Gas cooling: a new approach

In August of 2012 I was attending MSB's Fire Behaviour Course in Revinge, Sweden. During this course a lot of topics came up regarding interior firefighting. One topic of this training in particular drew extra attention: the application of gas cooling during interior firefighting. Afterwards in September 2012 three courses were organized at PIVO in Vlaams Brabant to train the CFBT instructors in the use of the T-cell. Australian instructor John McDonough was present to give his views on the matter of gas cooling. Both countries (Sweden and Australia) have taken gas cooling to the next level as opposed to Belgium. This article will try to explain these new developments.

1 Fires in the growth stage

1.1 Wherein lies the problem?

In the current basic firefighter course a lot of time and attention is spent to gas cooling. After all, firefighters entering a compartment filled with smoke are taking risks. It is possible that the smoke will ignite. This can happen because of flashover, ventilation induced flashover, backdraft, … During the growth phase of the fire, two separate zones can be distinguished. Up against the ceiling a smoke layer has been formed. This smoke layer will become increasingly darker, hotter and denser during the growth phase. Below the smoke layer a zone exists containing relatively fresh air. This air is at a temperature which doesn't differ all that much from the outside temperature. Inside the smoke layer there is hardly any visibility while underneath it, one still has a decent view. Using the 3D technique, firefighters are able to cool the smoke gases. Aside from that they are also able to maintain the distinction between the two layers, which means they also maintain visibility below the smoke layer.

1.2 Applying the 3D technique

When applying the 3D technique, water is directed into the smoke layer in the form of pulses (see [2] and [3]). At the nozzle, the cone of the water spray is set at an angle ranging from 40 to 60°. The angle of the nozzle in regard to the floor should ideally be 45° or more. The idea is for the nozzle operator to produce several short pulses at different locations in the smoke layer, hereby covering the entire width of the room (see figure 1.1 and figure 1.2). Figures 1.1 and 1.2 each depict a series of 3 pulses. In reality the number of pulses needs to be adjusted according to the width of the room. The water of the pulse should normally evaporate inside the smoke layer. In reality however, a portion of the water will end up against walls and/or ceiling causing it to evaporate at those places. A well trained nozzle operator will be able to achieve evaporation of the majority of the water inside the smoke layer.

1.3 Advantages of the 3D technique

This form of smoke gas cooling has a double effect. First and foremost, the water requires energy in order to heat up and evaporate. Subsequently the newly formed steam will heat up even further. At the location of the steam a balance has to be achieved between the temperature of the cooled smoke gas and the temperature of the steam. Readers interested in learning more about this particular process are encouraged to check the existing literature in the bibliography (see [4] p. 151 and further and [3] chapter 2). The energy needed for the transformation of water into steam is taken out of the smoke layer. A smoke layer that has been cooled, will have less chance of igniting. Aside from that, the heat that's being radiated from the smoke layer onto objects beneath it (tables, chairs, couches, cupboards, …) will also decrease. This leads to a reduced risk at flashover.

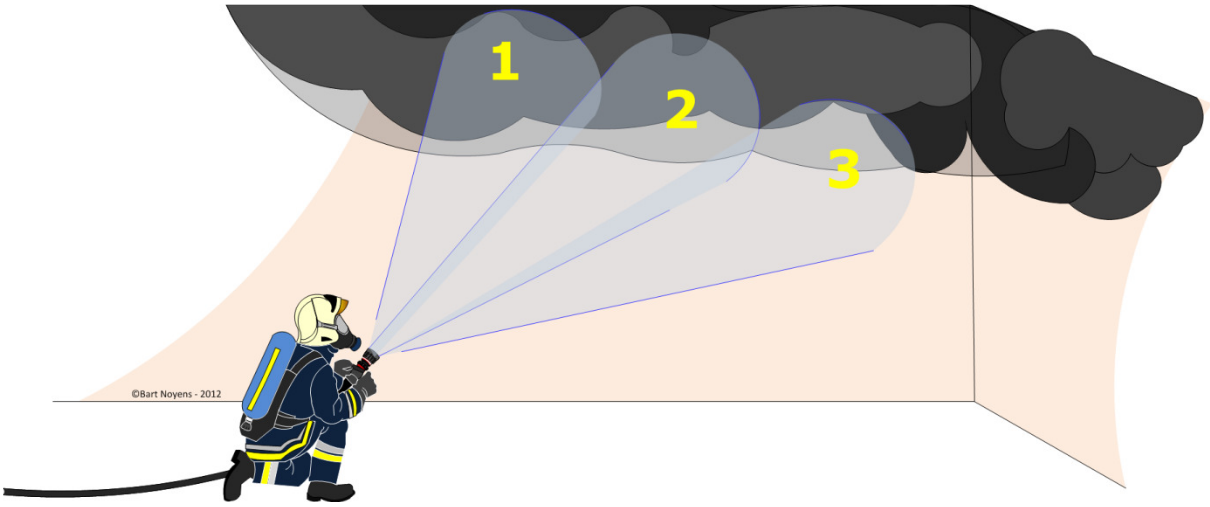

Figure 1.1 The nozzle operator is cooling smoke gases in the smoke layer during a fire in the growth stage. To achieve this he is using a series of short pulses directed into the smoke layer. The first pulse is directed to the left, the second one in the middle and the third one to the right hand side. *(Image: Bart Noyens)*

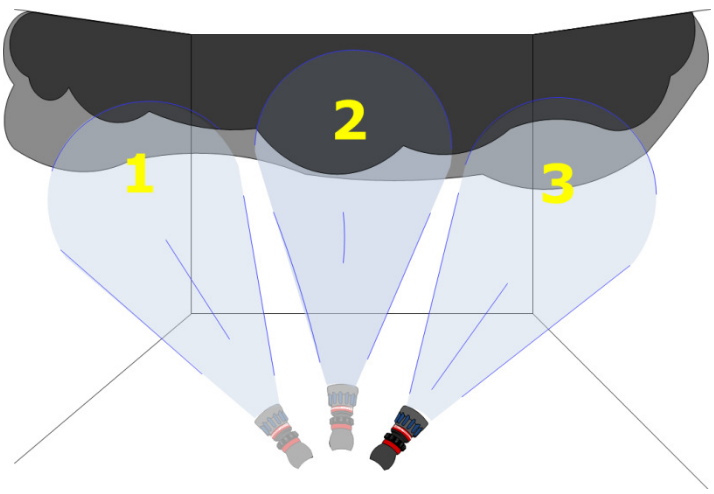

Figure 1.2 The 3D-technique as seen from the point of view of the nozzle operator. *(Image: Bart Noyens)*

A second way in which the 3D technique improves firefighting conditions, is the fact that water vapor remains present inside the smoke layer. When water droplets evaporate, a large volume of steam is created. At the same time the smoke layer will shrink. A mixture of flammable gas and steam will be formed. Contrary to the smoke gases, steam is nonflammable. The result is a decreased inflammability of the smoke layer. This is called 'inerting'.

The use of pulses implies a low amount of water is being used. Only one or two liters per pulse. It doesn't even matter whether a high pressure booster line or a low pressure nozzle is being used. When both nozzles are set to provide a 150 to 200 liters per minute flow rate, the effect will be the same. This form of firefighting prevents damage by excessive use of water. Secondly the water supply of the fire engine is saved up for extinguishing the seat of the fire.

Last but not least it's worth mentioning that the 3D firefighting technique also maintains the "stability" of the smoke layer. After applying the technique, two separate zones will still remain present. A hot, opaque zone filled with smoke will remain up against the ceiling. At the bottom an area consisting of cool, fresh air with clear visibility will still be present. If one were to use a continuous jet stream instead of pulses, the smoke layer will be completely disrupted. The two separate zones will become mixed up. This will lead to deteriorating conditions for firefighters. The temperature at the bottom of the room will rise. Visibility will be lost as well and last but not least, chances of survival for any victims that happen to be in the room will decrease drastically.

1.4 Long Pulse

Almost every time when instructing the 3D technique, short pulses are being discussed. These pulses result in a limited amount of water being directed into the smoke layer in order to evaporate. This is a very effective way to safely advance in interior firefighting operations during fires at growth stage. The cooling capability of this technique however is rather limited. Australian officer John McDonough aptly comments that the use of short pulses will not be effective for instance, when advancing through a hallway towards a fully developed bedroom fire. Even though much of the energy will exit through the window, hot smoke gases will also be pushed into the hallway. It's impossible to absorb such an amount of energy using short pulses. In Australia aside from the short pulse, the use of the long pulse is also advocated.

Figure 1.3 & 1.4 In the left image a short pulse is shown. The angle of the nozzle in regard to the ground level is 45°. The angle of the water cone ranges from 40° to 60°. The photograph on the right shows a long pulse. The angle between the nozzle and the ground level is approximately 30° and the angle of the cone is also 30°. *(Photos: Geert Vandamme)*

When executing a long pulse, several changes are being made compared to the short pulse or 3D technique. The angle formed between the nozzle and the floor level is reduced to about 30°. Likewise the cone of the water spray is reduced to 30° (see fig 1.3 and 1.4). The nozzle is no longer cracked open and shut as quickly as possible. For a long pulse the nozzle is first opened quickly and then after 2 seconds closed down slowly. This allows for a larger amount of water to be used. Aside from that the range of the pulse will be larger. This will allow the nozzle operator to cool hot smoke gases at a greater distance. When dealing with very hot smoke gases, the effect will be superior as opposed to using short pulses. These short pulses will result in water totally evaporating shortly after exiting the nozzle. In the case of very hot smoke gases flowing into a hallway or compartment, the long pulse allows for the improvement of safety in these situations.

2 Underventilated fires

2.1 What exactly is an under ventilated fire?

Due to a changing way of construction (more insulated and especially more airtight) firefighters are becoming increasingly confronted with underventilated fires.

"An underventilated fire is a fire that has become ventilation controlled before flashover"

These types of fires are defined by a serious lack of oxygen. In newer buildings very few air leaks exist. This means that a very small amount of fresh air will enter the building when the door and the windows remain closed. Therefore the fire development will halt because of a lack of oxygen. When the fire development halts before flashover has occurred then we are dealing with an underventilated fire. From there on it will depend on the characteristics of the building in which way the situation will evolve. If a window bursts, fresh air will flow back onto the fire. This will start up the fire development again. As a result ventilation induced flashover can occur.

Most of the time fire crews arrive on scene to find a building of which several rooms are completely filled with smoke. Smoke is being forced out through cracks. These kinds of fires display a lot of smoke but little to no flames. The moment firefighters open up the door to the room, a double layered flow manifests itself. At the top smoke is flowing outwards and at the bottom fresh air is flowing in. Heavily underventilated fires even create a tunnel effect. A tunnel of fresh air is being drawn in while the rest of the door opening is being used to push out smoke.

2.2 Risks

Steve Kerber's research showed us that an underventilated fire in a single story house develops into ventilation induced flashover in approximately 80 seconds. An underventilated fire in a house made up of two levels takes 160 seconds to achieve this phenomenon (see [5]). It is unwise to hold on to the exact numbers of these time frames. After all the time needed depends on the layout of the house, the location of the seat of the fire and the location of air inlets and outlets. These figures do indicate that things can get out of control really fast when ventilating an underventilated fire.

Often the following string of events occurs. The fire crew arrives at an underventilated fire. Firefighters open up the door or force entry through it to initiate interior fire attack. This causes fresh air to enter into the room. The power of the fire will increase. It may very well happen that the fire will progress too fast for the firefighters to find the seat of the fire. In that case they will be forced to exit and the fire will develop into ventilation induced flashover. A lot of case histories exist where firefighters testify a sudden appearance of flames all around them while they were advancing inside a smoke filled compartment. These firefighters literally had to crawl for their lives. Some of them jumped through windows to get out. For these firefighters it was a surprise that the fire progressed so suddenly and rapidly. This kind of fire development should however not be a surprise to firefighters. When air is being supplied to an under ventilated fire, the fires power will increase. If no water is applied to the seat of the fire, a ventilation induced flashover will occur.

2.3 Solutions

Just as is the case with fires in growth stage, one solution can be found by cooling smoke gases. Smoke gas cooling will deplete the smoke of energy and at the same time inert it by adding steam. By doing this, one can say that "time is being bought". The fire development is slowed down so that the fire crew has a larger time frame in which to do their job. As long as no water is being applied to the seat of the fire however, the situation will remain very dangerous.

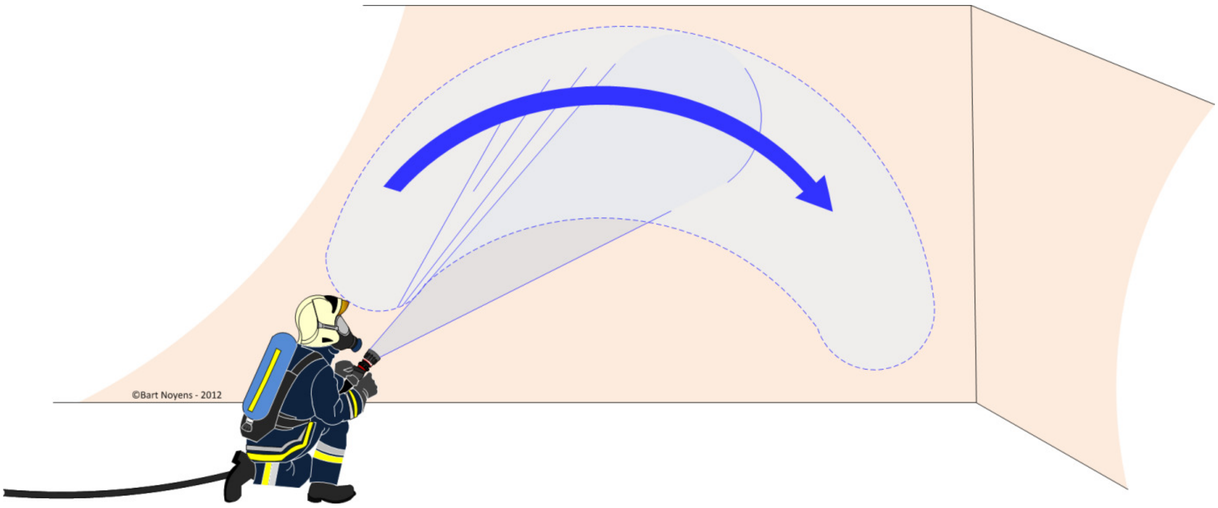

Figure 2.1 The nozzle operator is cooling smoke gases in an underventilated fire. He activates the nozzle and moves it in the form of an arch from left to right. The entire operation should be executed in a time frame of maximum 3 seconds. *(Image: Bart Noyens)*

The 3D technique is less suited for these situations. The goal of the 3D technique is to direct small amounts of water into the smoke layer in order to maintain its stability and to avoid water reaching hot walls or surfaces. When dealing with an under ventilated fire there no longer are separate zones. The smoke layer has reached the floor level and the room has completely filled up with smoke. Firefighters no longer need to be concerned about a little bit of water damage. The smoke has made sure that every surface needs to be repainted.

This doesn't mean that now an excessive amount of water may be used. However it is no longer ideal to use pulses. It's better to spray water in the form of an arc (see figure 2.1 and 2.2). To achieve this the nozzle is opened, moved sideways in an arc and subsequently closed. As is the case with 3D technique (or short pulses), the flow rate is limited to 150-200 liters per minute. The cone is set to 40 – 60°. This method of gas cooling means the nozzle will remain open for about 2 to 3 seconds. When using this

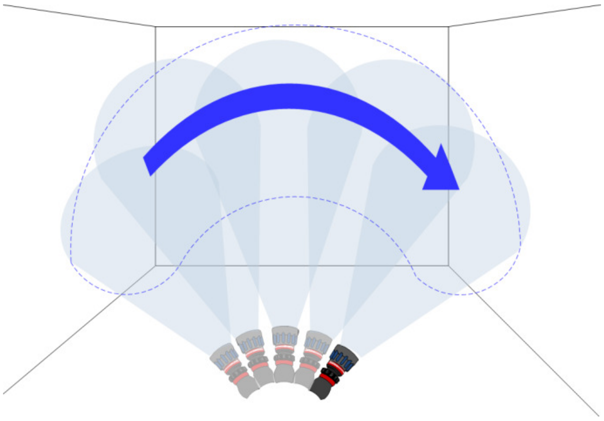

Figure 2.2 The nozzle is activated on the left hand side of the room and subsequently moved in the form of an arc to the right at which point it is closed again. *(Image: Bart Noyens)*

technique a lot of turbulence will be created and smoke will be mixed up with steam. However no practical problems arise because there wasn't any visibility to begin with.

During fires in the growth phase the 3D technique is used after shortly advancing the hose line. When dealing with underventilated fires the alternative technique is used after small advancements into the room. Should the temperature of the smoke remain too high to advance, an additional cooling action is performed. Because the arc movement is used, one can be sure that the entire width of the room is covered. Under ventilated fires offer practically no view on the size of the compartment as opposed to fires in growth stage. The latter allow for a view underneath the smoke layer. This makes under ventilated fires much more difficult in terms of assessing the coverage of cooling across the width of the room.

3 Alternative approach

People in Sweden started changing the way they build and construct houses after the first oil crisis in 1973. Temperatures during the winter period are substantially lower than over here. This means that when evenly insulated, houses have to be heated a lot more than in Belgium. The Swedes quickly realized that the traditional way of building (no insulation in cavity walls, single glass panes and plenty of cracks and air leaks) was no longer viable in the long term. Today in Sweden triple glass panes are the standard. The problems arising today in Belgium because of the new construction methods, have been occurring in Sweden since the 80's. Over the years our Swedish colleagues have come up with a number of solutions to tackle these problems.

3.1 TIC, cobra and ventilation

In 2010 I attended an introductory course on the cold cutting extinguisher, aka the cobra. This device allows to create tiny holes of just a couple of millimeters in doors, walls, floors, … To achieve this effect an abrasive substance is added to the water which is then sprayed at very high pressure (300 bar). After the hole has been produced the water will enter and penetrate very far into the room behind. Because of the high pressure a very fine water fog is created which is ideal for cooling smoke gases. The flow rate is rather limited at 60 liters per minute which doesn't allow for total extinguishment of the fire. It does provide a means to regain control over a fully developed compartment fire or to inert the hot smoke gases of an underventilated fire.

The cobra alone is not a complete firefighting method. In Sweden the IC will always perform a thorough size up of the incident. While he is doing this, preparations are made to start the interior fire attack. During the size up he will try to evaluate the fire behavior. Aided by a thermal imaging camera (TIC) he will determine the location of "hot spots”. At those spots a cobra can be used. The IC will then evaluate the effect of the cobra. He can monitor the change of the temperature of the exiting smoke gases. The cobra will be put to use at several different locations to make sure that the smoke gases have been cooled. Each time that the water has drilled itself into the room, water is sprayed inside for a short period of time.

After the use of the cobra has ended, several actions are undertaken. Close to fire a ventilation outlet will be created. Also the entry door will be opened up. A positive pressure fan will be started to vent the cooled smoke gases from the room. After that the interior fire attack will be initiated.

It’s of the utmost importance that all these different actions are coordinated. The instance the cobra is started, everything needs to be ready for the next step. Firefighters with SCBA’s need to be ready. Immediately after finishing the cobra the ventilation (inlet, outlet and fan) needs to be started to be promptly followed by the interior fire attack. This mode of operation allows for firefighting without additional damage by fire growth into adjacent rooms.

3.2 The piercing nozzle: “a poor man’s cobra”

The cobra system is very expensive. An alternative exists at a cheaper cost, but also with less possibilities. One of the Swedish instructors put it this way: “If the cobra is too expensive, first buy yourself a piercing nozzle. For a number of fires it will allow you to save up a lot of money. With that money you can then buy a cobra because it’s still a fantastic tool.”

The piercing nozzle is a steel tube fitted with a connection for high pressure or low pressure lines. A valve is in place to open and close the water flow. The front of the tube is a cone shaped ending with several small holes. Using a power drill a hole is made through the door, the window frame or the wall leading to the room in which water needs to be applied. After the hole has been drilled, the piercing nozzle is put into place and the water flow will be activated for a few seconds.

Because of the lower working pressure, the water droplets produced by a piercing nozzle are substantially larger than those of a cobra. The range of the spray is also less. The piercing nozzle is therefore a less efficient tool. It is however a simple tool that requires much less training than the cobra.

The fire ground application of the piercing nozzle is similar to that of the cobra. A coordinated effort is necessary for making the opening, putting the piercing nozzle in place, halting the water flow, creating the outlet for venting, opening the door, activating the fan and initiating interior fire attack. It is therefore imperative that the IC has sufficient knowledge to size up the situation before deciding on such fire ground tactics.

3.3 Positive Pressure Attack (PPA)

Sweden also has a number of fire departments that use similar tactics in which smoke gases are not cooled in advance of the interior attack. This method is practically identical to what our American colleagues refer to as Positive Pressure Attack (PPA). More information about this subject can be found in the article published in ‘de Brandweerman’ (see [7]).

Swedish colleagues however add one element to the tactic. The moment the interior attack is started, the attack crew will also perform smoke gas cooling. When properly executed this tactic allows for both quickly establishing control over the fire, and for venting the smoke. Some of our Swedish colleagues assume that the chances of survival of possible victims will increase because of this. Research will have to determine whether this is true for the fire compartment and for any other rooms connected by open doors. The research done by Steve Kerber (see [5]) has already shown that victims confined in rooms with closed doors are very likely to survive the incident. A rapid intervention of the fire crew can limit the time of exposure to toxic smoke gases of the victims.

Aside from the advantages this fire ground tactic comes with certain risks. The fire will be rekindled by the fresh air and will possibly progress into ventilation induced flashover. The attack crew will have to advance quickly and adequately to prevent this from happening. Likewise the IC will have to be very competent to assess the right approach of fire attack. It is clear that the 2012 Belgian officer course (sergeant) is not suited to provide this level of competence. With a total of 70 hours of theoretical instruction and no practical training, this course can be compared to written instruction on how to swim! Let's hope that in the future choices will be made in favor of a better training.

4 Acknowledgments and thanks

This article would not have been possible without the support of the KCCE and its director Johan Schoups. Special thanks are also in place for lt-kol Desneyder, fire chief of the Brussels Fire Department, for supporting me in my quest for knowledge. Finally I would like to thank Lt. Bart Noyens of the fire department of Kasterlee for providing me time and again with beautiful pictures to illustrate my articles.

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