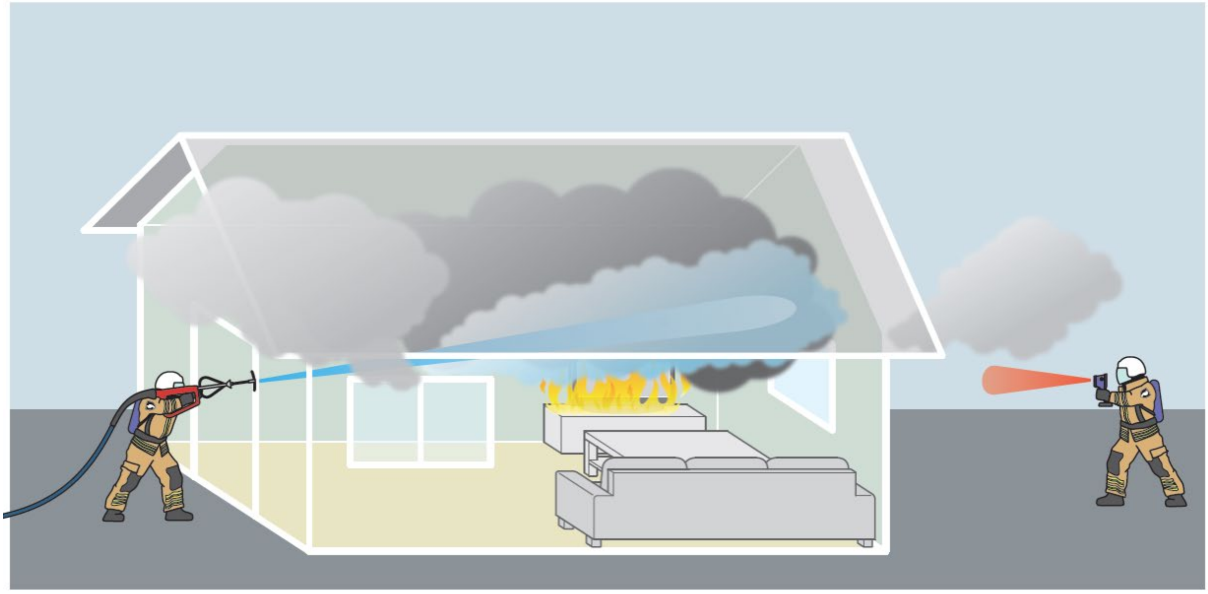
Coldcut™ Cobra – state of the art innovation in modern safe firefighting



Content

Preface

This report is a compilation of research projects that have been conducted using the coldcut™ Cobra firefighting system. This report should be seen as a literature review and as guidance to finding more information about new research results regarding Cobra and the Cobra Method. This report highlights research that is important for Incident Commanders and users to know, which will support a better understanding of why the Cobra works as it does and how to use it in the most effective way. This is the first report from Cold Cut Systems that collates and presents findings from research projects. The goal is to produce updates of this report when new research projects have been conducted. The reports can be found on our web page (www.coldcutsystems.se)

Summary

The Cobra ultra-high pressure water jet firefighting system is a Swedish invention that is used to fight fires both on land and at sea. The main application allows firefighters to fight fire in a modern, efficient and effective way from a safer location. Cobra is used from the outside of a fire compartment and, with the use of a cutting abrasive additive in the water, can pierce through compartment boundaries, efficiently cool hot fire gases and suppressing/extinguishing the fire without the need for firefighters to enter.

The Cobra Method (CEC) is a method that combines the use of thermal image cameras, Cobra and Tactical Ventilation. Many Fire and Rescue Services work with the Cobra Method and initiate an intervention with the incident commander scanning the building from the outside with a thermal image camera in order to determine where the hot spots are, and where the Cobra attack will have the best effect. Cobra is then used to cool hot fire gases, suppressing and/or extinguishing the fire if possible. Tactical Ventilation is then initiated to vent the fire gases and steam. A tactical plan incorporating a combination of these key capabilities can produce much safer working environments for firefighters to enter into.

Experimental measurements show that the spray is characterized by small droplets in the water jet travelling at a high speed [1]. The following characteristic diameters were measured at 10m distance from the nozzle using 260 bar injection pressure: arithmetic mean diameter $d_{10}\approx 60$ µm and the Sauter mean diameter $d_{32} \approx 170$ µm. The velocity at this distance from the nozzle was approximately 7 ms^{-1} in the spray core. These measurements support previous explanations of the efficiency of Cobra and have also lead to a more detailed understanding of the extinguishing process. The study showed markedly differences with other systems on the market and clearly shows the advantages with Cobra.

By the use of data from the spray characterization [1], CFD simulations have been conducted to simulate stirring effects, gas cooling efficiency and inerting for different room scenarios [2]. The simulation result showed that Cobra is outstanding to use for fighting fires in buildings compared to other systems on the market. Cobra is leading in:

- Gas cooling
- Inerting effect
- Efficiency of used firefighting water.

Important learnings from this study are that Cobra does reduce the possibility of fire spread and flashover in the compartment and at the same time provides a safe working environment for the firefighters to enter in to. This combination is unique for firefighting systems.

Introduction to the coldcut™ Cobra

Cobra is a mobile ultra-high pressure water jet system with penetrating, piercing and cutting capabilities. The system ejects approximately 60 liters of water/ minute at approximately 200 meters per second through a nozzle mounted in a hand held lance.
The hand lance is connected through a high pressure hose to the main high pressure system (300 bar) and is controlled by the lance operator. The system has the capability to mix an abrasive cutting agent into the water, thus enabling the operator to penetrate or cut through virtually any construction material. When the water jet combined with the cutting abrasive has cut through the building material, the water breaks out into a fine mist due to the high velocity of the jet as it passes through the nozzle. As the water mist enters the fire room, the atomized water evaporates and in the process consumes energy and heat. In the process steam will inert the fire gases by decreasing the oxygen concentration. If the fire is not situated immediately opposite the penetrated boundary, the continuous use of the Cobra can saturate the immediate volume and travel towards the fire. The speed of the injected water mist will aid in the process. If controlled ventilation is applied, the effect can appear even sooner.

Examples of penetration capability have been tested and are described in various reports. The Swedish Defense Materiel Administration (FMV) conducted tests at early stages of a fire, cutting through the following material [3].

- 4 mm mild steel, 10 seconds
- 8 mm carbon-fiber laminates, within 10 seconds
- 50 mm concrete slab, passed without noticing resistance

Cobra has been tested in accordance with EN 3-7:2004+AI 2007(E), Annex C. According to this standard, the electric current between operator accessed parts (like handle) and earth must not be greater than 0.5 mA when an alternating voltage of 35 kV is applied to a metallic plate. Cobra fulfills the requirements with the use of water and water and abrasives [4].

Cobra Method (CEC)

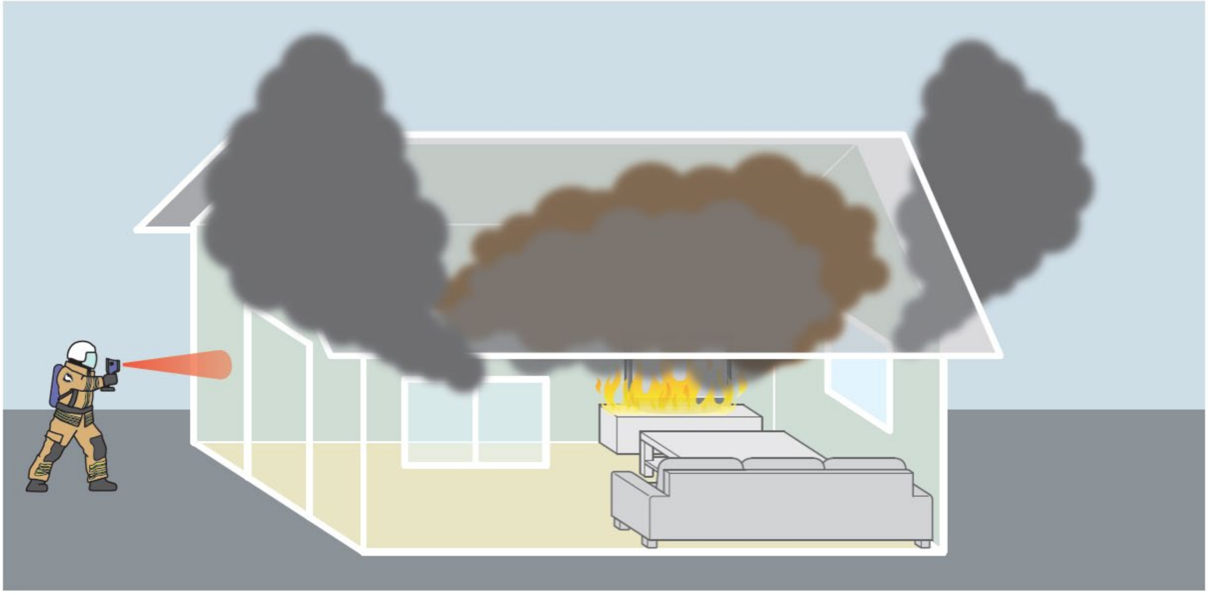


Figure 1 Safe firefighting from outside the burning building.

The Cobra Method (CEC) enables firefighting operations effectively from outside a fire compartment, without ventilating the fire, as shown in Figure 1. By such, it is a unique methodology for its effectiveness, external firefighting and offensive tactics. By fighting the fire from outside the building, the concept fulfils the stipulations in the Swedish Working Environment Authority (provision 2007:7) to fight the fire from a safe place outside the building to avoid a BA attack as long as possible.

Many Fire Services initiate the intervention with the incident commander scanning the building from the outside with a thermal image camera in order to determine where the hot spots are, and where the Cobra attack will have the best effect, see Figure 2. Figure 3 shows the combination of the Cobra attack and the monitoring of the temperature development by the thermal image camera.

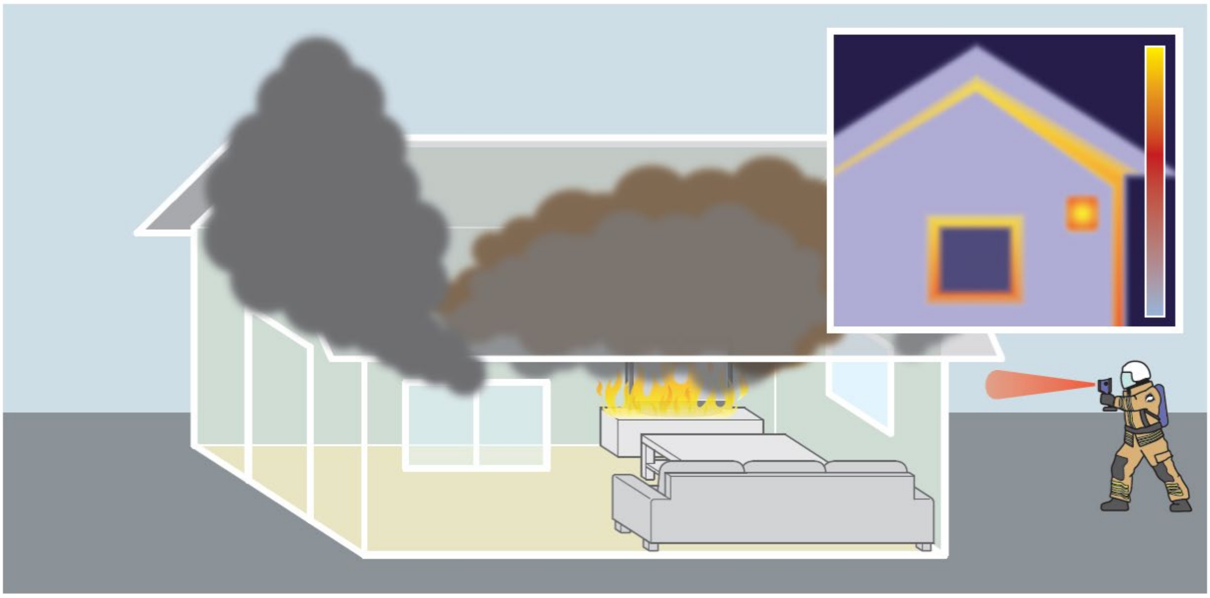


Figure 2 Usage of a thermal image camera to scan the building for hot spots.

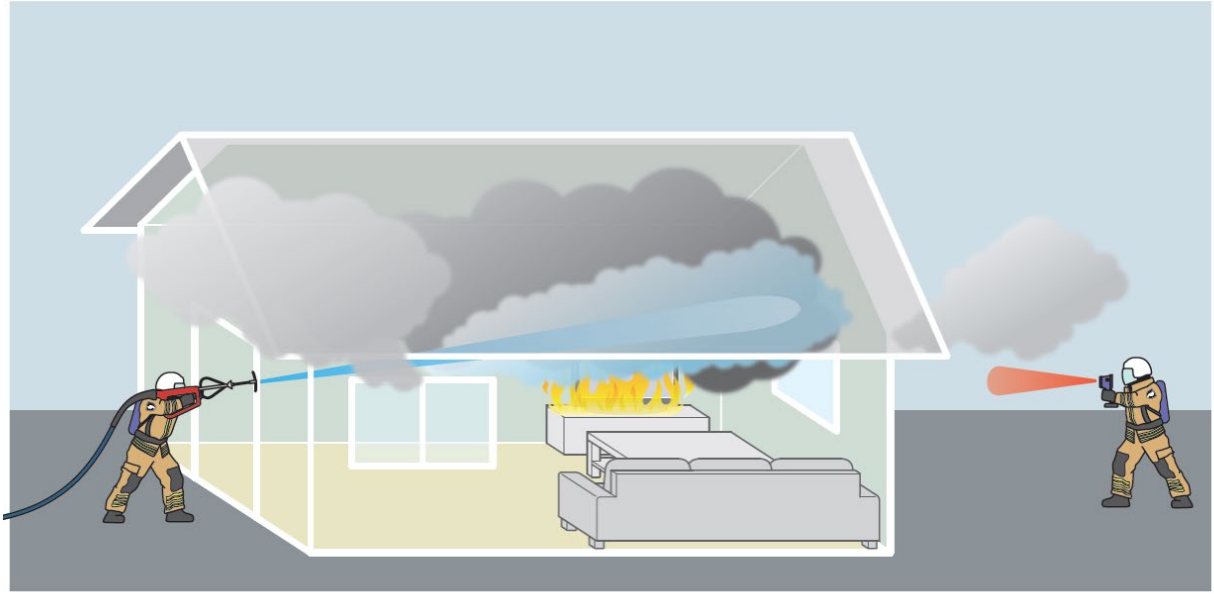


Figure 3 Cobra attack in combination with thermal image scanning.

Within seconds, the fire fighter can start the intervention with Cobra from a safe position. Cobra is very rapidly deployed due to the lightweight hose, which is 80 meters as standard - enough for most interventions, but can be extended up to 200 meters.

The Cobra lance operates with a very high pressure (300 bars), and with an abrasive which is induced in the lance, the water jet will cut through any building material, and most often reach the fire within seconds. A critical aspect in this phase is that the hot fire gases are rapidly cooled to a safer level, see the development of the temperature curve in Figure 4, the Cobra attack starts at the temperature peak of 700 °C.

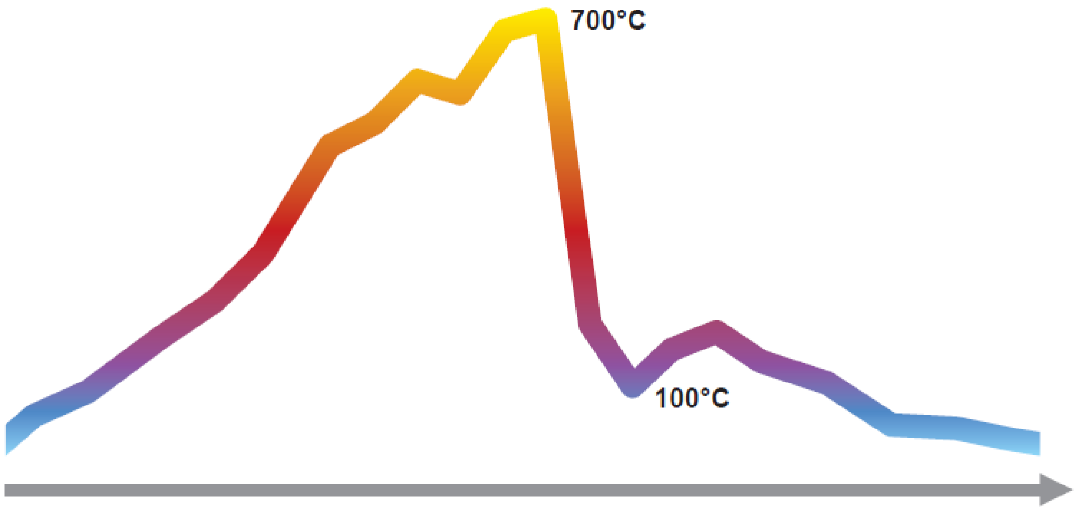


Figure 4 A temperature curve showing a room fire development. Cobra cools the hot fire gases which drops to about 100°C after a short time.

When the hot fire gases are cooled down to a low level and the fire is controlled, ventilation of the compartment can start as shown in Figure 5. This stage shall always be monitored by a firefighter with a thermal image camera to see if there are any hidden fires that needs to be taken care of.

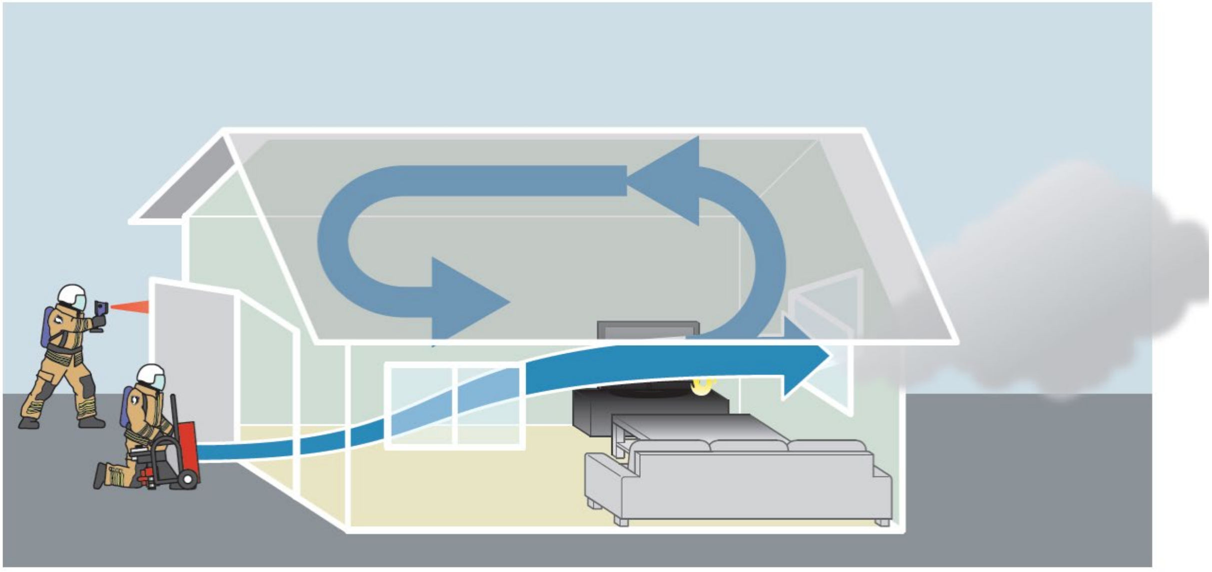


Figure 5 Ventilation after the hot fire gases are cooled down and the fire is controlled.

When a Cobra deployment suppresses a fire, the Method can create a window of opportunity to make a safer BA entry, see Figure 6. It is important to know, that a Cobra attack can be done during the time the BA crew prepares its operation, and that Cobra, by greatly reducing the hot temperatures, will make the BA operations much safer and faster. Cobra is therefore not seen as a complete alternative, but as complementary tactic to traditional firefighting. When the BA operations are committed they will be able to work in a relatively cool environment with lower risk exposure and much better visibility. Often a very limited usage of water is needed for the compartment firefighting following a Cobra attack.

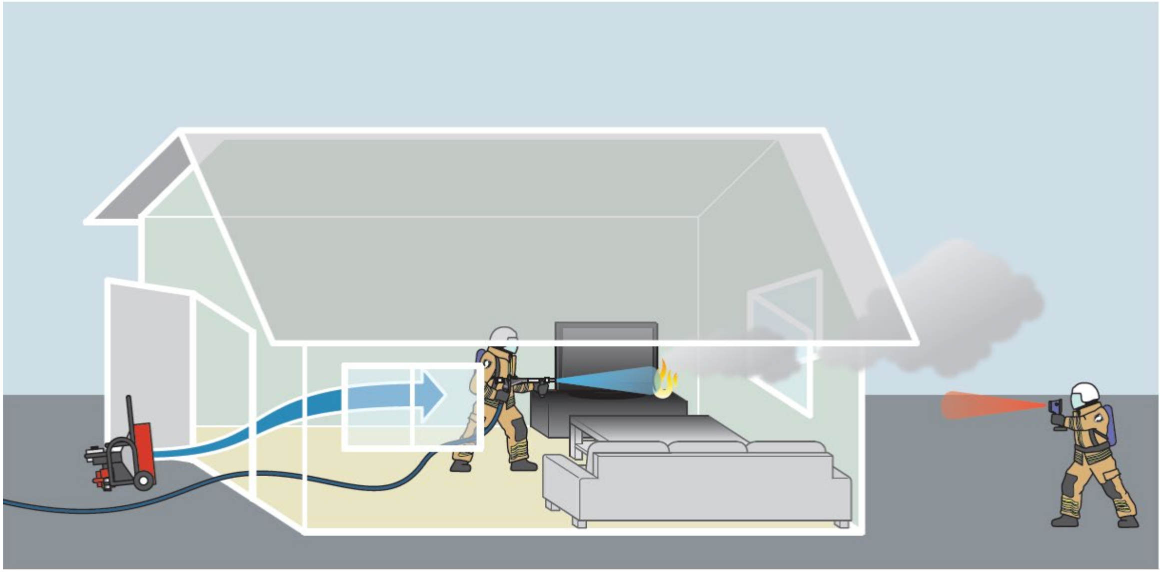


Figure 6 During the ventilation phase a BA team enters the compartment and extinguish small fires in a safe working environment.

Spray characterization of the cutting extinguisher

Spray characterization of the cutting extinguisher [1], is a report from SP Fire Technology. The report describes the implementation and results of laser measurements of the droplet size of Cobra. In the test series, other systems, nozzles and the influence of wetting agents were also evaluated to increase the understanding of the differences between various systems. Measured droplet sizes for Cobra, at a distance of 10 meters from the nozzle shows an arithmetic mean diameter d_{10}≈62 microns, the Sauter mean diameter d_{32}≈170 microns and the volumetric mean diameter d_{30}≈110 microns. With the involvement of the X-Fog and A foam reduced droplet size considerably. The arithmetic mean diameter decreased from 62 to 33 microns for the Class A foam and 62-38 microns for X-Fog. The Sauter mean diameter decreased from 170 to 149 microns for the Class A foam and 170-109 microns for X-Fog. Cooling, inerting and absorption of radiant heat becomes more efficient with smaller droplets than large drops in the conventional low pressure system. In the experiments were also conducted measurements on the water droplet velocity at different distances from the nozzle. At a distance of 10 m from the Cobra nozzle, the water jet had a speed of 7 m / s. For the other tested systems is the speed of the water droplets of about 1 m / s at a distance of 2-4 m from the nozzle.

Spray theory

Small droplets (< 2 mm) are in general close to spherical in shape and can therefore be described using a single parameter. Larger droplets are typically distorted by gravity. Different parameters are then used depending on the application. Sometimes the median diameter is used to characterize a spray. This parameter is of lesser interest for water mist, however, since large droplets will carry significant amounts of water and conversely the amount of water in the smaller droplets is low. Since very large droplets are not at all reflected in the median diameter this parameter is of less interest. d_{32} is the diameter of a droplet whose volume to surface ratio is the same as the volume to surface ratio of the entire spray. d_{32} is particularly important when mass transfer and the active area per volume is important. Therefore d_{32} is an appropriate parameter for water mist since the purpose with the small droplets in water mist is to achieve large surface related effects, such as cooling and evaporation, while using small volumes of water.

Water mist is generally interpreted as sprays with water drops of a size up to 1000 micrometers (1 mm). Small droplets add a number of features to it as a firefighting media. By atomizing the water into micron size droplets, the surface area of a given volume of water expands dramatically. At a droplet size of 1 mm, one liter of water covers the area of a third of a soccer goal (6 m^2). Assuming drops of 1 micrometer in diameter, one liter of water covers an area of approximately 6000 m^2, or the area of a football pitch. The surface area exposed by the atomization of the water reduces the time tremendously for the water to transform to steam.

Results from the spray characterization

Figure 7 shows how the fraction of measured droplets varies in diameter (counts during 30 seconds). In two measurements, additives X-Fog and a foaming agent (A-foam) were mixed in the water (1-2%). Two measurements were performed at a radial (horizontally) position of 40 cm and 80 cm, respectively, from the centreline of the spray.
The estimated uncertainty is ±10 % in the result.

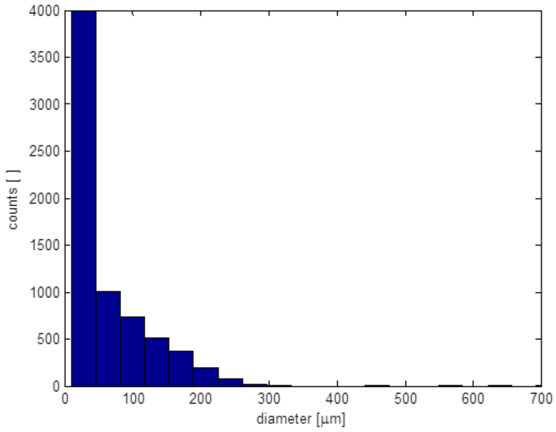


Figure 7 Drop size distribution from the cobra along the centerline 10 m from the nozzle. P_{nozzle}=260 bar.

Table 1, 2 and 3 shows the result from all measurements [1].

Table 1: Arithmethic mean diameter, d_{10}.

p_{nozzle} [bar]	z [m]	8	10	15
	comment	d_{10} [µm]		
200		60	77	85
260		46	62	86
260	A-foam		33	
260	X-Fog		38	
260	R=40 cm		64	
260	R=80 cm		43	

Table 2: Sauter mean diameter, d_{32}.

p_{nozzle} [bar]	z [m]	8	10	15
	comment	d_{32} [µm]		
200		157	174	174
260		160	170	196
260	A-foam		149	
260	X-Fog		109	
260	R=40 cm		127	
260	R=80 cm		97	

Table 3: Horizontal velocity.

p_{nozzle} [bar]	z [m]	8	10	15
	comment	V [m/s]		
200			6	4
260			7	5
260	A-foam		6	
260	X-Fog		5	
260	R=40 cm		4	
260	R=80 cm		3	

Cooling effects [1]

The droplets extract heat from flames and hot gases by heating the water from room temperature to 100 °C, and by evaporation where the extracted energy is used to induce a phase change from liquid to gaseous water. The rate of transport of energy to the droplet depends on the surface area of the droplet and the relative velocity of the droplet as compared to the air. The heating rate is proportional to the transferred power per unit volume. Therefore, d_{32} is useful when comparing the heating rate of the droplets. Assuming a d_{32} of 900 μm for conventional systems, the relative surface to volume ratio between the conventional systems and the Cutting Extinguisher is approximately 900/170 ≈ 5. The significance of this is that the generally smaller water droplets from the Cutting Extinguisher heat up much faster and extracts more power from the flames and hot gases. This in turn will lead to an accelerated evaporation, resulting in enhanced inerting and much faster gas cooling.

Inerting (reduction of the partial pressure of oxygen) [1]

The fire can be efficiently controlled if the air is partly replaced by water vapour. This reduces the partial pressure of oxygen. This can reduce or even extinguish the fire. For example, when the oxygen concentration is reduced from 21 % to 13 % (wood fire) or to 7% (petroleum fire) the fire will self-extinguish [5]. The evaporation rate in gas will be enhanced for fine mists. It should be pointed out that inerting can be greatly inhibited if fresh air is entrained in the spray. Therefore, using a nozzle that can interact with the fire without the introduction of fresh air greatly enhances the extinguishing capacity of such a system, e.g. if the extinguisher can be introduced into the compartment through a minimal hole. Indeed, in such cases the system may even act to entrain vitiated air from the fire back into the combustion environment further enhancing its performance.

CFD simulations of the cutting extinguisher [2]

This report [2], shows that Cobra is outstanding for fighting fires in buildings compared to other systems on the market. The effectiveness of the very small droplets is greatly enhanced by the stirring effect due to the high speed in the water jet and a dimensioned water flow where almost all of the used water vaporizes and causing no water damages.

The report presents simulation results of Cobra when used for firefighting in conventional structures by the aid of computerized simulations and experimental data.

The simulations were done using Fire Dynamics Simulator (FDS), which is an open-source code for modelling well-ventilated fires. As input for the spray model, data was used from earlier research focused on droplet sizes and velocities in the spray [1].

Different room types were used to analyze differences that appear with different geometries, obstructions, ventilation aspects etc. For validation, real scale fire tests were conducted for the living room scenario. The result from each scenario demonstrated that Cobra was outstanding in gas cooling, stirring effects and effectiveness of used water, compared to other systems that were simulated.

Findings of this study confirm that Cobra can be used for combating fires in confinements using less water than traditional methods with an outstanding result. This is done by reducing both the gas temperature and relative concentration of oxygen in the room instead of cooling the surface of the fuels as traditional methods do. Other systems that were evaluated was the enhanced low pressure system (fog nail) and a 100 bar system with a flow rate of 40 liters/ minute ("alternative cutting extinguisher").

The exact understanding of the jet behavior has been lacking until recently when the drop size distribution of the spray from the cutting extinguisher was measured experimentally using laser diagnostics. Knowledge of droplet size distribution allows for a more analytic analysis of the effect of the Cobra, as well as for numerical simulations.

Some of the results from the study are shown in Figure 11-16 below (living room scenario). The results are summarized in the following bullet points:

- Gas cooling effect

The high velocity of the Cobra jet induces mixing in the confinement (stirring effects), enhancing the interaction of droplets with hot combustion products and promoting the vaporization of the injected water. Furthermore, the induced momentum to the gases in the room together with the vaporization of the injected water reduces the overall gas temperature inside the room way faster and more efficient than any of the other systems.

- Inerting effect

The result shows that the mean water concentration in the room is as high as 35% for Cobra, 27% for the "alternative Cobra", and as low as 15% for the fog nail, for the simulated conditions. The high concentration (35%) is very important for the inerting effects in the room and was maintained for a well ventilated scenario.

- Accumulated water on walls and floor

Water damages due to firefighting water is a current subject for discussions both in Sweden and on an international level. The simulations shows that the firefighting water from Cobra vaporize up to 90 % causing no water damages. The result is equal for the "alternative cutting extinguisher". The results for the fog nail shows that almost all used water was accumulated on walls and floor, causing costly damages on the building.

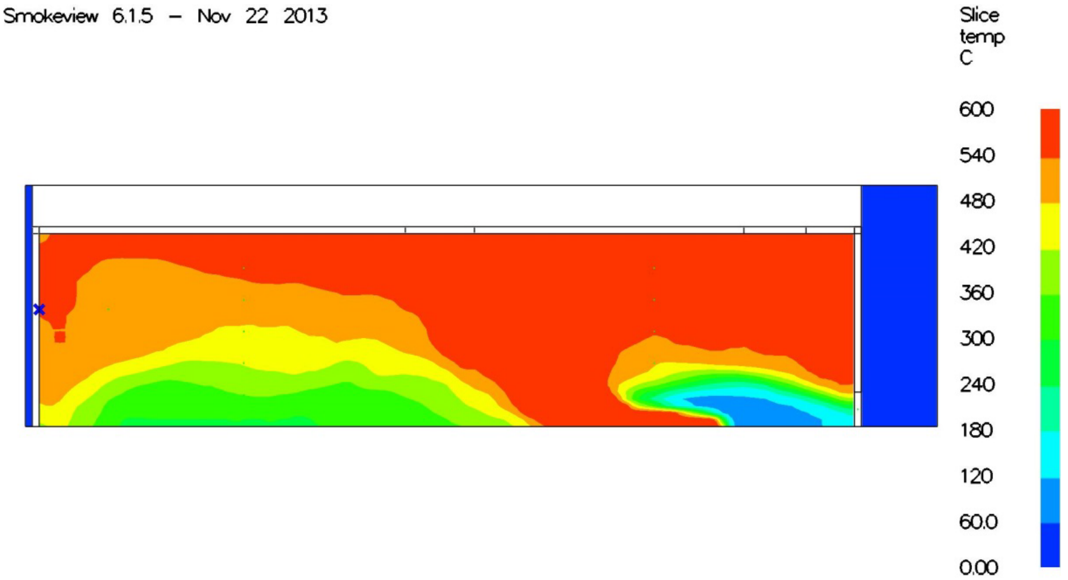


Figure 8 Temperature field in Plane A in the living room right before any spray is injected. The field is averaged over 10 s.

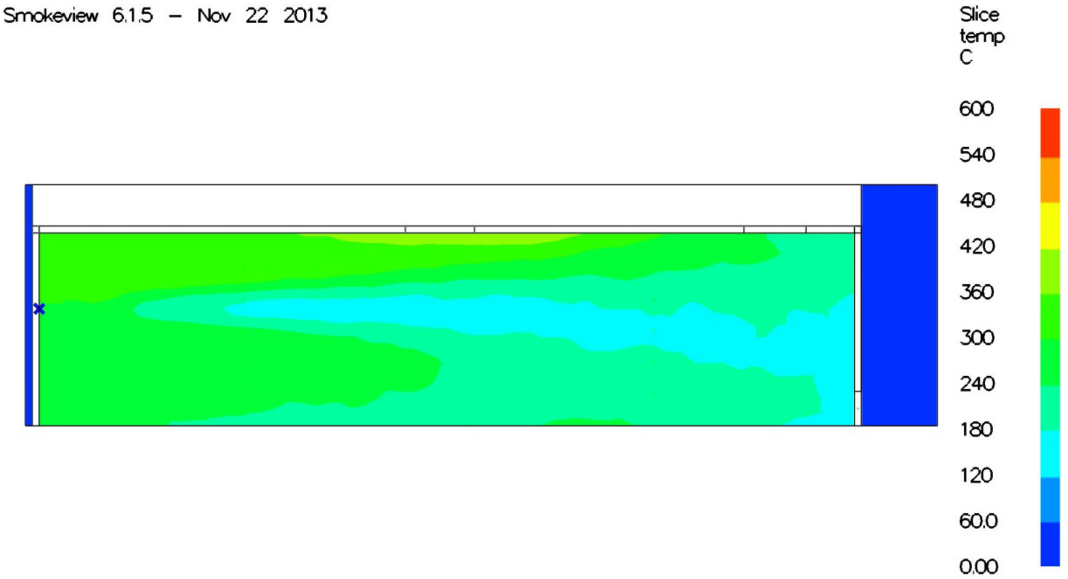


Figure 9 Temperature field in Plane A in the living room after 10 s use of the Cutting extinguisher. The field is averaged over 10 s.

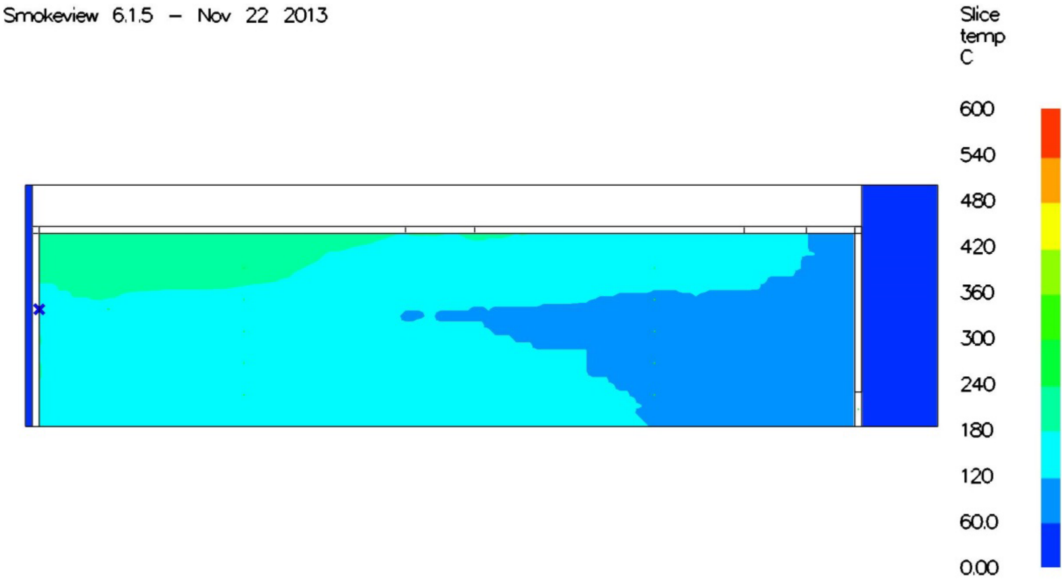


Figure 10 Temperature field in Plane A in the living room after 60 s use of the Cutting extinguisher. The field is averaged over 10 s.

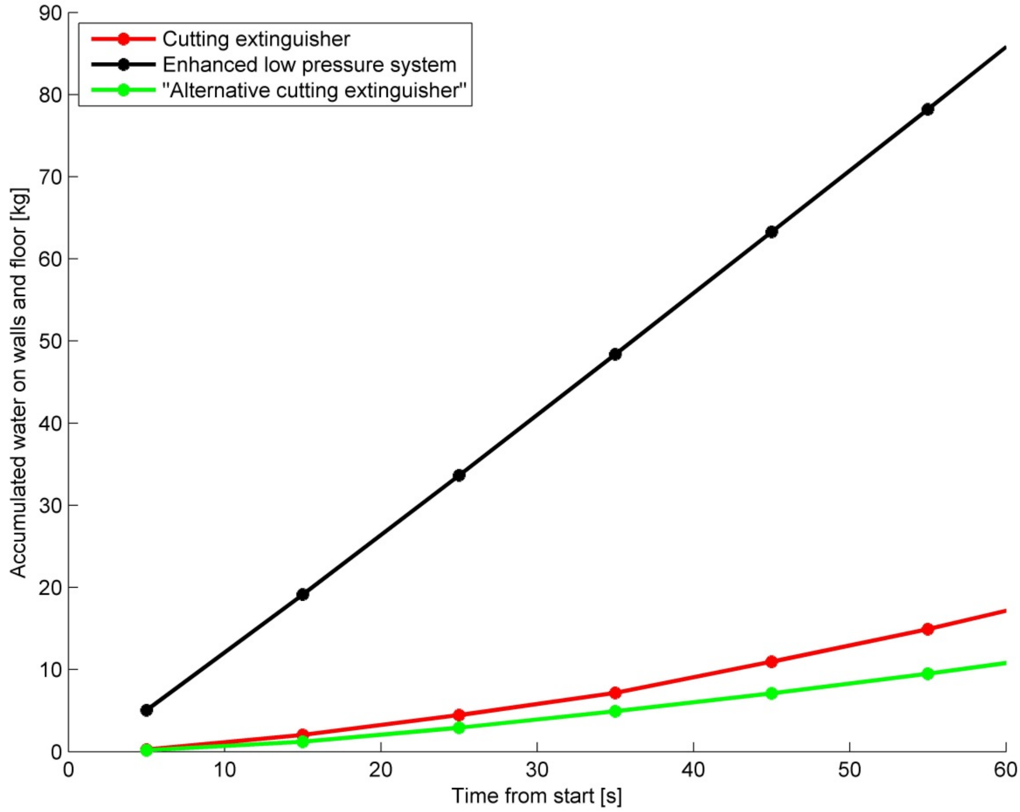


Figure 11 Accumulated water on walls and floor for the studied systems. The total amount of water sprayed into the living room is 60 and 100 liters during 1 minute for the Cutting extinguisher and the enhanced low pressure system, respectively.

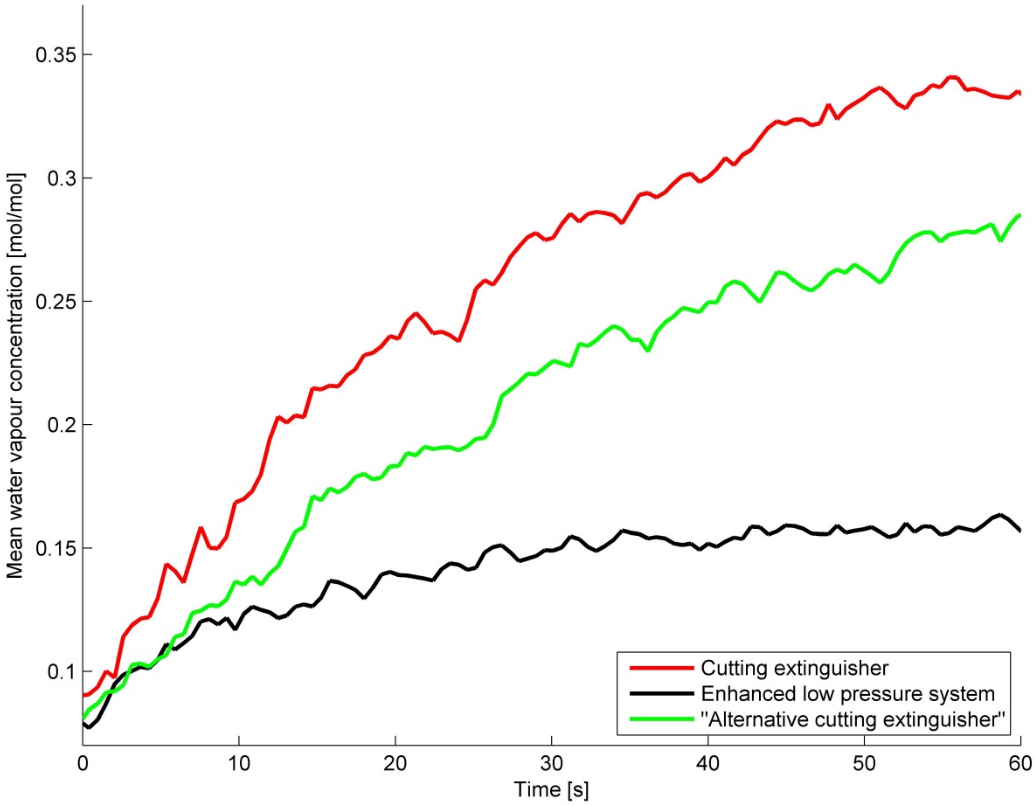


Figure 12 Comparison of water vapour concentration as function of time between the nominal Cutting extinguisher and the enhanced low pressure system.

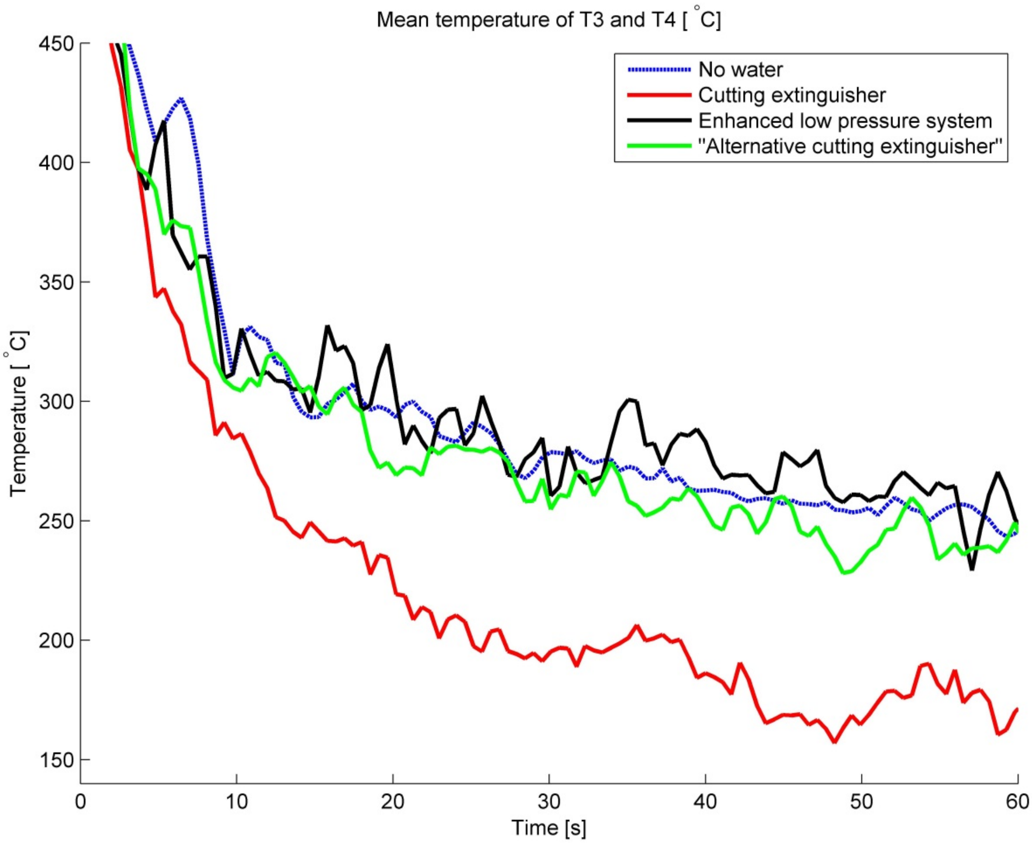


Figure 13 Comparison of gas cooling for the nominal Cutting extinguisher and the enhanced low pressure system. In T3 and T4, we cannot see any difference in gas temperature with or without the use of the enhanced low pressure system according to the simulations.

Cutting Extinguishing Concept – practical and operational use [5]

A report was developed in a collaboration between Södra Älvsborgs Fire & Rescue Service (SERF) and SP Technical Research Institute of Sweden (SP) commissioned by the then Swedish Rescue Services Agency (now the Swedish Civil Contingencies Agency, MSB). The project team conducted studies of the CEC on the basis of reported and documented experience of almost ten years of practical use of the method. The report includes concrete examples of actions at fires where the cobra has been used and a description of research projects during this period. The following bullet points summarize the findings from the report:

- Cobra effectively cools the fire gases, promotes the fire spread and inserts combustion gases with low temperature.
- Positive pressure ventilation is facilitated thanks to cobra's ability to control fire gases before ventilation begins. Cobra allows a faster start to affect the fire and fire gases during an operation.
- Cobra allows for extinguishing fires in walls and, double floors, ceilings and attics for example, that are notoriously difficult to extinguish with other systems.
- Tactical options has increased markedly when one connects modern infrared technology, Cobra and PPV.
- Knowledge of the CEC concept increases the frequency of use and the operational efficiency and create greater confidence in the CEC capability.
- Water and environmental damage associated with fire suppression has reduced considerably and in a number of cases completely ceased after the cobra has been used.
- The concept improves the working environment for fire personnel.
- Cobra can effectively control interior fire and cool fire gases, while other actions are proceeding, to force security doors etc.

FIREFIGHT I och II [6]

FIREFIGHT I and II are two projects funded by the EU commission. These projects have been coordinated by the Swedish Civil Contingencies Agency, MSB. The project covers a total concept for safer working environment through the use of infrared camera, cobra and ventilation. In FIRE FIGHT II project a web-based e-learning program was developed. The program will be used as a basis for future courses. (www.eufirefight.com).

Use of ventilation in combination with the use of Cobra [7]

The report was produced in collaboration between SERF and SP on behalf of the former Swedish Rescue Services Agency, today MSB. The report highlights experimental surveys around pressure ventilations efficiency in several composite rooms, pressurization of the adjoining premises, use of pressure fans to shorten long access routes and ventilation in the stairwells. The capacity of Cobra at different conditions, the effect of additive in the extinguishing water and the possibilities of combining pressure ventilation with use of Cobra has also been investigated. Experiments conducted showed that it is the air speed through the room, the room size and interior doors relative positioning in the room that is crucial to how effective the fire gas is ventilated out of each room. A general conclusion based on experiments is that the air speed inside the building is primarily determined by the fan capacity, number and size of the door openings in the building, protruding parts in the building as well as the weather and wind conditions outside the building. The results show that there is no practical reason to place an additional fan inside a long corridor. The increase is 20-30% of the maximum pressure and flow. Large scale experiments with Cobra at the fire school in Kuopio shows a certain cooling of the fire gases for the used amount of experimental local (1700 m3), the amount of fuel (8.3 m2 diesel) and the ventilation ratio. The temperature of the fire gases fell on average from 430 ° C to 300-330 ° C in 3 minutes. In the experiment with two Cobras extinguished the fire in 3 minutes. The same experiments with the use of fog nails showed no significant reduction in the temperature of the fire gases. Fog nail number two was activated for 5 minutes after the first, resulting in a temperature reduction in the fire gases from 450 ° C to 300 ° C in a 3 minutes time period.

Capacity and limitations of extinguishing systems used against fires in buildings - focus on environmental issues [8]

Cobra is the only tool with the help of water and abrasive can penetrate walls and bringing in the extinguishing agent directly into the fire area. Cobra is a useful tool when fires are enclosing without free supply of oxygen. Using water mist cools the fire gases efficiently in space and the partial concentration of oxygen is reduced. Water mist is not intended for surface cooling, but should primarily be used to cool the fire gases. The actions identified in this report have been attacks with Cobra used to achieve just that. Surface cooling can be achieved at longer deposition times when the fire gases are already cooled. At fires in attics and similar, with a very limited supply of oxygen, the water mist cools the hot fire gases effectively and thereby reducing the pressure in the premises and ultimately extinguish the fire. Several practical applications show that Cobra often needed to be imposed for a while to take effect. This has proven particularly important in efforts to premises with large volumes where the intention was to cool the combustion gases.

The amount of water used differs sharply in comparison with conventional methods (low pressure systems with high water flow rate). Cobra has a water flow rate of 58 l / min compared with a conventional low pressure system with about 300 l / min of flow. The low flow rate, small droplets and high speed in the water jet limits the water damages in the building due to non-evaporated extinguishing water.

One advantage of Cobra in comparison with several other systems is that the fires in the building's construction, such as walls, double floors and ceilings, are not exposed to the fire compartment needs to be opened up. Fires in building constructions can be located efficiently with thermal image cameras and extinguished with Cobra instead of breaching the floor or wall and increasing fire development caused by the introduction of fresh air with new oxygen.

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