble is reduced. Smoke that has been vented into the outside, can no longer cause any problems. When time allows for it (there is no clear seat of the fire or it has been put out), it is therefore always a good idea to vent the smoke present in the compartment.

Prevention is better than cure. Sometimes it's possible to prevent smoke from entering neighboring buildings (e.g. row housing). This is done by using a positive pressure fan. Opposed to normal venting, no exhaust is made. The air flow of the fan causes the building to be in constant overpressure in contrast to the room where the fire is. This will make it harder for smoke to enter the protected building. However it is important to check for fire spread first in the room that's going to be pressurized. If fire has already spread to there, the fan will do more harm than good. Most of the time, a fan with a combustion engine will be used. This will of course protect the room, but will also produce carbon monoxide. After the fire, the CO can be vented by natural ventilation or by using an electric fan. It's important that fire crews perform a CO-reading before giving the all clear on the building.

6 Bibliography

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