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Experience of Shipboard firefighting with Cutting Extinguishers

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Anders Trewe, Cold Cut Systems Svenska AB

Abstract

For the last 15 years, cutting extinguishers and the cutting extinguisher method have been used in thousands and yet thousands of fire interventions by municipal firefighters around the globe.

The numbers of cutting extinguishers installed on ships are few in comparison to the numbers in use by the fire and rescue services. Adding the higher level of safety awareness on-board naval vessels, compared to the general public, naval shipboard fires, and thus experience, tend to be scarce. It's hard to find real cases.

However, in many areas, special units from municipal fire and rescue services, such as Maritime Intervention Response Groups and similar teams, are assigned to shipboard firefighting when vessels are near or alongside quays. These units are trained to fight fires on board ships and have great routine and experience in fighting fires, on-board as well as on shore.

Cross discipline learning is crucial to reach high efficiency in introducing new technology and methods. This paper will describe and illuminate the experiences, procedures and methods from fighting real fires on-board ships using the cutting extinguisher and its method. It will also conclude in lessons learned from the actual incidents.

Key words

Shipboard Firefighting, Cutting Extinguisher Method, Safer Firefighting, Efficient Firefighting, Water Mist, Exercise, Capability, Experience, Redundancy, Disruptive Technology

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Introduction

For the last 15 years, cutting extinguishers and the cutting extinguisher method have been used in thousands and yet thousands of fire interventions by municipal firefighters around the globe.

When the Visby Class Corvette project was launched by the Swedish Defence Material Administration (FMV) together with Kockums Naval Shipyard, it was designed for prolonged flexible missions, in complex environments and with a very high grade of adaption to disruptive situations.

Requirements on the solutions integrated with the Visby ships included very high grades of redundancy. On naval vessels, mission comes first. Risk mitigation is therefore thoroughly applied on sub system level as well as on system platform. The Cobra Cutting Extinguisher was chosen as a risk mitigating system on-board the Visby class.

The numbers of cutting extinguishers installed on ships are few in comparison to the numbers in use by the fire and rescue services. Adding the higher level of safety awareness on-board naval vessels, compared to the general public, naval shipboard fires, and thus experience, tend to be scarce. It's hard to find real cases.

However, in many areas, special units from municipal fire and rescue services, such as Maritime Intervention Response Groups and similar teams, are assigned to shipboard firefighting when vessels are near or alongside quays. These units are trained to fight fires on board ships and have great routine and experience in fighting fires, on-board as well as on shore.

Cross discipline learning is crucial to reach high efficiency in introducing new technology and methods. This paper will describe and illuminate the experiences, procedures and methods from fighting real fires on-board ships using the cutting extinguisher and its method. It will also conclude in lessons learned from the actual incidents.

Background

Cold Cut Systems

Cold Cut Systems, CCS, the company behind the Cobra Cutting Extinguisher, was founded by master mariner Lars G. Larsson in 1988. The main business was in salvage and decommissioning, using water jet cutting technology. In 1994 CCS was invited by the Swedish Rescue Agency to take part in a project to find safe entry procedures through roofs of buildings. In 1996 a large scale test took place, where water jet cutting was used to cut entry holes through roofs. Initially the scientists thought the cables to the thermocouples were cut off by the water jet since the displays indicated such rapid temperature drop.

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The result was astonishing; the cutting tool actually extinguished the fire. CCS received first patents in 1997 and soon put the cutting extinguisher on the market.

Marine implementations of cutting extinguishers

Since Cold Cut Systems itself has a maritime heritage, as the company started with decommissioning services using high-pressure waterjet cutting, maritime agencies and companies have been a natural market for the product.

Swedish Navy

In 2000, the first Visby Corvette was launched – acting as a pilot test platform under ownership of FMV. In 2012, the first two Visby Corvettes was delivered to the Royal Swedish Navy, in version 4. To date, five Visby Corvettes have been produced and upgraded to version 5. The last vessel, HMS Härnösand, was delivered to the Royal Swedish Navy in the end of March 2015, and the project ends in September 2015.[1]

Parallel with the technological endeavors at Kockums, the Royal Swedish Navy and FMV sought to adapt to a number of issues that was brought in the wake of the decisions to construct the ship in light weight composite. Three issues were imminent when it came to damage control:

- Innovative construction material and stealth features
- Fighting fires with less crew
- Evacuating personnel

Other issues connected to the requirements of lean manning and extended operability were *redundancy*, minimizing the crew detachments and time needed for incident intervention as well as training demands.

Risk reduction management on HMS Queen Elizabeth Aircraft Carrier Class

Babcock Marine Services uses two sets of cobra units to de-risk operations onboard the HMS QE in conjunction with test runs of engines and turbines. Pre-determined Cobra Attack Points (CAPs)[2] have been identified and marked on board. Crew from Scottish Fire and Rescue Services is operating the cobra units on board the HMS Queen Elizabeth and HMS Price of Wales during construction/commissioning. The training of method and operation for SFRS has been carried out by Fire Service College (FSC) with personnel from Northampton Fire and Rescue Service.

[1] (FMV - Swedish Defence Material Administration, 2012)
[2] For further explanation of CAPs, please see section ”The Cutting Extinguisher Method on Swedish Navy Vessels” on page 9

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Figure 1 HMS Queen Elisabeth - Contains public sector information licensed under the Open Government Licence v1.0.

Fire and rescue services, MIRGs and Salvage companies

Over the years, more than 1000 Cobra cutting extinguishers have been delivered to fire and rescue services around the world. Most of them are used on a regular basis in fighting fires. In the early years a few fire services stood out and implemented cutting extinguishers on all their first responders. Often there was a driver of understanding the encouraged such wide implementation. In Sweden, SERF of Borås fitted 12 vehicles; the decision was based on their previous understanding of offensive ventilation. Cooling fire gases before entering and ventilating would make the operations much safer and quicker. In the UK, the Northampton FRS management realized the fact that the cobra method drastically reduced risks of the firefighting operations, to firefighters, to society and to environment, and implemented a plan of 23 Cobra units on their first responders. Similar rationales can be found with Kent FRS, Tyne & Ware and others.

On the seaside, several fire and rescue services have implemented multi-purpose Cobra units; the German Havariekommando have invested in 5 units which are placed at five fire services along the German coast lines, to be used in municipal firefighting, but available for shipboard firefighting alongside and at sea. Smit Salvage is a forerunner when it comes to Cobra use in salvage operations around the

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world. Today Smit Salvage have two units placed in Rotterdam and Singapore, ready for high sea firefighting. Other maritime agencies, fire services and salvage companies have followed suit.

The features of Water in Fire Fighting

Conventional firefighting has used water as extinguishing media since the beginning of time. By intuition, the method applied has been pouring water on the flames.

Other extinguishing media has been developed over time, such as gaseous fire suppression, inerting / isolating the oxygen in the gas volume surrounding the fire. Examples of these gases are Halon, Argon or CO_2. Unfortunately, these gasses have other features, adding suffocation risks and environmental hazards.

Thereto, water has a heat capacity and evaporation enthalpy that far exceeds named gases.[3] Applying 30 liters of water per minute, we have enough theoretical heat extraction effect to keep a 1 MW energy release per second under control.[4]

The Cutting Extinguisher

The Cutting Extinguisher is a semi fixed high pressure water jet system with penetrating and cutting capabilities. The system ejects approximately 30 to 60 liters water, at approximately 250 bar and 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 system 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 abrasive slurry has cut through the bulkhead or hatch, the water breaks out into an ultra-fine mist due to the high velocity the jet receives as it passes through the special nozzle.

The cutting extinguisher combines some of the main features of fixed installed ultra-high pressure water mist fire suppression systems with penetrating and cutting abilities and adds mobility. In addition, to minimize the risk of re-ignition of fibrous solid fuels, a Class A detergent may be added by the control of the operator.

When the water jet enters the fire room, the water atomizes due to its high velocity and cavitation when passing through the nozzle. The water mist starts to break up at about 5 meters from the nozzle and reaches about 15 meters.[5]

[3] (Schürmann, 2002)
[4] (Gsell, 2010)
[5] (Holmstedt, 1999)

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The system is developed by Cold Cut Systems and is presently standard issue on many Fire and Rescue Services in Sweden, Norway, UK, as well as on other markets. The Royal Swedish Navy has adopted the system and method for naval use, as have several other maritime organizations and businesses, such as the German Central Command for Maritime Emergencies (Havariekommando) and Smit Salvage. Furthermore, several navies are in the evaluation process of introducing the cutting extinguishing method.

The cutting extinguishing method for Fire & Rescue Services was initially developed by the Swedish Rescue Service Agency together with SERF, a regional Swedish Fire and Rescue Service, and is being enhanced and refined continuously.[6] Two European Union funded projects, with contributors from 10 European fire and rescue services, fire academies, governmental agencies and firemen unions, have refined the method to the *de facto* standard method now used in several European countries, including the UK, the Netherlands, Sweden and Denmark. The concept includes the use of thermal imaging cameras and positive pressure ventilation (PPV), as well as multiple-use of cutting extinguishers in large volume fire rooms.[7]

Water Mist

Referring to NFPA 750 (1996), Stefan Särdqvist describes *water mist* in three classes: class 1 through 3[8].

Water Mist Class	Definition, NFPA 750 (1996)
1	> 90% by volume of the droplets > 400 microns
2	90% by volume of the droplets > 200 and < 400 microns
3	> 90% by volume of the droplets <200 microns

Table 1 Water Mist Classification according to NFPA 750 (1996)

In later issues of NFPA 750, the definition is aggregated to "sprays with water drops of a size up to 1000 microns, or 1 mm". The rationale is that this description will serve as an effective mist for both Class A and Class B fires.[9]. However, this is a compromise: In principle, as all systems from a 10 bar fog nozzle to a 300 bar high pressure water mist system is covered by this definition, as one could see in Figure 2, below. In the previous NFPA definition, the cobra cutting extinguisher would have been graded to a Water Mist Class 3, while the 10 bar nozzle would have been in Class 1.

Looking at SOLAS' Res. MSC.365(93) Container Firefighting, Res. A.800(19) Sprinkler Equivalent or MSC 1165/1269 Water Based Equivalent Fire-Extinguishing Systems for Machine Room, all mention water mist, but none define water mist.

[6] (SERF in collaboration with SP Technical Research Institute of, 2010)
[7] (EU Firefight II)
[8] (Särdqvist, 2006)
[9] (NFPA, 2015)

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Research has shown that water broken up into smaller droplets adds 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. [10]

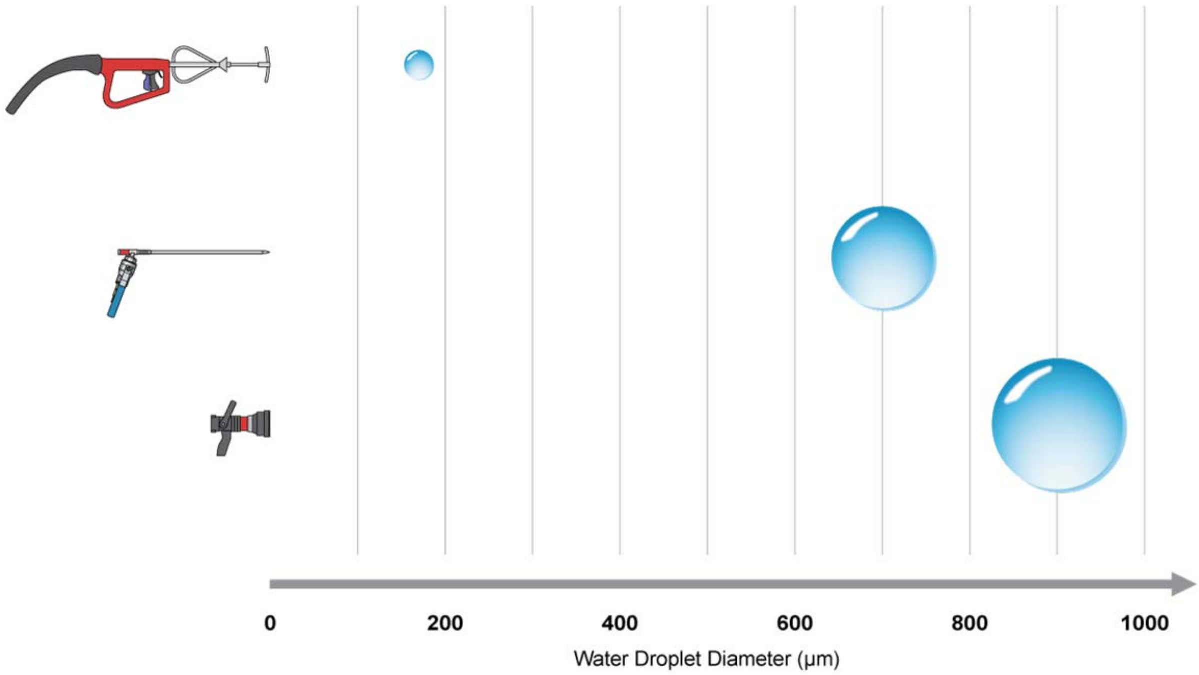

Figure 2 Water droplet Sauter mean diameter of different firer fighting tools, adapted from additional tests to (Svensson, Lindström, Ochoterena, & Försth, 2014)

When studying the efficiency of water mist in heat extraction, a measurement that relates the volume of the droplet to the surface of the droplet is necessary. This measurement is called Sauter Mean diameter. Studies made by SP Technical Research Institute of Sweden shows that the Cobra cutting extinguisher produces a water mist at a Sauter Mean diameter of 170 microns (60 micron arithmetic mean diameter) 10 meters from the nozzle. By introducing an additive to the water, such as a Class A surfactant or a saline additive, the water droplets size decrease significantly, thus expands the surface area exposed; the Sauter Mean decreases to 110-150 microns.[11] This confirms initial tests by the Swedish Navy showing that if the cutting extinguisher was utilized with a Class A detergent, the gas cooling is even more apparent[12].

At a droplet size of 1 mm, one liter of water covers the area of a third of a soccer goal (6m^2). At 1 micron, 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

[10] (Svensson, Lindström, Ochoterena, & Försth, 2014)
[11] (Lindström, Försth, Ochoterena, & Trewe, 2014)
[12] (Dahlberg, 2001)

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to steam.[13] However, Försth and Möller conclude that, with respect to heat absorption, there is a threshold at a water droplet size at about 1 to 10 microns, or 0.001 to 0.01 mm.[14]

To conclude, trying to extinguish burning oil with rainfall sized droplets is not wise. Similarly, it is hard to drench porous fires with 100 micron water droplets. However, combining the two will be a powerful method, as will be showed below.

Adding piercing capability; suspension vs entrainment

The cutting extinguisher adds the piercing feature to the water mist lance, through introducing an abrasive, a cutting agent into the water stream. In general, there are two ways of introducing a cutting agent into the water stream; through a *suspension* system or an *entrainment* system after the high pressure water pump (piston pump) and before the hose reel. The simpler entrainment system might seem to be a good idea, but looking at the technology and adding some aspects of the method of operations, it will soon show the opposite:

Suspension system

In a *suspension* system, the abrasive is introduced to the water line. Through a control system, the hand lance operator will call for abrasive from an abrasive vessel, typically containing 20 kg of abrasive, situated close to the hose reel. On a 30 liter per minute system, this will be enough for at least 6 minutes of piercing. The abrasive slurry then travels through the hose and exits through the nozzle of the hand lance. The transportation of abrasive will take approximately 20 seconds from the time the trigger is pulled to when abrasive is at the nozzle. Replenishing of abrasive will take place at the abrasive vessel/hose reel.

The piercing abilities of the Cobra cutting extinguisher have been tested and described in various reports. FMV conducted tests at early stages[15]:

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

Entrainment system

On the other hand, an *entrainment* system works as a water blaster. As the water passes through the first nozzle in the hand lance, into a venturi chamber, the abrasive material is sucked in to the water stream and accelerated through the second nozzle. The diameter of the second nozzle is roughly twice the first, rendering a four time as large area of the second nozzle. This will affect the area of the hole to be pierced, thus the amount of abrasive used. In addition, the acceleration of the abrasive have a

[13] (Gsell, 2010)
[14] (Försth & Möller, 2011)
[15] (Dahlberg, 2001)

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reducing impact on the speed of the water and the venturi chamber creates turbulence, both affecting the water jet speed and its water droplet distribution negatively. This implicates that the entrainment system will use at least four times as much abrasive to penetrate the same object as a suspension system; and, to get the same water droplet distribution, the nozzle has to be changed to one without venturi chamber once the hole is pierced.

To be ergonomic, an entrainment hand lance cannot have more than two kilos of abrasives in the bottle attached. This means that after 30 seconds of piercing, the operator has to stop the operation to change the abrasive bottle. This in turn means that the operator has to have a logistic support set up to transport abrasives from a rear supply position to the scene of the fire. This requires more personnel and adds extensive risks to crew and ship, as the supporting crews have to move through the ship, in smoke and heat, during firefighting operation.

Doing the job: Gas cooling, oxygen depletion, radiation shielding

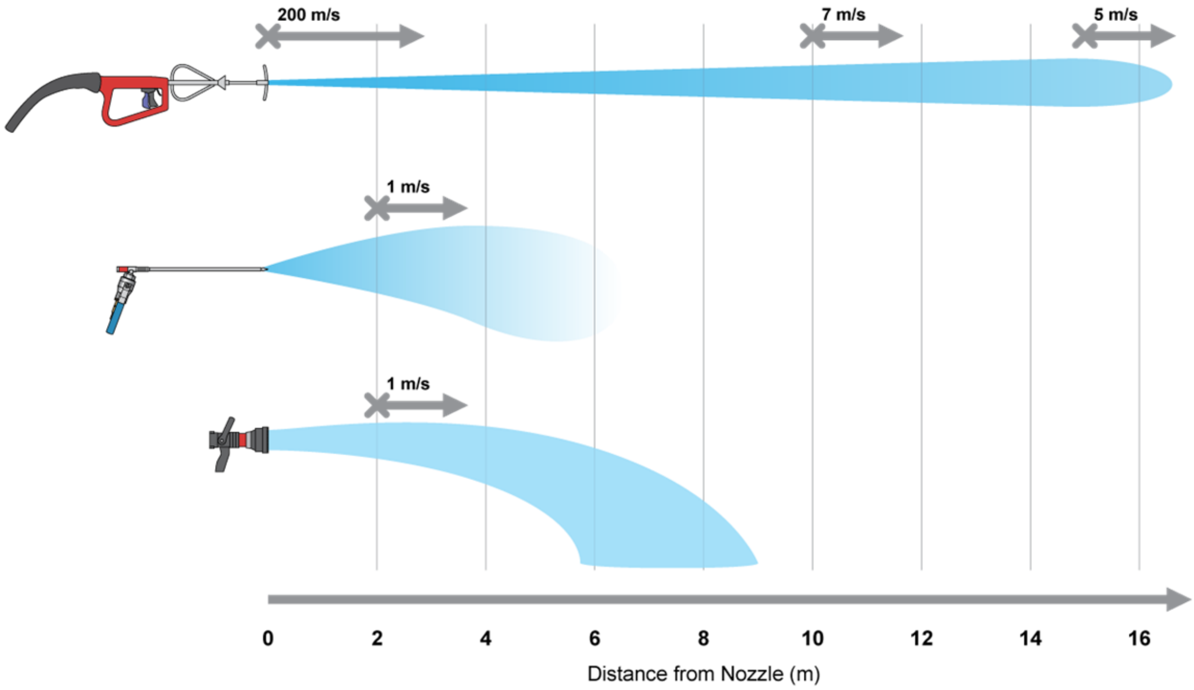

Figure 3 Water jet velocity of different firer fighting tools, adapted from additional tests to (Svensson, Lindström, Ochoterena, & Försth, 2014)

Heat extraction is not the only effect of water mist to fire gases and fires, as Gsell points out. In addition the oxygen depletion, surface shielding (especially with a saline or surfactant additive) and radiation attenuation adds effect. The cutting extinguisher also adds a relatively high velocity to the jet and to the

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extinguishing process – which, apart from making turbulence, carries the water droplets swiftly into the fire room.[16]

If the fire is not situated immediately opposite to the penetrated wall, the continuous use of the cutting extinguisher water jet will soon 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 (positive pressure ventilation), the effect will appear even sooner: the fire will consume the air between the water mist and the fire, eventually sucking in the water mist into the flames and choking itself.

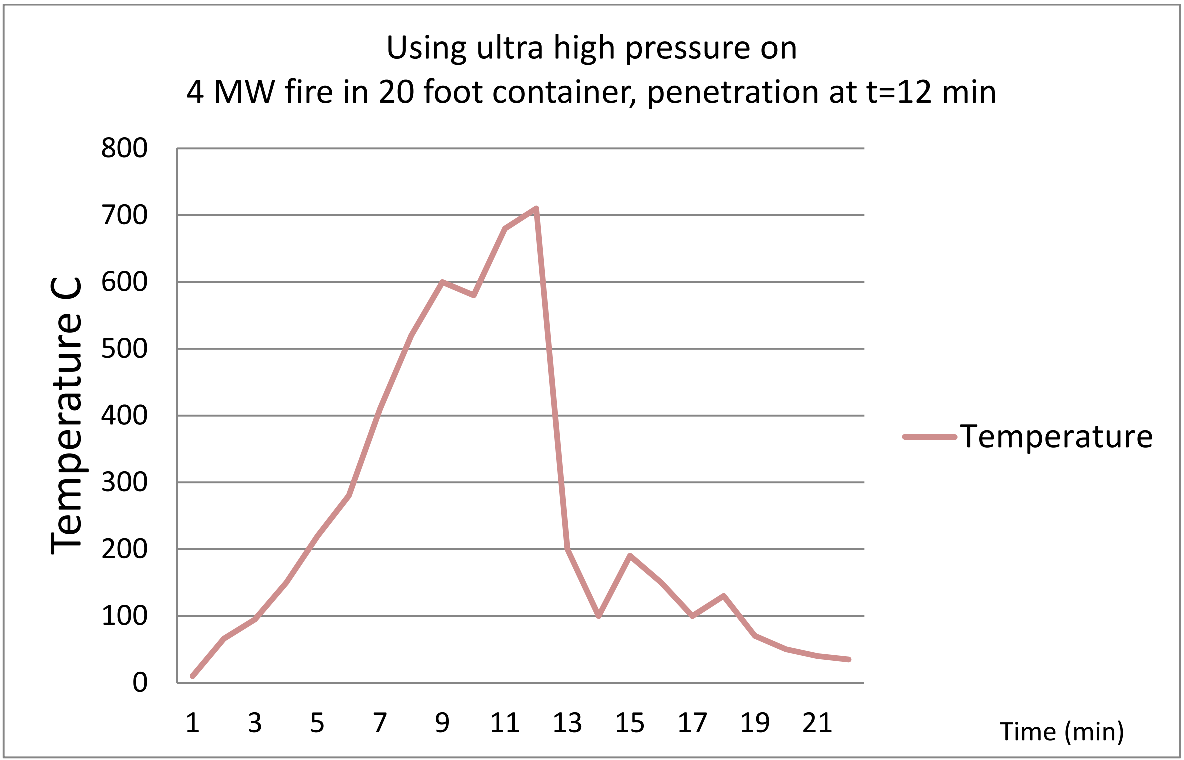

Figure 4 Rapid Temperature Reduction

A typical scenario is a fire room of 75 cubic meters (2.4m x 6.5m x 5.0m) with a 3.6 MW fire (diesel pool of 3.6 square meters). With a fully developed fire, the temperature of the room is approximately 600 C. By applying a 28 liter per minute cutting extinguisher, the temperature will decrease to 100 C in 30 seconds, using just short of 15 liters of water.[17]

[16] (Gsell, 2010)
[17] (SERF in collaboration with SP Technical Research Institute of, 2010)

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The Cutting Extinguisher Method on Swedish Navy Vessels

The cutting extinguishing method is a combined methodology, where the cutting extinguisher is used as a part of the standard operation procedures. The cutting extinguisher should not be viewed as an omnipotent tool that will make other tools obsolete; rather it is tool used to minimize risks for the crew, shorten the time of the intervention, decrease the dimension of loss and thus minimize the impact of both direct and collateral damages.

Fire and Rescue Services in the UK and Sweden use Thermal Imaging Cameras and Positive Pressure Ventilation (PPV) in combination with the Cutting Extinguisher to extract full efficiency of the combined technologies.

The Thermal Imaging Cameras are used to find hot spots and assess the effect of the Cutting Extinguisher. PPV fans are used both to over pressurize adjacent compartments, refraining hot gases to expand from the fire room, as well as ventilating cooled fire gases/steam from the compartment, to make the re-entry procedure more efficient and safe. This combined integrated method, the Cutting Extinguishing Concept, is described by the EU Fire Fight project.[18]

While the Swedish Navy is continuously studying how to become more efficient, minimize time and cost for training, they came up with the idea of a set of Cutting extinguishing Attack Points (CAPs). These attack points are pre-determined intervention points, specially designed for cutting extinguishers.

Figure 5 Cutting extinguisher Attack Point "(S)" at a hatch and "(25)" on deck, photos courtesy Royal Swedish Navy

The CAPs are mapped on DC drawings, numbered from stern to aft, even numbers on port side and shows fire sections of the ship. DCO uses the numbers to give command for cobra attack. On deck and hatches, the CAPs are marked with bright red markings. The markings are placed according to a set of criterions; plausible fire starters, avoiding critical installations, ship construction, accessing and maintaining the CAPs.

[18] (SERF in collaboration with SP Technical Research Institute of, 2010)

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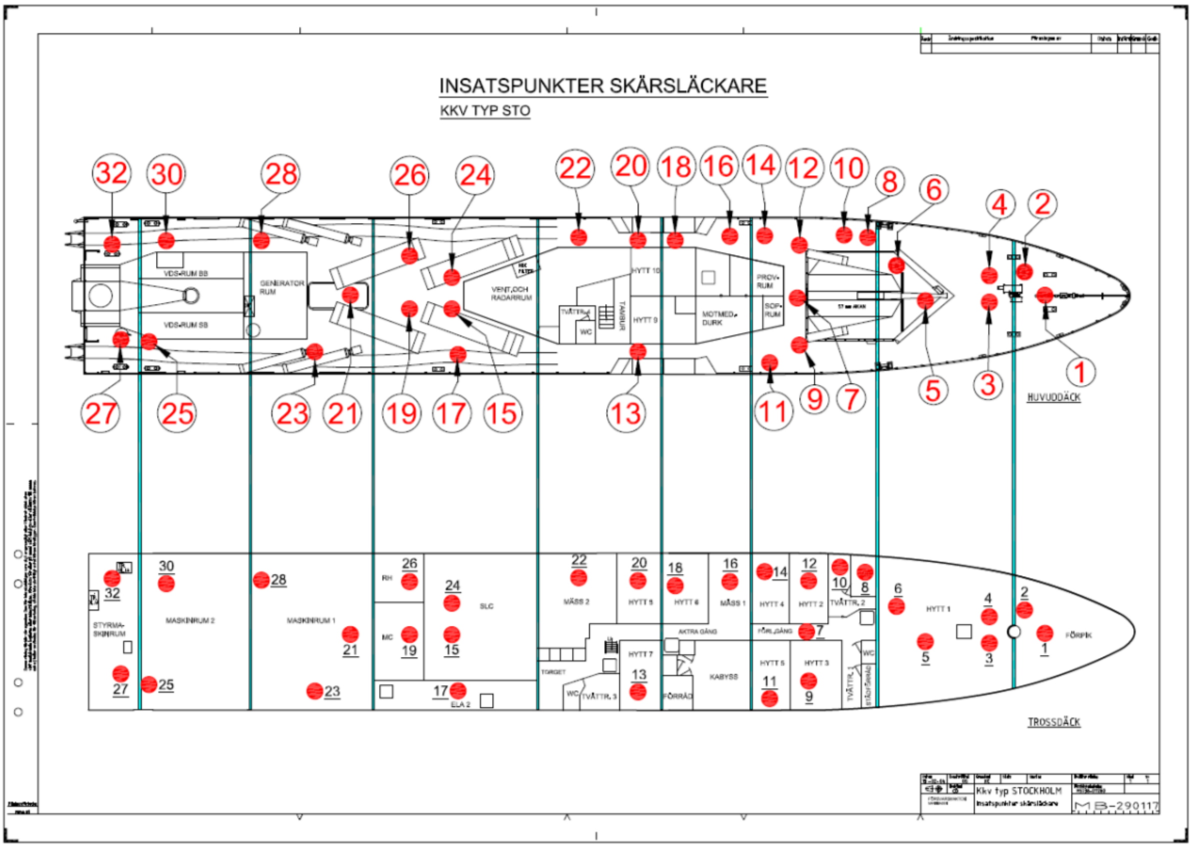

Figure 6 Cutting extinguisher Attack Points schematics on ship outline, illustration courtesy Royal Swedish Navy

If CAPs are not present, the damage control crew is trained to attack through hatches and other construction parts where there is low probability to have obstructions on the opposite side. The cutting extinguisher is trained to be used together with thermal imaging cameras and optical recon of the effect at the target, i.e. change of characteristics of smoke from black to steam. [19]

[19] (Osbäck, Presentation of Swedish Naval Warfare College, 2012)

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Figure 7 CAP adopted by Greater Gothenburg Fire and Rescue Service, illustration courtesy GGFRS

The use of pre-determined CAPs has been adopted by civilian fire and rescue services, for instance Greater Gothenburg FRS at industrial and heritage constructions.

Royal Swedish Navy Shipboard Firefighting enhanced with cutting extinguisher method

In a lean manned mission critical or combat situation, time for letting the fire consume all fuel, or, personnel for boundary cooling might not be available. A premature re-entry procedure could be one of the few options at hand, not to compromise the mission as a whole. However, entering a fire compartment at a stage where the fire is starved of oxygen, could feed the hot fuel-rich gases with a gravity current of cold air, and induce a backdraft. This is one of the most hazardous situations a firefighter could face. In relation to this situation, BA-attacks are considered as one of most dangerous and high-risk occupations in the civil society – which is also valid for naval vessels.[20]

Pre-action preparations and integral training is of essence to combat fires successfully. Preparations also cover structural protection, fixed fire suppressing systems, equipment control, awareness and readiness.

The tactics for shipboard firefighting enhanced with the cutting extinguisher method are initially similar to standard procedures. However, on LWC ships, containment through water consuming boundary cooling is not relevant – the modern sandwich construction itself isolates the desired cooling of the externally applied water. Given the fire zone in question is classified, i.e. is isolated with fire resisting material and having fixed installed fire suppressing systems or other means, there are some time available to suppress the fire prior to constructional damage occur. If the fixed fire suppression systems are breached, or if the actual fire is induced by weapon or accident at an area deemed a low or a non-fire hazard zone, time to suppress and get in control of the fire is even less.

[20] (Carlsson & Lundmark, 2011)

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A shipboard fire on a composite ship is always critical to mission. The fire must be intervened immediately and from the inside, where the fire develops. Using BA-attack in this situation would induce risks and hazards not acceptable, neither by naval standards, nor by the supporting civil society.

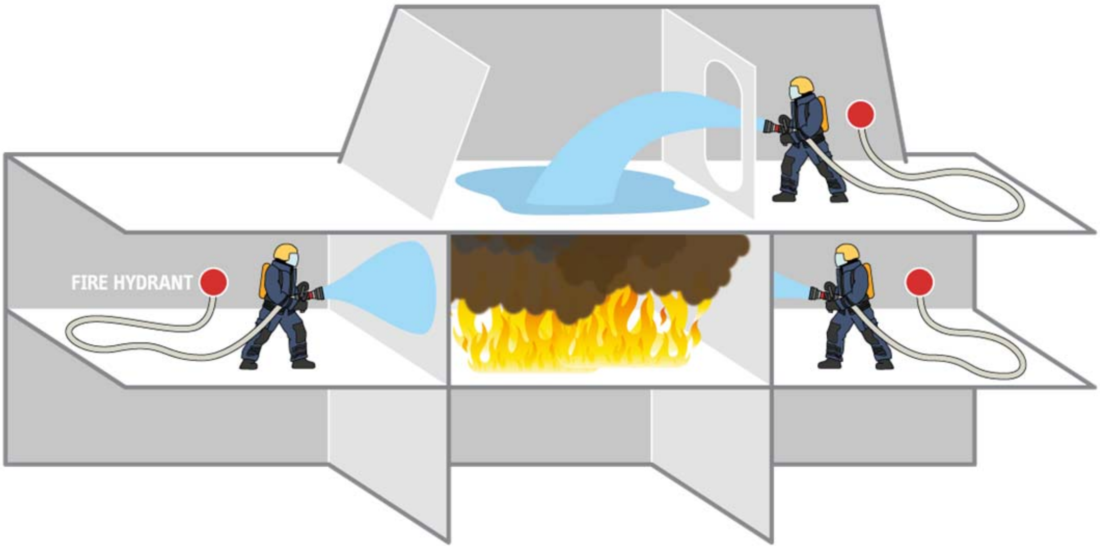

Figure 8 Boundary Cooling, traditional shipboard firefighting

For steel vessels, the rationale of the cutting extinguisher is somewhat different, but the advantages are the same; initially, the fire is fought from a safer position, at an earlier stage than otherwise and with an immediate knock down effect of the fire. The crew numeral involved may be held to a minimum, as could the water use. The redundancy to fixed installed systems of the cutting extinguisher system is the same. The rapid cooling of the fire gases and often complete extinction of the fire, inhibits distortion of the hull, and decreases the risks for BA-crew in conjunction of the re-entry procedure.

As the water mist enters the fire room, depending on the fire situation, it is exposed to the hot fire gases, the radiation of the fire and the actual flames. The energy transforms the atomized water to steam, and in the process consumes the energy and heat. In the process, the steam inerts the fire gas by decreasing the oxygen fraction.[21]

As described above, adding the cutting extinguishing method to the standard shipboard firefighting procedure, some extra preparations had to be made. Since all crew are to be able to handle the cutting extinguisher, the personnel are trained accordingly. To eliminate risks of aiming the hand lance at places

[21] (Gsell, 2010)

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on the deck or bulkheads which have obstacles on the opposite side, *Cutting extinguisher Attack Points* (CAPs) were marked at pre-defined places: a white S on a bright red field[22].

When it comes to procedures, the third action encompasses the cutting extinguisher attack, thus called Second Attack:

1. Early Detection - Alarm
2. Initial Attack - First Attack
3. Containment & Control - Second Attack
4. BA-Attack - Safe Re-entry Procedure[23]

The initial two actions are the same as in standard shipboard firefighting procedures, they are also the same independently whether it is an incident onboard a composite vessel or a steel hull vessel.

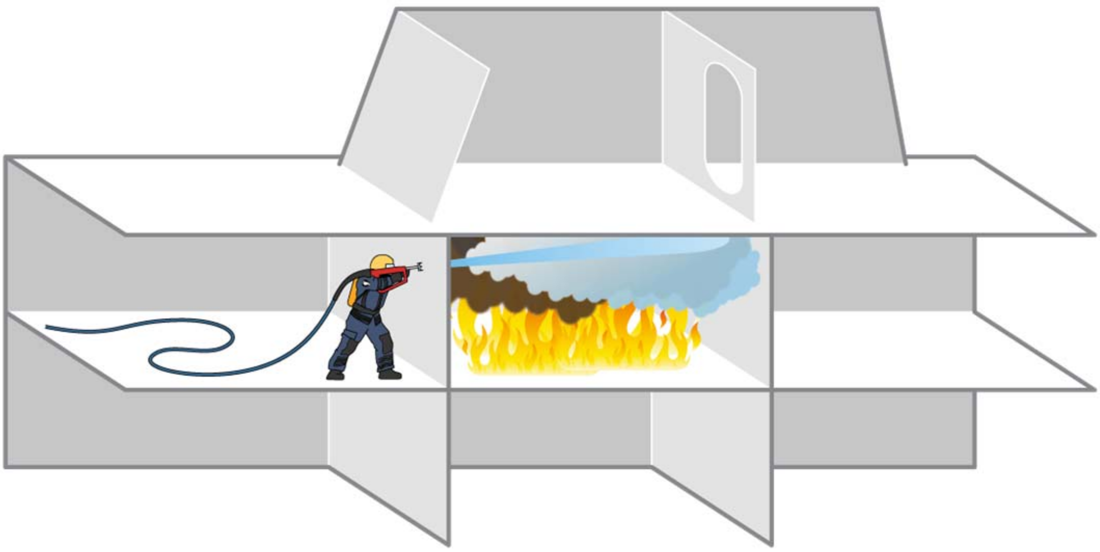

Figure 9 Advantages of the Cutting Extinguisher – "boundary cooling from the inside", applied from a safe position outside

The third step has the cutting extinguishing method included as a first choice or as a complement to fixed installed fire suppressive systems – depending on the assessment of the situation. At the same time, on steel ships, boundary cooling is prepared, but not executed. Boundary cooling is executed on command of the DCO. If the fixed installed fire suppression systems fail, redundant measures are of essence.[24]

[22] (Osbäck, Presentation of Swedish Naval Warfare College, 2012)
[23] (Royal Swedish Navy, 2003)
[24] (Osbäck, Cutting Extinguisher, CAPs and SOPs on Swedish Naval Vessels, 2016)

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Onboard at steel hull vessel, using the cutting extinguisher at pre-defined attack points might well make external boundary cooling and fixed fire suppression systems redundant – making the incident handling less crew demanding, both in numbers and with respect to exposure to danger. It will also reduce the quantity of water needed to control the fire. Since the time from detection to applying the cutting extinguisher method normally is less than mustering crew for boundary cooling, the time for the fire to develop in the exposed compartment is held at a minimum, thus reducing the risk of spreading and impact on the mission as such. The actions taken are generally monitored by thermal imaging cameras or compartment monitoring systems on board.

Figure 10 Cobra Attack – Second Attack onboard Visby Corvette

When fighting fires onboard a composite vessel, the third step includes the cutting extinguisher as well as fixed installed fire suppression systems where available. Boundary cooling from the outside is not an option since the bulkheads and decks insulates both heat and cooling. For composite vessel firefighting, time is even more crucial, since the structure itself has less resistance against heat. Prolonged exposure could result in adding fuel to the fire from the structure, as well as adding structural damage to the vessel at an earlier time frame than on a steel construction.

The forth step, entering the fire compartment, cannot be done in a safe way until the fire has been suppressed or reached its decay stage. Enhancing the firefighting with the cobra cutting extinguishing

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method efficiently decreases the temperature to a comfortable 100C-150C, which enables a safe re-entry procedure. The cutting extinguishing method also enables the forth step to be initiated earlier than otherwise, due to less time elapsed. If the structure has been damaged or skewed, the cutting extinguisher and/or the cutting frame could be used as clearing tool to make way for final BA-attack and damage assessment.

Future developments

The Swedish Navy is studying ways to implement such adopted integrated method; on naval architectural level, in combination with equivalent technologies, such as ship damage monitoring systems and engineered integrated pressurization systems, as well as in procedures. [25]

Some Swedish Fire and Rescue Services are using rather simple thermal probes to read the inside temperature after applying the cutting extinguisher. This would also be an excellent addition in assessing the situation onboard ships, since Class A60 compartments and insulating composite structures would reveal little heat due to conductivity through the construction and for a thermal imaging camera to detect.

Fires on merchant vessels and the use of cutting extinguishers

This short resume of fires onboard ships are mainly based on content of public fire investigation reports. There are at least two major drawbacks on retrieving information from investigation reports:

1. The objective of the reports is in general to look in to the cause of the fires, not into how the fire was extinguished, at least not the particular method.
2. In the case the actual efforts of firefighting are commented, it is primarily looking into how the crew acted in compliance with regulations from the time of fire alarm until the arrival of the salvage company or MIRG
3. The knowledge of the cobra cutting extinguishing method is often not present among the investigators, thus the awareness of the effect or the efficiency of the method is not noticed nor described in the investigation reports. One report names the FRS teams equipped with cutting extinguishers as “Specialist Units” and the cutting extinguisher as a “specialist tool”. As a contrast, the Swedish basic vocational firefighter training includes compulsory cutting extinguishing method training[26]

To complete the understanding of the effect and efficiency of the cutting extinguisher method in these cases, personnel of the firefighting crew has been interviewed.

[25] (Averin & Lindström, Swedish Naval Shipboard Firefighting, 2014)
[26] (Swedish Civil Contingencies Agency)

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Container vessel Yang Ming Green, 2006, Singapore

August 8th 2006, Smit Salvage was called to a fire onboard the container ship Yang Ming Green, 5551 TEU, off the coast of Singapore. As a part of the response team, a crew from Falck Emergency Response Team (previously Falck RISC/Nutec) was deployed. This incident turned out to be the first incident at sea where the Cobra Cutting Extinguisher where used.

The initial explosion spread fire to 28 containers mid ship. On arrival of the emergency response team from Smit Salvage, the firefighting crew members reported that CO_2 had been used and that they believed that the fire had been extinguished. However, this showed not to be the case, since CO_2 would not be able to reduce the oxygen level enough to extinguish smoldering fires. When the salvage team opened the hold, it became apparent that the fire was still going on; it was impossible to enter the hold due to heat, smoke and steam. After ventilating the hold for several hours, the ER team managed to identify the burning containers by Thermal Imaging Cameras and Gas detectors. They also located the seat of the fire in a container storing batteries which had exploded.

Initially, the salvage team was not allowed to cut open the containers with a normal cutting tool and hose down the content, due to time lag to receive required permits from the insurers – a process that would take several weeks.

To minimize further damage and avoiding further fire spread, a barge was ordered, to which the burning containers were evacuated by crane. On the barge, still not being able to open the containers due to negotiating with insurers, each burning container was attacked with a Cobra cutting extinguisher which had been supplied by Smit Salvage from their Singapore base.

Using the Cobra eliminated risks of spreading the fires, as it was used to cool all containers which could then be approached by standard operation. This way to operate saved weeks of work of containing the fire traditionally, awaiting the administration of the insurers. If waiting for the normal procedures to come through, the risk of a greater loss than 28 containers would be obvious.[27]

RO-PAX Vincenzo Florio, 2009, Palermo, IT and Lisco Gloria, 2010, Fehmarn Belt

On Friday May 29th 2009, Ro-Pax vessel Vincenzo Florio had a fire break out at 03.36 about 25 miles off the Sicilian port of Palermo, Italy. The vessel was travelling from Naples to Palermo when the blaze started. The origin of the fire is not determined, but is probable that the fire started in either a refrigerated truck or in a private car. The crew fought the fire until approximately 06.00 when the ships master decided to evacuate the passengers. 516 passengers and 53 crews were evacuated in lifeboats,

[27] (Knegt, 2012)

no casualties reported. After the evacuation of the passengers, the vessel was towed to the port of Palermo, Sicily.[28]

Smit Salvage worked together with the local company SOMAT, which asked Smit to perform additional firefighting as the ship docked alongside. On May 30th, a salvage team was mustered, arriving the same evening. A charter plane with Cobra equipment from Rotterdam arrived the next morning, together with an additional salvage team.

The salvage team started to fight the fire, which was mainly located on one of the car decks. High temperatures and poor visibility made the fire fighting a difficult task. Over a period of 10 days the team worked from one end of the deck to the other, to get the fire under control, using the Cobra cutting extinguisher to kill off persistent fires on the car decks.[29]

The repair works, worth some 20 million euros, should last about 9 months, starting after completion of the judiciary investigations on the damaged vehicles still onboard. They will entail a rebuilding at 25% of the ship (including the hull), while other parts will be simply refitted. [30]

A similar incident was reported concerning the Lisco Gloria on the Baltc Sea. This RO-PAX ferry was *en route* between Kiel, DE and Klaipeda, LT on the 8th of October 2010. A fire broke out on a refrigerated truck on upper car deck just before midnight as the ship was passing the Fehmarn Belt. The drench system located just above the truck was activated manually, but it did not work. A few minutes later, another drench system was activated automatically. The pipework for this system parted where it passed the engine room, causing an uncontrolled flooding of the same. At 00.09 the master ordered evacuation of the ship. At 00.13 Mayday was sent out on VHF16. At 01.15 all passengers and crew were evacuated, except for 13 crew. Fifteen minutes later, all 235 souls had abandoned ship.[31]

The fire spread through the car decks and the entire superstructure, causing a total loss at 450 million DKR (€60 000 000).

M/V Charlotte Maersk, 2010, off Port Klang, MY

At 21.19 on July 7th 2010, a fire broke out on the Danish vessel M/V Charlotte Maersk, 8160 TEU, off the coast of Port Klang, Malaysia. Some 160 containers on board took 11 days to bring under control and finally extinguish

In the Marine Accident Report, The Danish Maritime Accident Investigation Board came to the conclusion that the fire most probably originated from a container with methyl ethyl ketone peroxide

[28] (SP Fire Technology, 2010)
[29] (SMIT Salvage, 2009)
[30] (Scorza, 2010)
[31] (Federal Bureau of Maritime Causalty Investigations, 2012)

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(MEKP) in bay 23. In the proximity were four other IMDG containers, three containers of calcium hypochlorite and one with Trichloroisocyanuric acid.

The firefighting organization and the crew were very well drilled onboard the Charlotte Maersk, which lead to a wide variety of safety decisions and measures were taken within an immediate timeframe after the fire broke out. Immediately after the initial fire, the ship was turned 50 degrees to starboard to get side wind; thus limiting the heat traveling through radiation and conductivity and having the smoke to the port side. Going through the manifest, a container with LPG was in located on deck on bay 30. Thus, within the hour of the accident, a boundary cooling effort was set up at bay 26 as delimitation line.

The firefighting effort onboard continued throughout July 9th with assistance of three Malaysian Coast Guard vessels with small monitors as well as a larger tug. A Malaysian Coast Guard firefighting aero plane was dismissed in the morning of July 8th, as it did not have any effect on the fire.

On July 9th, at 19.00, firefighting teams from Switzer Salvage (today A) arrived and relieved the crew. The teams brought additional firefighting equipment, including a Cobra cutting extinguisher. The boundary cooling efforts were kept up for the coming week, while nearby containers were cooled and extinguished by various means.[32]

Following the present tactics these hot containers in the boundary are to be “drowned” i.e. filled up with water. To separate the hot from the not yet affected containers. The usual practice is to make a hole with a burning torch in the side of the container just under the roof. The hole must be large enough to put a hand line nozzle into.

“With the Cobra we could directly and efficiently cool down a number of containers with good result. Especially containers with goods stowed in a way that sufficient volumes of free space would be effectively cooled with the Cobra. For solidly packed containers with materials like textile, etc., giving no free space for gas cooling, the practice of drowning with vast amounts of water seems to be the most efficient method.”[33]

MSC Flaminia, 2012, Atlantic Ocean – Wilhelmshaven, DE

At 08.04 on July 14th, 2012, an explosion occurred in hold 4 onboard MSC Flaminia *en route* from Charleston, NC to an scheduled arrival on the 16th of July to Antwerp; BE. The position of the ship was mid Atlantic Ocean, approx. N48.14, W27.58. The explosion caused the death of three of the crew. Prior to the explosion, the crew had tried to extinguish a fire in the same area as the explosion occurred. Due to incorrect installation of the CO_2-system, CO_2 was released in the engine room at the same time as in the cargo hold. This caused loss of engine, which was not reclaimed until the master called abandon ship.

[32] (Danish Maritime Accident Investigation Board, 2012)
[33] (Nater, 2010)

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The explosion was believed caused by 54 tons of destabilized divinylbezene in three tank containers in hold 4.

Since the ship was abandoned, and consequently was not in the distress context of saving lives, according to the SAR Convention, several EU-countries declined the stricken ship safe harbor. The politics delayed the ship to come alongside for at least a month, whilst still on fire. Finally, Germany, the flag state of the ship, granted safe harbor in Wilhelmshaven, DE. With reference to 2009/17/EC, the flag state acquired permission from several states to tow the ship through the English Channel to Wilhelmshaven. She arrived, still on fire, on September 9th 2012. As the BSU points out, the complex legal situation, encompassing the SAR Convention, IMO 949(23), IMO 950(23) and 2009/17/EC, has several loop holes.

Figure 11 MSC Flaminia at Wilhelmshaven, DE; photo courtesy Havariekommando

The vessel operator, NSB, awarded the salvage contract to Dutch Smit Salvage on the same day. Smit Salvage reached the stricken vessel with three tugs between the 17th and 21st of July. Due to weather conditions (winds at 6 Beaufort or more, >27 m/s), the salvage operations on board was discontinued for more than 21 days. From the 29th of August, the salvor was permanently on board the stricken vessel.

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Onboard the vessel, personnel from the salvor restored the shipboard power to supply the ship's fire pumps and to set up a water shield between bays 50 and 54 in front of the superstructure. When the superstructure was secured, they worked forward to identify and extinguish single hot spots. For this purpose, they used a Cobra cutting extinguisher supplied from Rotterdam. According to the BSU, the salvors also used a cutting frame with the cobra to cut ventilation openings.[34]

When the stricken vessel finally arrived on the 9th of September to the new deep-water harbor in Wilhelmshaven, singular fires were still present, especially in holds 3 and 7. The firefighting duty were handed over from Smit Salvage to the maritime incident trained Fire and Rescue Service of Wilhelmshaven, deployed through the Havariekommando[35]. The Havariekommando had previously invested in five Cobra cutting extinguishers, which are placed at five MIRG's at fire and rescue services along the North Sea and Baltic Sea coast lines, of which Wilhelmshaven is one.

The Wilhelmshaven FRS continued the firefighting on board the ship, localizing persistent smoldering fires. The content of the containers still on fire were in general of fibrous fires, such as paper pulp. The temperatures were often more than 1000C. To prevent the fires to re-ignite, an encapsulating agent was mixed with the water. However, the area of operation was severely contaminated, so to relieve the personnel from the duty, fognails were used for prolonged times.[36] This of course contributed to the 35000 tons of contaminated water that had to be pumped out and transferred for proper disposal.[37]

Fishing trawler Johanna Maria (SCH118), 2014, Scheveningen NL

At approximately 08.45 on Monday the 23rd of May 2014 a fire broke out onboard the fishing vessel Johanna Maria at Scheveningen Harbor in the Netherlands. The Johanna Maria is a 6500 ton, 120 meter trawler.

The fire was caused by hot work onboard, while the vessel was alongside for maintenance and over haul. During work with a blow torch on port side on the tween deck (deck below weather deck), under the superstructure, a pressurized (140 bar) hydraulic line bursted in the immediate proximity of the torch, and there was a rapid growing fire. The worker was injured, but managed to get away from the fire.

At the time of the fire, 85 workers and 13 hired firemen were onboard the vessel. The firemen were hired through a private company to de-risk the hot work. They were equipped with portable extinguishers, but had no fire truck or breathing apparatus available. One firefighter was supervising the blow-torch work, and immediately tried to extinguish the fire with the means available. However, the heat and the smoke from the fire had him to retreat from the scene. The hydraulic oil keeps on spraying

[34] (Federal Bureau of Maritime Causalty Investigations, 2014)
[35] In English: Central Command of Maritime Emergencies (CCME)
[36] (Tober, 2013)
[37] (Federal Bureau of Maritime Causalty Investigations, 2014)

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until the system reaches atmospheric pressure. In the surroundings of the fire, a lot of combustible materials are present, adding to the fire load. Meanwhile, the ship was evacuated.

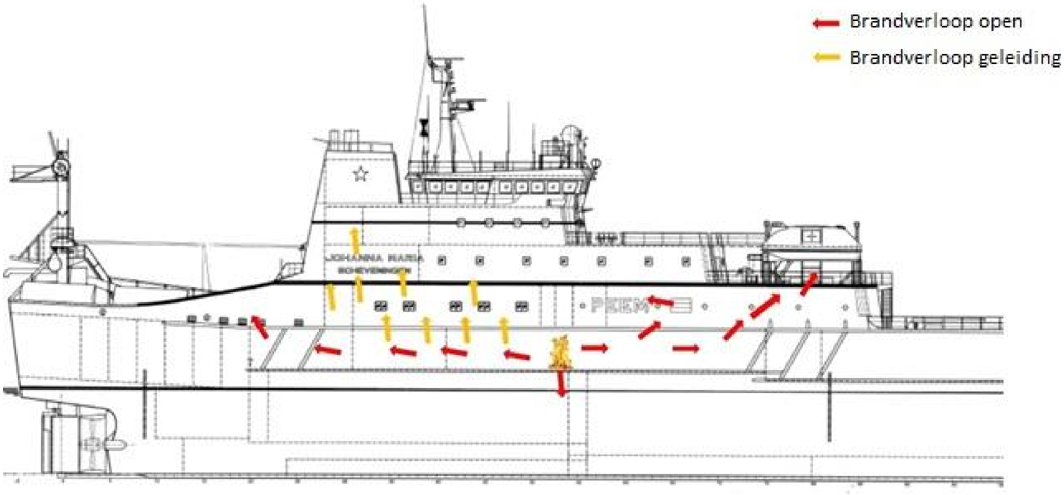

Figure 12 Spread of fire onboard the Johanna Maria: Read - openings, Yellow - conductivity

At 08.54, a 112-call was made to the joint control room of fire services Haaglanden and Holland-Middens reporting on a severe fire onboard the Johanna Maria. Several fire boats are called to the scene; a tug from Rotterdam-Rijnmond FRS and two smaller vessels from the Coastguard and the Dutch Navy. These vessels used monitors to cool the side of the ship, especially around the fuel tank. Two tenders arrives from Scheveningen Fire Station and gets reports that one person is missing. Both teams do breathing apparatus search and rescue operations on deck 0 and deck -1. They have to retreat due to heat and smoke. They also find out that due to maintenance, a lot of hatches in bulkheads and on decks are open and/or removed. At 09.07, while preparing for a second search and rescue operation, the commanders of the FRS receives message that no one is missing, all are ashore except for four people on the bridge.

At 09.30, the incident commander of the FRS receives information that the trawler is equipped with CO_2 fixed firefighting equipment and decides that this equipment should be used. However, it was not known to the decision makers that the CO_2-system was only available in the engine room at the time of decision. But because of all open doors and manholes, due to maintenance, the incident commander decided to carry out the CO_2 extinguishing anyway, hoping the CO_2 would transfer to other all compartments. In order to have effect, the hatches on the weather deck should be closed. Since the hydraulic is out of order on the trawler, a crane is ordered by the ship owner to do the job. It arrives at 10.08. At 11.45 the CO_2-systems was activated, but had no effect. It later showed that the CO_2 installation did not work at all because there was no emergency power for the CO2-system available.

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During the time from the arrival of the fire service, no other firefighting measures were taken, except for the CO_2-attempt and the cooling from the fireboats on the side of the trawler.

Meanwhile, a fire vehicle with a Cobra cutting extinguisher and a Maritime Incident Response Group (MIRG) from Rotterdam-Rijnmond FRS is ordered. They arrive at 11.09 but have to wait for the CO_2-effort. At 11.45 they start to cool the Tween deck. The goal was to set up a delimitation line between the superstructure and the insulated freezers mid ship. This area contained vast volumes of combustible insulation material, and it was of great importance to keep the fire away from this area. However to heat is immense and they have to shift teams every ten minutes. The MIRG requests that additional Cobras are sourced from Amsterdam-Amstelland as soon as possible. The Amsterdam units had been ready to go since 09.30 when they first were advised that the fire had broken out. In fact they had called the command central several times during the day, to aid in the situation. Finally, at 15.01, two Cobra vehicles arrive with police escort from Amsterdam.[38]

Figure 13 Cobra Cutting Extinguisher applied by Amsterdam Amstelland Brandweer from an aerial ladder on the SCH 118

[38] (Brandweeracademie, 2015)

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After briefing, the two Amsterdam cobra units were deployed on boat deck (0) and upper deck (+1) while the Rotterdam cobra unit continued the delimitation work on tween deck (-1). The delimitation work created large volumes of steam emerging from an opening between tween deck and the levels above, making it impossible to continue with the work on boat deck and upper deck.

Instead the Amsterdam crew regrouped to an aerial ladder on the dock, using one cobra unit from the forward part of the superstructure, moving aft in steps of approximately 2 meters at the time, cooling off/extinguishing each compartment. When reaching the aft part of the superstructure at boat deck level, the Amsterdam team attacked the upper deck above in similar way, moving forward. At approximately 18.30, the fire was extinguished. It took another 24 hours for the construction to cool down.[39] The ship was later declared a total loss.

During the incident, several entities were engaged; the ship owner, the maintenance workers, the privately hired firemen, the local FRS, Rotterdam FRS, later Amsterdam FRS. In addition fireboats from the Coast Guard, the Navy and Rotterdam were working at the scene. From the report one can deduct that there was not a clear chain of command set up, thus the actions were hard to coordinate. Each singular action cannot be monitored in a strict hierarchal fashion of course, but the top management must have a feedback line of intel for situation awareness and to decide on tactical and strategical actions.

The fireboats and tug were in principle working on their own flooding the ship, eventually causing a list. The bilge pumps were believed to be working, but showed not. The understanding of the CO_2-system was not clear to the incident command. The supporting Navy vessels didn't have radio communications with the commander of the incident. In essence, the supporting units from the different FRS where not coordinated, but worked separately (although professionally) once they were engaged.[40] The evaluation report of the fire concludes that, even though the multi-regional joint firefighting scenario was not practiced in a scenario exercise nor the strategic command worked properly, the professionality of the fire service units and the tactical command definitely were an important basis of the success of extinguishing the fire.[41]

Dieppe Seaways, 2014, Dover, UK

The Dieppe Seaways is a 30500 GT, 204 m LoA, 1200 passenger, 110 semi-truck, RO-PAX, vessel on regular 90 minute service between Dover, UK and Calais, FR. All times are reported in ship time, i.e. CET. This made some confusion in the later reports, since most of the action took place in the UK, using GMT.

On May 1st 2014 she departed Calais at 11.30. At 12.31 an alarm sounded on the ships fire detection system, it was a smoke detector on deck 9 on the port boiler room that had gone off. The cause of the

[39] (Butter, 2016)
[40] (Brandweeracademie, 2015)
[41] (Duin & Wijkhuis, 2015)

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alarm was investigated; a light haze in the compartment was reported. The boiler room extended down to deck 7. At 12.36 the boiler room ventilation was shut and a few minutes later the chief engineer reported that there was an uncontrolled fire in the furnace in the boiler room. The master had already required priority entry to Dover port, and now requested Kent FRS to meet up alongside on arrival. At 13.08 a 15 kg fixed installed powder system was activated in the port boiler room. Apparently, it had little effect on the fire. At 13.21 the ship berthed alongside in Dover. The 365 passengers were evacuated before the FRS was embarked.

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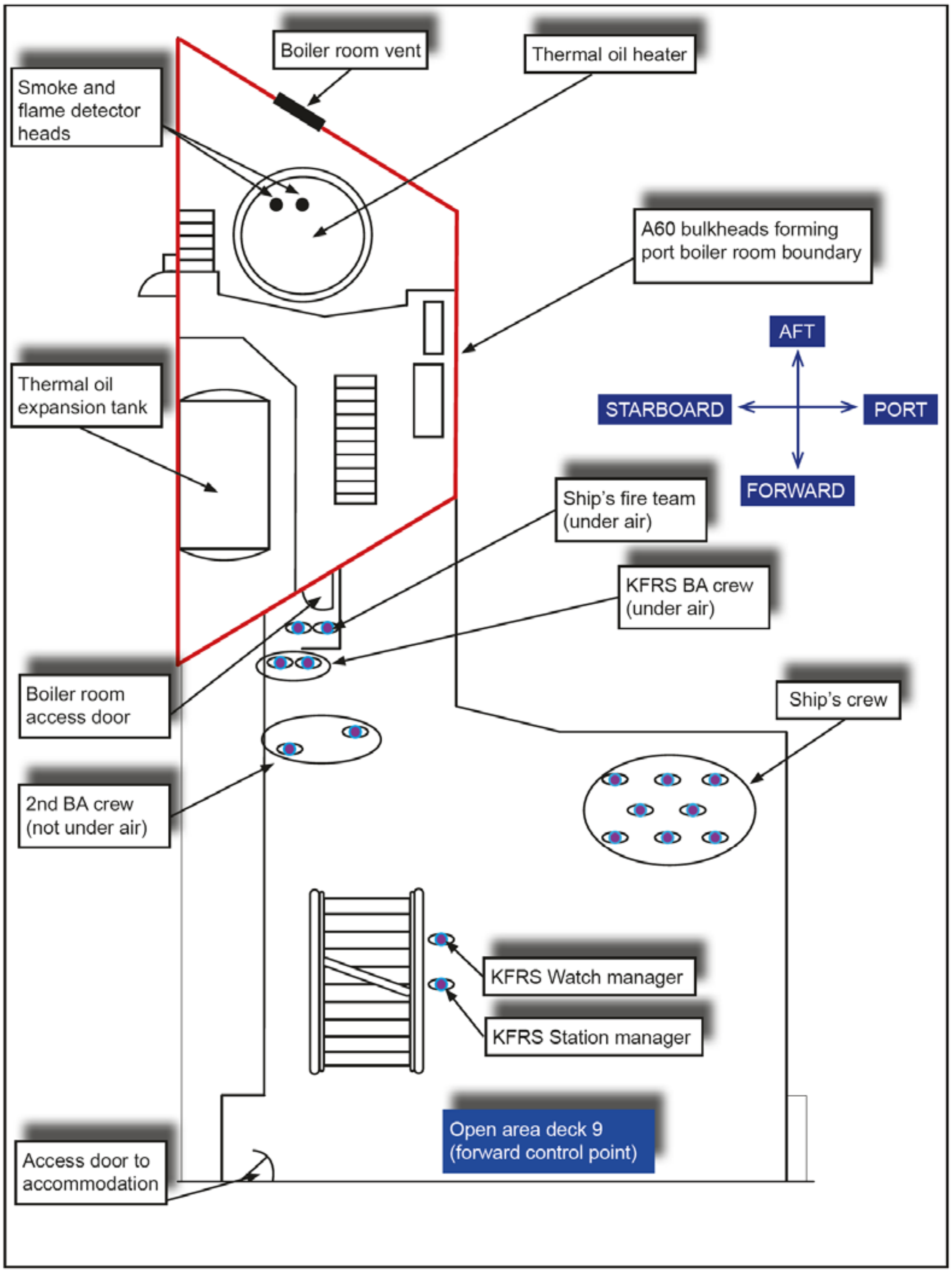

Figure 14 Diagram of location of port boiler room and personnel at the time of fire ball. Illustration with courtesy to MAIB

A forward control point was set up by the Kent FRS adjacent to the entrance of the port boiler room at deck 9. Monitoring the exhaust gas temperature from the furnace, it became apparent that the temperature had risen from 280 C to 340 C between 13.25 and 13.41. Not known at the moment, there

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was a leak of oil into the furnace. It later showed that the hatch of the furnace was not shut properly and that heat from the uncontrolled fire was emerging through the open hatch into the boiler room at deck 9.

As it still remained the understanding that the fire was restricted to the furnace, the joint groups prepared and effort to extinguish the fire: two ship's crew prepared to open the code lock of the entry to the boiler room, while four Kent FRS crew prepared hand held extinguishers. Just before 14.20, the door to the boiler room was opened. When the door was opened, an unexpected fire ball swept with immense force across the forward control point, knocking a number of personnel to the deck. 6 ferry crew and 4 KFRS personnel needed treatment, of which 3 were transferred to burns center.

The back draft situation was contributed by several reasons:

- There was an understanding that the fire was contained inside the furnace. A similar incident in 2009 had left the crew with the understanding that this incident was of the same case. This information had been passed over to the Kent FRS
- The smoke and fire detectors inside the compartment had not gone off – they had been destroyed by the immense heat emerging from the not latched furnace – this had probably been left unlatched unintentionally when the fire was checked upon prior to berthing. This had prohibited the fixed installed high pressure water mist system to automatically engage
- The ship's chief engineer's previous experience of a similar incident lead to preconceived conclusions on the actual situation
- The communication between the ship master and the Kent FRS was not set up properly. All relevant information present, was not at hand for the decision makers, thus the initial risk assessment was not duly made by the FRS
- The use of thermal imaging cameras did not reveal the actual situation since the compartment was an A60

After the backdraft, the fixed installed water mist system was engaged manually. This had no significant effect according to the exhaust temperature monitoring. Efforts to use the pipe works for the dry powder system to inject foam was made. Due to clogging of the pipe works, it did not have much effect. In parallel, boundary cooling of the compartment was arranged. These actions took approximately 3 hours, due to communications between the stake holders, a FRS shift change and clearances. The MAIB reports states that none of the actions had any significant effect on the fire[42].

At approximately 17.30, one of the Kent FRS firemen suggested to use the cutting extinguisher provided on their fire trucks to cool the boiler room. This idea was championed by the FRS management. However, to receive permissions to "cut hole in the ship" needed some negotiations. Finally at approximately one hour later, the cobra intervention could commence. The cobra was operated actively

[42] (Marine Accident Investigation Branch, 2015)

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for approximately 45 minutes, according to the first Marine officer on bridge of Kent FRS. During this time, the temperature monitoring of the exhaust of the furnace dropped significantly.[43] At 21.15 the compartment was deemed safe to enter according to ship's master and at 00.51, the fire was confirmed extinguished.

Reference cases on shore

For reference purposes, two on shore incidents are described below. They represent incidents on the far ends of the implementation of the Cutting Extinguisher Method; one high-end large volume industrial fire, and one "normal" domestic house fire.

Industrial Fire, Corby, Northampton shire, UK

The Northampton Fire & Rescue Service serves Northampton Shire situated in mid-south England. The shire has 700 000 inhabitants and an area of 2400 km^2. The FRS has 22 fire stations with 23 cobra cutting extinguishers. They have operated cobra cutting extinguishers since 2006.

On March 24th 2011 a fire broke out in an industrial complex in Corby, Northampton Shire. The site of the incident housed development, manufacture and packaging services for pharmaceutical, biotechnology and consumer health companies. The property is approximately 100 meters by 100 meters, divided into five main sectors. The seat of the fire was in a 30 meter by 30 meter sector, used as a high bay warehouse, situated in the middle of the complex.

The cause of the fire was accidental ignition of sandwich panels during maintenance hot work, welding. When the fire and rescue service arrived, flames already came through the roof.

Initially, three aerial ladders with monitors were engaged; however, as the roof was more or less intact, most of the water ran off, causing collateral and environmental damages. The monitor action was soon aborted. At this moment, the building was believed to be lost.

[43] (David Brown, 2016)

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Figure 15 Industrial fire at Corby; initial situation and after incident; photos from (Emberson, 2013)

The just arrived incident commander decided, based on a scenario exercise on a similar case he had recently attended, to use multiple cutting extinguishers in a dual purpose action; to cool hot fire gases and simultaneously boundary **cool** the four walls of the compartment of the fire. Multiple positive pressure ventilators (PPV) pressurized the four adjacent sectors to keep hot fire gases inside the original sector. The action was continuously monitored by thermal imaging cameras, both inside and outside of the construction. The multiple cutting extinguisher attack was continued for two hours.

The fire was extinguished in 12 days, and the fire service could leave after 28 hours. Although the roof as completely burned off of the original sector; the four adjacent sectors were saved. Offices, production lines and unaffected warehouse could be reclaimed by company within 48 hours.[44]

Domestic House Fire, Halmstad, SE

The Halmstad Municipal Fire & Rescue Service serves Halmstad county situated in south east Sweden. The county has approximately 100 000 inhabitants and an area of 1000 km^2. The FRS has 6 fire stations with 4 cobra cutting extinguishers. They have operated cobra cutting extinguishers since 2009.

In March 2011, a fire broke out in a domestic house in the city of Halmstad, SE. The fire originated in the living room, close to the TV-set. The family evacuated immediately and called the fire service.

During the FRS approach it was confirmed that the entire family had left the building. Smoke is coming out from the eaves and vents. On arrival, the incident commander and the BA team leader scans the house from the outside with a thermal imaging camera to evaluate the situation and to do risk assessment. After the scan, the BA team leader leads the cobra attack, continuously scanning the building. After 3 minutes of cobra engagement, the turbulent black hot smoke has turned into slow flowing white steam and the building is deemed safe to enter. At this moment, the driver has prepared hoses and the BA-crew is ready to enter. Supported by PPV in the back to clear out steam through a broken window on the opposite side, the BA-crew extinguishes remaining fires and embers. The house is scanned on the inside for hidden fires with thermal imaging cameras. 8 minutes into the incident, and with 180 liters of water used, the house is reclaimed and the fire is out. The FRS can leave after 16 minutes.[45]

Summary and discussion of incidents

Cross discipline learning is crucial to reach high efficiency in introducing new technology and methods. This paper will describe and illuminate the experiences, procedures and methods from fighting real fires on-board ships using the cutting extinguisher and its method. It will also conclude in lessons learned from the actual incidents.

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[44] (Emberson, 2013)
[45] (Nielsen, 2012)

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Would a cutting extinguisher, with a trained operating crew, ready at hand on board the ships make any difference in preventing the course of the events or at least limit the damage?

Container vessels

The three incidents with the *container cargo vessels* all started with explosions, due to destabilized chemicals in the holds. Obviously, the root problem is of a dimension that must be handled at another level. No onboard method or tool, with however excellent trained personnel would be able to mitigate such explosions. However, hindsight of the explosion, the salvors all used cobras to limit further damages. On the Charlotte Maersk and the MSC Flaminia, the salvors used the efficiency of the cobra where applicable – on containers which could be gas cooled, i.e. containers with a feasible space suited for gas cooling. On the MSC Flaminia, the salvor used the cobra to cool and extinguish containers while the political issues of safe harbor were resolved. On the Yang Ming Green, the salvor used the cobra to circumvent the normal time frame to get insurers' permits to proceed to open hot containers with a cutting torch and drench them. Instead the containers were lifted on to a barge, where the cobra could cool the containers to a temperature level where permits were not necessary. This method would of course not be possible, less the salvors were completely knowledgeable and proficient of the efficiency of the cutting extinguisher.

RO-PAX vessels

The three incidents concerning RO-PAX vessels had two different origins of the fires; The Vincenzo Florio and the Lisco Gloria fires started in a single vehicle on car deck, while the Dieppe Seaways origin was in a boiler furnace on the port side decks 9 through 7. The courses of the events of the car deck fires were somewhat different. On the Vincenzo Florio, the crew fought the fire for three hours before the master decided to abandon ship. There were no reports on malfunctioning fixed installed firefighting systems. On the Lisco Gloria, the fixed installed firefighting system on the car deck not only failed, it was installed improperly, causing the engine room to be flooded, resulting in loss of engine. One should bear in mind that vehicles are constructed in a similar fashion as houses; they are designed to keep rain on the outside. A working sprinkler system would therefore not extinguish a fire in a vehicle on car deck, but it would probably reduce the acceleration of the spreading of the fire. This is probably the difference between the outcomes of these two incidents.

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Figure 16 Vincenzo Florio at Palermo (2009) and Lisco Gloria at Fehmarn Belt (2010)

In essence, this made it possible for the salvor to enter the car deck on the Vincenzo Florio once it was alongside in Palermo, to fight off the fires in the vehicles using the cobra, and finally save 75% of the property, at a loss of €20 000 000. The Lisco Gloria was a 100% loss, at €60 000 000. Johan Luijks, one of the contracted salvors of Yang Ming Green and Vincenzo Florio, later said that if there had been a cobra onboard the Lisco Gloria, the fire could have been limited to the truck that originally caused the fire.[46] This was also one of the driving facts for the German Havariekommando to invest in five marine cobra units in 2011 for their MIRG's operating out of five coastal cities in the Baltic Sea and the North Sea.

The Dieppe Seaways incident originated from an oil leakage in a boiler furnace. As the situation evolved, the fire spread through expansion of hot fire gasses from the furnace into the surrounding compartment. The situation deteriorated due to preconceived conclusions of the ship's chief engineer, lack of or misinterpreted liaisons between the ship master and the command of the FRS. The situation prior to opening the door was not assessed properly. If the risk of back draft had been on the agenda, one would probably not been content with the dry power action and one would probably had checked whether the fixed water mist system had been activated automatically – after all, water mist is the best extinguishing media to mitigate risk of back draft.[47]

However, immediately after the backdraft, proper liaisons were set up, thorough risk assessments were made and evaluations of available actions were done. In the course of this work, it became apparent that the automatic function of the fixed high pressure firefighting had not gone off. This was engaged manually, but did not have significant effect based on the monitoring of the exhaust temperature from the furnace. Eventually, a firefighter suggested that the cobra should be used, which, when finally engaged, showed significant temperature drop of the exhaust temperature. Again, suggesting and using the cutting extinguisher at this situation, requires knowledge and understanding of the efficiency of the

[46] (Luijks, 2011)
[47] (Gottuk, Peatross, Farley, & Williams, 1999)

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cutting extinguisher method. Of course, if the cobra would have been used prior to opening the door to the boiler room, the back draft accident would have been prevented.

Fishing trawler

There are some similarities between the Dieppe Seaways and the Johanna Maria incidents; both had fires involving oil leaking under pressures and both had local FRS engaged in the alongside firefighting. Both incidents had fixed firefighting systems that failed. However, when the situation deteriorated, the paths of the two incidents took different ways. For the trawler incident, the notion of the situation, a couple of hours after the failed CO_2 activation, was described in the Brandweeracademie report as the fire was playing a “cat and mouse game” with the crew.

In the aftermath considerations, the Brandweeracademie report states that the incident was complex and chaotic as well as complicated and in need of specialist expertise.[48] The IFV report, on the other hand, credited the fire service for the professional work that actually was the basis of the successful outcome in fighting the fire – even though lack of strategic leader ship. One of the suggested actions on the action list was to introduce scenario exercises on the strategic level, to keep the organization on top and to reveal shortcomings, be it logistical, political or others.[49] The tactical method used and the witnessed outcome, described by the Amsterdam Cobra Unit commander, complies with the *de facto* Cutting Extinguisher Method used elsewhere (see for instance “The Cutting Extinguisher Method on Swedish Navy Vessels”, page 10 or “Reference cases on shore”, page 28).

However, a nautical nation, such as the Netherlands, have abundant expertise and knowledge in fighting shipboard fires “in house”; it is just not compiled, coordinated and made available for appointed fire services.

Conclusions

The cutting extinguisher method has showed great benefits in the cases were there was a cobra moment, i.e. a contained or semi contained space with relative high temperature fire gases. There is a higher level of achieved benefits, when the knowledge of the capabilities are known to the strategic decision makers, that is understanding when in the firefighting process the cobra should be used.

We have seen incidents where the cutting extinguisher have been used in various types of fires; contained and semi contained fires, hidden or concealed fires, fires out of reach for fixed installed firefighting systems, and large volume fires with multiple-use of cutting extinguishers. Timing is of essence to get the most effect out of an intervention with a cutting extinguisher; when to introduce the cutting extinguisher in the fire development process and what to do with the window of opportunity the cutting extinguisher provides.

[48] (Brandweeracademie, 2015, p. 41)
[49] (Duin & Wijkhuis, 2015)

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One could speculate in what the outcome would have been if the cutting extinguisher had been available and used in an earlier stage of the Ro-Pax incidents described: if the concealed fires on the vehicles could have been extinguished in a situation prior to deterioration, if the cutting extinguisher would have been used prior to opening the door to the boiler room on the English Channel ferry or while. Similarly, what would the outcome had been with the fishing trawler fire if the cobras would have been used in an earlier stage not only to set up a delimitation to the freezer areas, but to cool the fire spreading through the decks from the original seat of fire. This could have been done if the Amsterdam cutting extinguishers would have been at the scene while waiting for the CO_2-activation.

Although the incidents presented are relatively few, and cannot be described as a statistical significant sample, they show a number of issues that are worthwhile discussing with respect to risk assessment and application of method.

- Knowledge, training (exercise) and capabilities
- Thinking outside of the box
- The importance of redundancy

Knowledge, training (exercise) and capabilities

No method or technology will do the job out of sheer existence. An organization cannot acquire a resource, in terms of ability, without knowing how to operate the resource, tactically and strategically. In the examples above, we have seen a number of incidents that turned out with various levels success. One common denominator of a high grade of success, independently of process or operation, is how well trained the operator, the crew or the organization is.

The understandings of the intrinsic abilities of a certain action or a process enables the decision maker to effectuate measures accordingly, or even beyond the known limits. On the bottom line, in order to act together as a group in a real situation, the conditions of an authentic situation have to have been practiced and exercised.

Municipal fire and rescues services have the advantage of being specialized in their trade, they fight fires. And they often have a lot of time to practice, both on staged fires and real ones. This becomes most apparent in the cases where the command level is exercised and the operators are trained together; such as the (well chosen) municipal fire service cases. On the trawler incident, the cobra crews from Amsterdam and Rotterdam showed professionalism in their part of the incident, and even if their superiors didn’t understand what they were doing, they made a difference in the outcome.

A crew member of a naval ship is a jack of all trades in comparison to the municipal firefighter. The firefighting is a secondary activity for a sailor, with limited time to practice and yet even more limitations to face real fires. On the other hand, the knowledge base that is contained with the fire and rescue service is public domain. And there are ways to migrate and adopt their knowledge and capabilities to naval settings.

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Thinking outside the box

Professionalism requires a given level of understanding of the method. Only when this level has been reached might a certain grade of creativity be appropriate as a leverage to solve unorthodox problems.

In the case of Yang Ming Green, the salvors found a way to commence their work in advance of required permissions, since they understood the capabilities of the cutting extinguisher and could use this to navigate through the archipelago of regulations.

In a naval setting, the creativity should probably be intrinsic to the method developed and adopted; as of the introduction of CAPs on the Swedish naval ships and on the Queen Elisabeth Class. This reduces the time to find correct places to operate the cobra, and they aid integrating the method with the standard operating procedures.

A Latin proverb states: Every innovation startles us more by its novelty than it benefits us by its utility. A Swedish proverb states: It is hard to see the forest because of all the trees. These proverbs sums up disruptive thinking at both ends – it is not innovative to use an innovation just because the innovation is available; and at the same time, one might not see an innovative method, because of one’s preconceived perspective of what’s in front of you.

Redundancy in firefighting systems

If an incident is bound to get out of control, a municipal fire and rescue service has the possibility to more or less indefinitely scale up the resources available by requesting reinforcements from neighboring forces in the region. This is of course not the case when it comes to ship or a naval vessel at sea – the resources you have onboard are the ones you have to operate with. To handle unforeseen situations, a ship needs to be equipped with redundant systems to a certain feasible level, to avert possible and plausible risks.

When the Swedish Navy initially sourced a cutting extinguisher they found it comply with a number of requirements on their lists. One of them was that it provides a valuable redundant system to fixed installed firefighting systems and for use in hard to reach compartments, such as cofferdams.[50]

I have in previous papers[51] [52] discussed the other requirements, such as fast incident control, fighting fires in an efficient and safe way using minimum number of crew. However, redundancy has only briefly been addressed. The importance of redundancy became very clear a in a presentation made by the Bahamas Maritime Authority (BMA) on the reliability of fixed installed sprinkler and water mist systems:

As of 2012, the IMO issued MSC.1/Circ.1432 – Revised Guidelines for Maintenance and Inspection of Fire Protection Systems and Appliances. This circular introduced new guidelines on inspection of water mist,

[50] (Averin, Report on trials with the cutting extinguisher, FMV VO SJÖ 38 150: 48280/04 (English translation), 2004)
[51] (Trewe, Efficient and Safe Shipboard Firefighting – More Cooling with Less, 2012)
[52] (Trewe, Cutting Extinguishers and SOPs on Naval Vessels, 2015)

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water spray and sprinkler systems: “7.5.17 test a minimum of two automatic sprinklers or automatic water mist nozzles for proper operation.”

A Bahamas recognized organization undertook this test on a passenger ship, and both tests failed. As the scope of the test expanded, more sprinklers failed. As the BMA was notified and as the severity of the findings indicated that further investigations were needed, the BMA issued a testing program with increased extent of testing.

Initially, the failure was believed to be limited to a certain type of high pressure water mist system, but as the tests evolved, the failures were not isolated to this type. The BMA found filter clogging, mineral and scale deposit in internal components as well as corrosion to internal components, in all types of systems; wet, dry and high pressure.

In conclusion, up to one third of the sprinklers failed to engage when tested. When confronting the suppliers with these facts, three manufacturers advised that water quality as the root problem. However, only one of the manufacturers supplied measurable quality criteria for the term “fresh water”.

IMO has then amended testing guidelines and water quality analysis based on the BMA test procedures. However, even if testing the water is the only non-destructive way of monitoring the systems, it might not be effective –especially on already installed systems: Other non-conformities are on the table, such as design, construction and installation. And most of the new set of rules does only affect new ships, not the 30 year heritage installations.[53]

With these findings in mind, there is no doubt that redundancy is a top requirement. In three of the incidents described above, non-working sprinkler systems could be partly held accounted for the escalation of the incident.

[53] (Parkhouse, 2016)

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