Cutting Extinguishers and SOPs on Naval Vessels

Integrating the cutting extinguisher with existing naval firefighting Standard Operating Procedures

A discussion on the practical results of the Swedish Navy; onboard traditional mild steel naval vessels as well as light weight composite stealth vessels

Cutting Extinguishers and Firefighting Standard Operating Procedures onboard Naval Vessels

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"Sword and mind must be united. Technique by itself is insufficient, and spirit alone is not enough." — Yamada Jirōkichi

Abstract

Recently, Cutting Extinguishers have been commissioned and evaluated by several navies. Today used as an enhanced firefighting tool at initial firefighting, for redundancy in case of breached fixed installed systems, as well as equivalents, the use of Cutting Extinguishers are expected to broaden in coming years.

What possibilities and obstacles have the Cutting Extinguisher, as an innovative firefighting tool, brought along when it comes to method, traditional doctrines and standard operating procedures? If introduced efficiently, what additional value, apart from safe, efficient and effective firefighting, have the organization experienced from the integration of the Cutting Extinguisher?

A discussion on the practical results of the Swedish Navy; onboard traditional mild steel naval vessels as well as light weight composite stealth vessels

Key words

Shipboard Firefighting, Cutting Extinguisher Method, Safer Firefighting, Efficient Firefighting, Water Mist, Standard Operating Procedures, disruptive technology, sustaining technology, doctrines

Introduction

In the end of the 1980ies, the Visby Class Corvette project was launched by the Swedish Defence Material Administration (FMV) together with Kockums Naval Shipyard. The Visby Class Corvette is designed for prolonged flexible missions, in complex environments and with a very high grade of adaption to disruptive situations.

Among the initial demands was the use of stealth technology to avoid radar or other sensor detections. The requirements of the stealth properties were outstanding, as well as the result. Visby is the first vessel in the world with stealth all the way – a genuine holistic approach to stealth, named GHOST®[1]. Another demand in the specifications was lean manning, requiring the ship system to be operable with only half of the already lean crew.[2] These requirements added a very high grade of innovation and ingenuity to the engineering of the ship and its subsystems.

New and disruptive technology does not only put the engineers to the edge of innovation; novel naval technology also puts present navy doctrines and organization to test.[3]

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. 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.

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.[4]

[1] (SAAB Kockums, 2014)
[2] (FMV - Swedish Defence Material Administration, 2012)
[3] (Kulve & Smit, 2010)
[4] (FMV - Swedish Defence Material Administration, 2012)

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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 was minimizing the crew detachments and time needed for incident intervention as well as training demands.

Societal changes in the civilian area have had impact on the Royal Swedish Navy and the military forces as a whole. Austerity is omnipresent, as is mitigation of the same. However, reducing personnel and mission capability according to a political “cheese slicer” method is not feasible. Technical and methodological innovations advocate the challenging of traditional doctrines and methods in order to gain full efficiency of the technological change. In the same way, societal and economical change drives technological and methodological change.

Regulations on work environment have become more aligned between the civil society and military organizations. Opinion does not accept unnecessary risks, putting sailors at stake. Thus, views of crews as expendable assets have become obsolete – saving property, at least in peace time, cannot rely on calculations including risks that involve severe injury and death of personnel.
Similar transitions have been made earlier in many European fire and rescue services, where, for instance, Northampton FRS and Greater Manchester FRS have taken the lead in the UK.

Implementation of new SOP in Naval Organization

Firefighting is one of the oldest professions in the world, where traditions are generally considered as a well-guarded heritage. Pouring water on the fire has worked for many generations of firefighters, and introducing new methods are often viewed as a threat to the organization since it turns over the traditional ways. Military traditions are likewise held with honor, often connected to bravery beyond expectance. “If something works, why change it?” seems to be argument. The answer to that question is that the environment and surroundings keeps changing and over-adaption and digging in to past successes, fails the ability to unlearn traditional success factors.[5]

Kulve and Smit points out that technology change, especially when it involves disruptive technology, has a very hard time to overcome the inertia provided by strong traditions. The core concepts of technology change may be viewed as *reinforcing* or *overturning*; and how the core concept is linked to the new

[5] (Nonaka & Takeuchi, 1995)

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components, as *unchanged* or *changed*. This results in a four-leaf matrix distinguishing incremental, modular, architectural and radical innovations[6]:

		Core Concept	
		Reinforced	*Overturned*
Linkages between Core Concept and Components	*Unchanged*	Incremental innovation	Modular innovation
	Changed	Architectural innovation	Radical innovation

Table 1 Henderson and Clark's typology of technological innovation, adapted from (Kulve & Smit, 2010).

As examples: Using an additive with water as extinguishing media can be classified as an incremental innovation, using a chain saw instead of an axe is a modular innovation. Closed cycle diesel engines in a submarine could be classified as an architectural innovation, whilst a submarine equipped with a Sterling engine is an example of a radical innovation due to its complete stealth possibilities.

Technological change may or may not match existing doctrines and procedures; resulting in sustaining or disruptive doctrinal innovations. Sustaining innovations enhance the traditional doctrines and procedures, while disruptive technologies improve the performance in a trajectory that has not yet been valued by the organization. This of course requires new ways of thinking, as it may change the way the organization operates. Since it might have profound implications on the organization, and its traditional structure, it could meet resistance at various hierarchical levels.[7]

The integration of new technology and method involves a knowledge creating process. This knowledge creation basically comes from within the organization; a successful integration cannot be forced by top management or painted on by a consultant. In any organization, there is *explicit knowledge*, often defined in procedures, methods and traditions, but also a vast amount of *tacit knowledge*, of general as well as specific nature; the knowledge creation should involve both types. Most often, or with little effort, middle management have this information within reach. The trick is to induce projects/processes that encompass general abilities and demands, develops and supplies new technologies and methods to the organization, as well as internalize the technology into the organization and method into the crew.[8]

The change in naval firefighting encompasses a number of issues, starting at political level, including austerity, political opinions, technology innovations, change of missions, and change of enemies on the scene of battle. The demands on the individuals, the units and the organization, to handle more activities

[6] (Kulve & Smit, 2010)
[7] (Kulve & Smit, 2010)
[8] (Nonaka & Takeuchi, 1995)

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and integrated operations, simultaneously, increase continuously. The crew of a ship must be able to create task forces and adapt to emerging situations within minutes, and the doctrines, organization, and procedures onboard must be able to support this. No longer is there room for unmitigated personnel to handle a few specific situations; simply because there is neither enough crew available, nor officers to manage such organization. Instead, the organization must adapt from a steady state situation to a dynamic scenario when needed. This requires multiple group structures with overlapping knowledge and social reliance.[9]

The Cobra cutting extinguisher and its method was initially viewed as a mere technology – a tool to introduce water to the fire affected compartment, a tool to cool fires in an innovative construction and a tool to evacuate personnel. Soon, both naval units and the Sea Safety training School realized that the implementation of the tool in the organization required change or addition to SOP – the tool did not fit as normal water branch. The Swedish Navy repositioned the Cobra from the incremental innovation classification to an architectural innovation with some radical features. This required implementation of new methods and thus new procedures.[10]

Steps forward implementation of the cutting extinguisher

The political ambitions are translated into organizational requirements, which are, on unit level, compiled into a *Tactical Organizational Financial Objective.* Next step is to find technical solutions for these objectives, compiled in *Technical Tactical Financial Objectives*. This step might include studies, at FMV and unit level, sometimes in cooperation with private enterprises and universities or other scientific research parties.

In general terms, the last step is compiling the *Technical Specifications* of the system as well as a plan for training and integration of the system into the unit's SOP's and doctrines – which in part or as a whole goes out for public tender.

In a naval setting, the efficiency of water mist introduced to a compartment with a fully developed fire has been documented in scientific reports, such as *The development and mitigation of backdraft: a real-scale shipboard study*.[11] One of the first national studies on the issue, referring to this study, and on behalf of FMV, was made by Carlsén and Winkler at the Department of Fire Safety Engineering at University of Lund in 2000. In their master thesis in fire engineering, they studied the cutting extinguisher as a firefighting tool and as means of clearing way onboard.[12] In aiding their studies they

[9] (Nonaka & Takeuchi, 1995)
[10] (Robert Averin (FMV), 2014)
[11] (Gottuk, Peatross, Farley, & Williams, 1999)
[12] (Carlsén & Winkler, 2000)

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had assistance of the *Sea Safety Training School* at the Swedish Naval Warfare Centre. Lt Dahlberg of the Sea Safety Training School produced a parallel report in conjunction with thesis from the university.[13]

The Swedish Navy consequently sourced a cutting extinguisher to perform further tests. The cutting extinguisher was found to providing the shipboard firefighting crew to[14]:

- Reach the fire without adding oxygen
- Rapidly lowering the temperature in the fire room
- Minimizing the water use, hence minimizing collateral damages and stability issues
- Reducing the number of crew occupied with firefighting
- Enabling the crew to fight the fire efficiently from a relatively safe position
- Providing the a method to get an overall faster incident control

Steel Hulls and Light Weight Composite Materials

Traditionally, a naval ship is constructed with a steel structure. In terms of combustion, this is a good choice. However, steel's ability to conduct heat brings on a number of challenges when it comes to firefighting. When a steel bulk head or deck is exposed to fire or heat, an intact construction will conduct heat to the adjacent side reasonably fast. Thus, an un-insulated steel panel will not work as a fire shield. To protect the vessel from spreading of fire from the incident area, the vessel's construction is separated into insulated fire zones. A fully developed fire in a fire zone is nevertheless likely to ruin the content of the complete fire zone.[15]

Normally, developed shipboard fires in a limited fire zone on steel hull vessels may be contained and controlled by cooling the boundaries, making it possible to wait out the fire before initiating the re-entry procedure.

In contrast, light weight structures are often made out of combustible materials, such as carbon fiber and PVC-foam combined into carbon reinforced plastic laminate. In case of fire, there is an imminent risk that the light weight construction will contribute to the fire development. To protect the construction from fire and heat, intumescent paint and/or insulation is amended to the construction panels. The construction itself may also contain redundant supporting beams, allowing either one to be weakened or destroyed by fire without distortion or collapse of the structure itself.
The construction of a light weight composite insulates heat well, and does not conduct heat away from the fire room. Even though the composite material insulates well, at a certain point of the fire development, the supporting structure will degenerate and cause collapse.[16]

[13] (Dahlberg, Report on Completed Tests with Cutting Extinguishers, 2001)
[14] (Averin, Report on trials with the cutting extinguisher, FMV VO SJÖ 38 150: 48280/04 (English translation), 2004)
[15] (McGeorge & Høyning, 2002)
[16] (Johansson, 2012)

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Traditional boundary cooling has no effect on fires onboard light weight composite ships due to the construction material's insulating properties – the "thermos effect". Instead, one needs to rely on passive protection, early warning systems, automatic fixed installed water mist systems, etc.

For both traditional steel hull and light weight constructions vessels, fixed installed high pressure water mist systems are often limited to designated high risk fire areas due to cost and limitation of auxiliary emergency power. Breach of such systems, or fires caused by external attacks at a non-designated area, would require traditional boundary cooling and/or BA-attack; both intervention methods requires lots of crew and lots of water, involves high risks, and thus, compromising the mission.

Visby Class Stealth Corvettes – Light Weight Composites

Carlsén and Winkler's study approached two issues; the ability to fight fires in LWC structures, as well as the ability to evacuate personnel from areas which had undergone distortions due to fire and weapon impact. In their tests and trials, they used a cutting extinguisher producing 28 liter per minute of water mist at a minimum of 260 Bar at the nozzle. This cutting extinguisher was engineered for fire and rescue service use.

The tests of firefighting abilities were conducted through multiple trials using a 3.6 MW diesel fire in a 40 foot container with a LWC mock wall. The temperature reached in the fire room prior to introducing the water mist was approximately 500 C. The fire was extinguished in 10 seconds.

The test of clearance was made with three different laminate layers' thickness; 2mm, 5mm and 8mm, and three different operators; the two authors (as unexperienced) and an experienced operator from CCS. The average cutting speeds were:

Cutting Speed (mm/min)	***Operators***		
Laminate thickness	***H.W.***	***T.C.***	***Exp Op***
2 mm	380	660	660
5 mm	350	450	390
8 mm	140	180	300

Table 2 Cutting speeds in laminates (mm/min)

Carlsén and Winkler also added suggestions on future engineering to comply with Swedish Naval requirements, among the where:

- Reducing the hand lance's length to comply with room available on board
- Replacing the radio control system with an EMC adapted solution.
- Additive injector, operated in a similar way as abrasive, to apply various additives.
- Redundancy concerning water supply and hydraulic power supply.[17]

[17] (Carlsén & Winkler, 2000)

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In principle, all suggested alteration has been applied to the C330H Naval Kit later installed on the Visby Class.

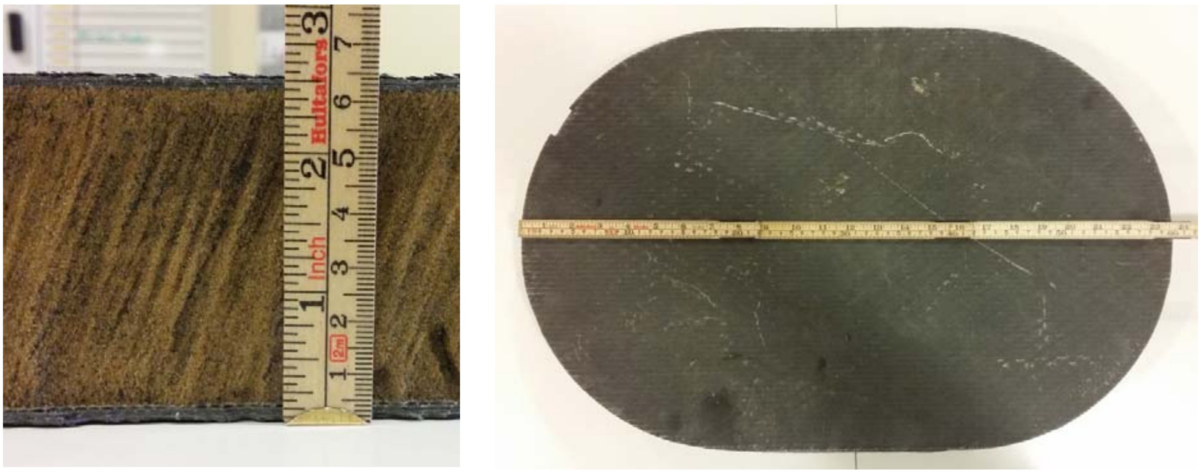

Figure 1 65 mm thick Light Weight Composite manhole extraction (600mm x 400mm), cut by the Cobra Cutting Frame

As a result of these studies, Cold Cut Systems engineered the Cutting Frame, which is a frame with a guided cart carrying a cutting extinguisher nozzle. Using this equipment, a 600 x 400 mm manhole in a Light Weight Composite hull material of 65 mm thickness, with a total cutting distance of 1650 mm, will be cut in 3 min 10 sec (520 mm/minute). This frame may be applied to a bulkhead and connected to the hose of the cutting extinguisher. As a comparison, 4mm aircraft duraluminum will be cut in 2 min 30 sec (66 cm/min).

Operation Atalanta

While the work with developing a cutting extinguisher for the novel ship Visby Stealth Ship class, political ambitions created an opportunity to enhance the damage control on the existing steel ship fleet. In December 2008, the Swedish government appointed three Swedish naval vessels under the disposal of the EU *Atalanta Operation* in Aden Bay. Since the appointed vessels were corvettes for mainly costal missions, they had to undergo fire zone classification according to *Regler för Militär Sjöfart*[18]*/Naval Ship Code* (ANEP 77) prior to introduction to the operation fleet at open sea. Compared to insulating zones, bulkheads and decks, and retrofit fixed installed automatic fire suppression systems, the most cost effective way to obtain classification was to install cutting extinguishers as *equivalents*.

[18] (Royal Swedish Navy, 2010; Royal Swedish Navy, 2010)

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Figure 2 Operation Atalanta - Escort by HMS Stockholm[19]

A lot of the already prepared work for the Visby Class could in short notice be re-engineered for the steel hull Stockholm Class. In May 2009, a set of fully working prototypes was delivered prior to the ships' commissioning in Djibouti. The experience from the mission in Aden Bay was later integrated into the final product; the self-contained diesel propelled C330D Marine Unit. The units were also equipped with CBRN wash nozzles and auxiliary submersible pumps, supplied with power from the unit.

The preparations and experiences from the initial live trials were brought back into the project, both on organizational and technical level. While studying ways to minimize time and cost for training, a set of Cutting extinguishing Attack Points (CAP's) were identified and introduced on each ship. The CAP's are bright red markings with a white "S" marked on deck, hatches and bulkheads, indicating pre-determined places where the cutting is to be used, "at will", at an incident.

[19] (Averin, Säkrare arbetsmiljö i Somalia - Safer work environment in Somalia, 2011)

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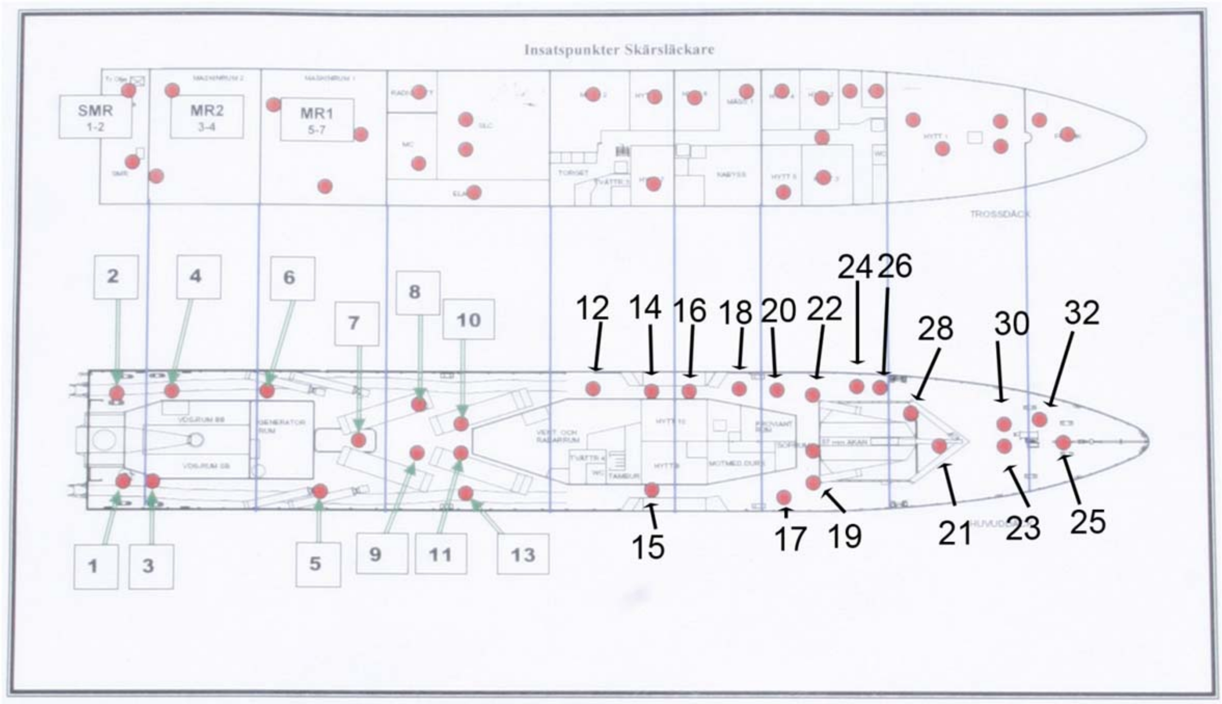

Figure 3 Cutting extinguisher Attack Points schematics on ship outline

If CAP's 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.

Figure 4 Cutting extinguisher Attack Point "(S)" at a hatch; CAP adopted by Greater Gothenburg Fire and Rescue Service

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

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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 CO2. 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.[20] 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.[21]

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.[22]

Water Mist

Water mist is generally interpreted as sprays with water drops of a size up to 1000 microns, or 1 mm[23]. Recently, research has shown that water broken up into smaller droplets adds a number of features to it

[20] (Schürmann, 2002)
[21] (Gsell, 2010)
[22] (Holmstedt, 1999)
[23] (NFPA, 2010)

as a firefighting media. By atomizing the water into micron size droplets, the surface area of a given volume of water expands dramatically. [24]

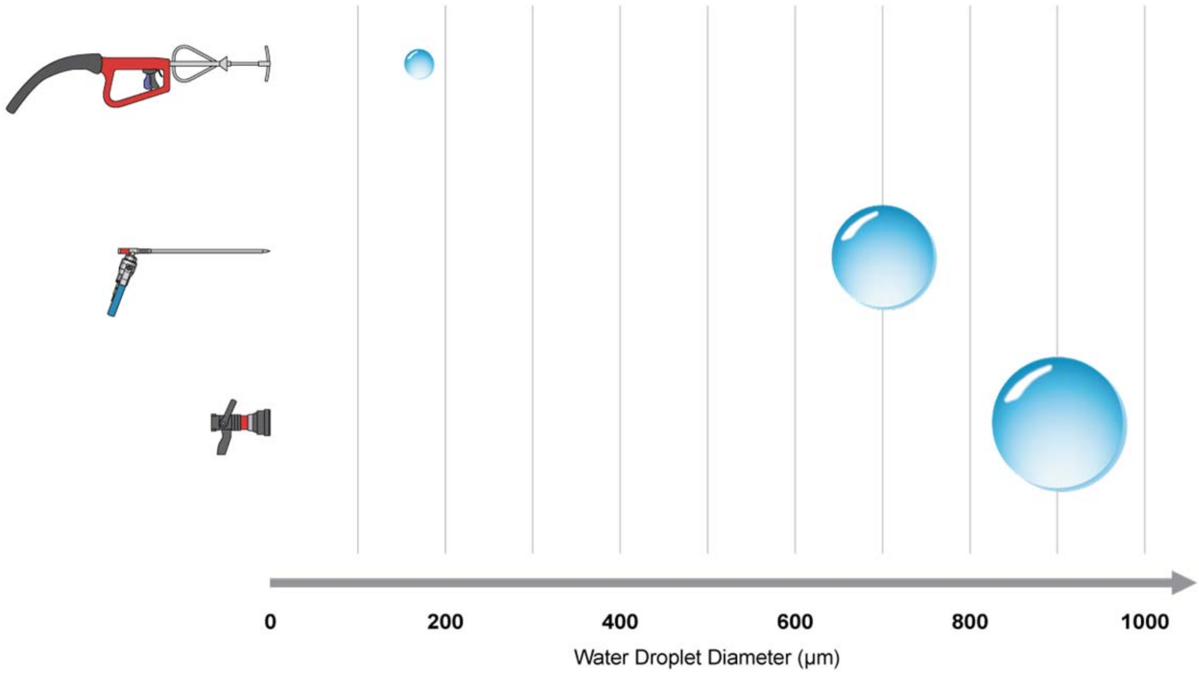

Figure 5 Water droplet Sauter mean diameter of different firer fighting tools, adapted from additional tests to (Svensson, Lindström, Ochoterena, & Försth, 2014)

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 detergent or a saline additive, the water droplets size decrease significantly, thus expands the surface area exposed; the Sauter Mean decreases to 110-150 microns.[25] This confirms initial tests by the Swedish Navy showing that if the cutting extinguisher was utilized with a Class A detergent, the cooling is even more apparent[26].

[24] (Svensson, Lindström, Ochoterena, & Försth, 2014)
[25] (Johan Lindström, 2014)
[26] (Dahlberg, Report on Completed Tests with Cutting Extinguishers, 2001)

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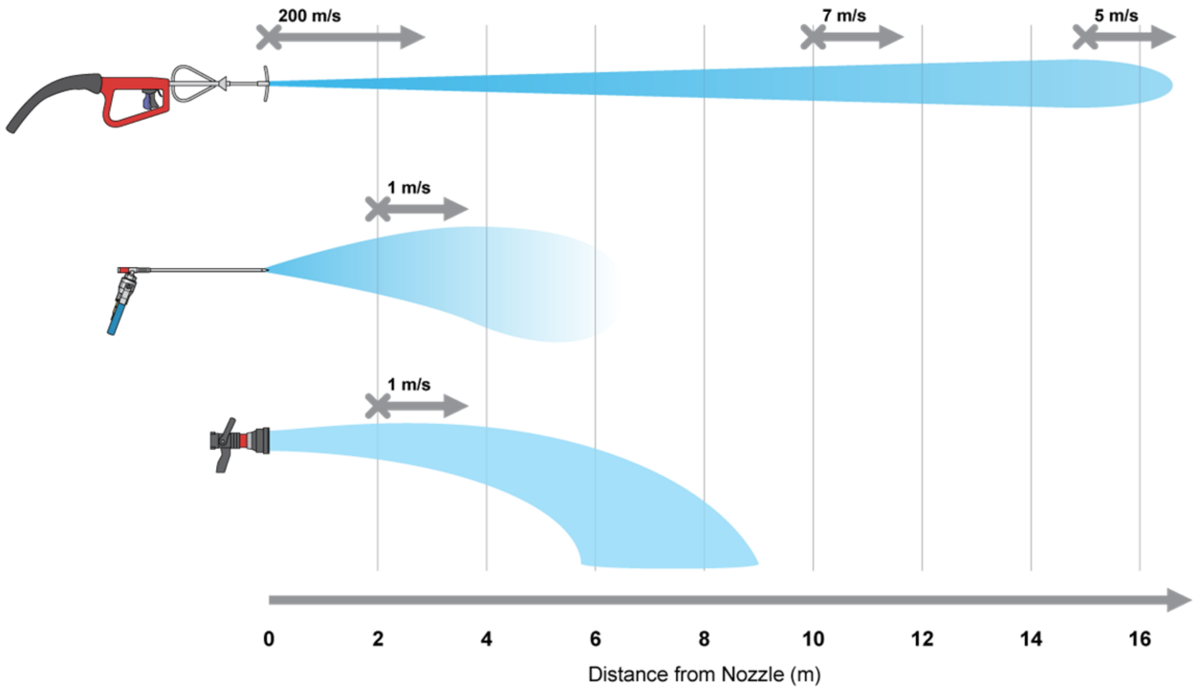

Figure 6 Water jet velocity of different firer fighting tools, adapted from additional tests to (Svensson, Lindström, Ochoterena, & Försth, 2014)

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 and radiation attenuation adds effect. The cutting extinguisher also adds a relatively high velocity to the jet and to the extinguishing process – which, apart from making turbulence, carries the water droplets swiftly into the fire room.[27]

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 to steam.[28] 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.[29]

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.

[27] (Gsell, 2010)
[28] (Gsell, 2010)
[29] (Försth & Möller, 2011)

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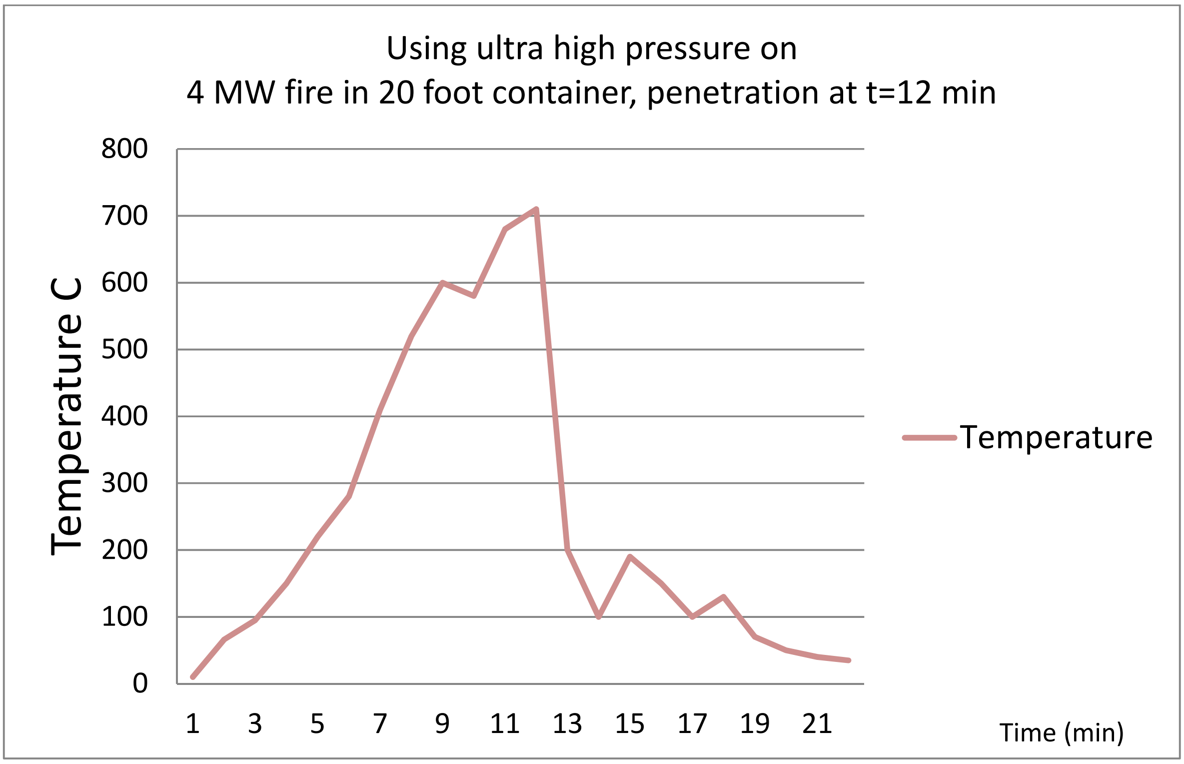

Figure 7 Rapid Temperature Reduction

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.[30]

Examples of penetration abilities are tested and described in various reports. FMV conducted tests at early stages[31]:

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

The cutting extinguisher is primarily a tool for rapidly and efficiently cooling fire gases produced by solid or liquid fires (Class A and B) from a safe position. By adding a Class A detergent, additional positive effects on solid fibrous fuels will occur.

[30] (SERF in collaboration with SP Technical Research Institute of, 2010)
[31] (Dahlberg, Report on Completed Tests with Cutting Extinguishers, 2001)

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The cutting extinguisher has been tested in accordance with EN-3-7:2004+AI 2007(E), Annex C. According to this standard, the 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. The cutting extinguisher fulfills the requirements with the use of water and water and abrasives.[32]

The cutting extinguishing method for Fire & Rescue Services has been developed by the Swedish Rescue Service Agency together with SERF, a regional Swedish Fire and Rescue Service, and is being enhanced and refined continuously. 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[33].

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.

Royal Swedish Navy Shipboard Firefighting

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.[34]

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.

On live incidents, traditional standard operating procedures for firefighting tactics onboard conventional vessels include four main actions:

1. Early Detection - Alarm,
2. Initial Attack,
3. Containment, Control,
4. BA-Attack - Safe Re-entry Procedure.

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[32] (SP - Measurement Technology Department, 2009)
[33] (SERF in collaboration with SP Technical Research Institute of, 2010)
[34] (Carlsson & Lundmark, 2011)

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Primarily, early detection is of essence to extinguish the fire in its growth stage, before the fire has fully developed.

Secondly, immediately after detection and alarm, the first attack is made by personnel detecting the fire. By using fire extinguishers or other means to suffocate the fire and/or removing the fuel, the crew and the ship might avoid a larger incident.

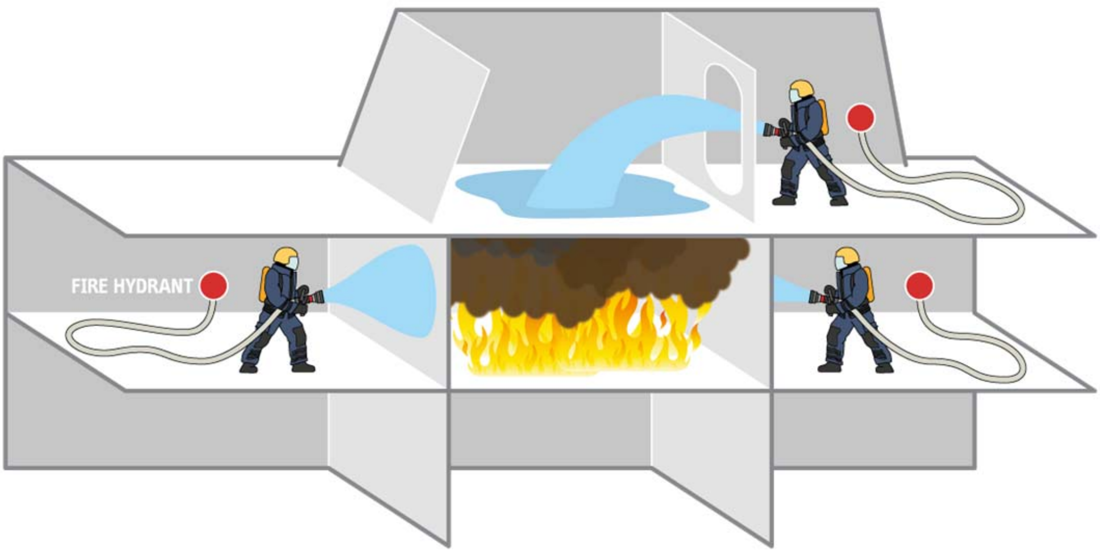

Figure 8 Traditional Boundary Cooling

The third step, if the initial procedures fail, is to contain the fire in the fire compartment. Sealing off the area to prevent the fire to spread, removing fuel, and to minimize oxygen supply, are measures made to buy time for the fourth step to muster. To contain the fire, automatic, semi-automatic or manual fixed installed fire suppression systems, if present and deemed proper action, should be engaged.

If the fixed installed fire suppression systems fail, boundary cooling of the ship structure is of essence. Since conventional ships normally is constructed with mild steel, a highly heat conductive construction material, the heat from the original fire is likely to travel through the construction and ignite other cells/compartments. Boundary cooling requires vast amounts of water applied to the decks and bulkheads surrounding the initial fire compartment – water that needs to be pumped out from the ship. Depending on the size of the initial fire compartment, a sufficient number of personnel are required to operate the nozzles applying water for boundary cooling.

Forth step is the re-entry procedure, BA-attack on the fire compartment. This cannot be done in a safe way until the fire has been suppressed or reached its decay stage. The latter adds time to the total

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lapsed time to get in control of the fire. During this time, boundary cooling must be applied continuously[35].

Enhanced shipboard firefighting with cutting extinguisher

The tactics for shipboard firefighting enhanced with the cutting extinguisher method are initially similar to standard procedures. However, on LWC ships, containment is not relevant since boundary cooling is obsolete – 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.

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.

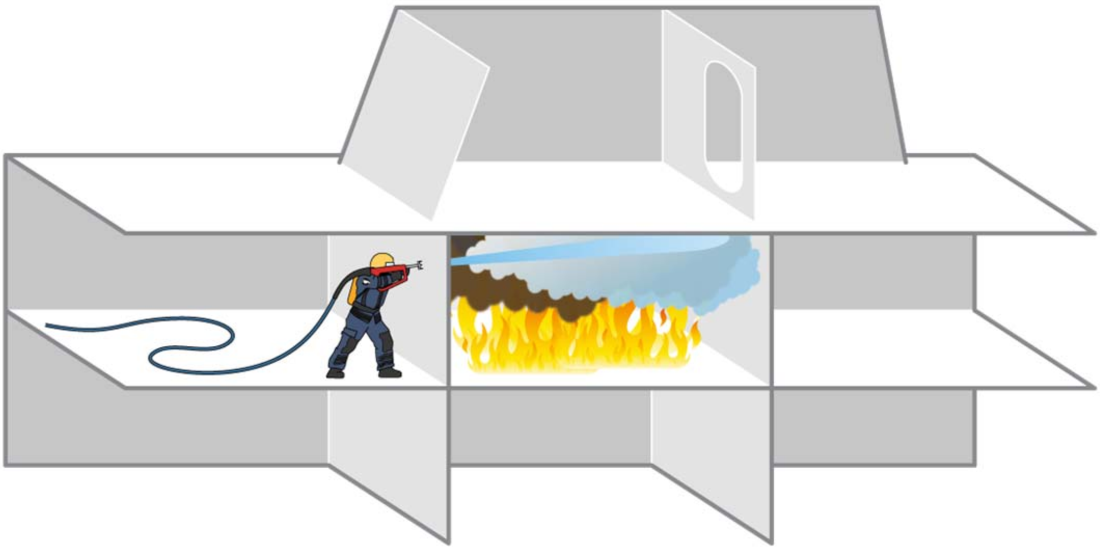

Figure 9 Advantages of the Cutting Extinguisher – "boundary cooling from the inside", applied from a safe position outside

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

[35] (Royal Swedish Navy, 2003)

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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.[36]

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 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[37].

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

1. Early Detection - Alarm,
2. First Attack,
3. Second Attack,
4. BA-Attack - Safe Re-entry Procedure.

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.

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.

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.

[36] (Gsell, 2010)
[37] (Osbäck, 2012)

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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 is again similar to standard naval shipboard firefighting, with a major difference in ambient temperature at the fire compartment. The high pressure water mist has efficiently decreased the temperature to a comfortable 100C-150C. The forth step could also 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 enhancements

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 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.[38]

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. [39]

Conclusions

In order to embed new technologies into the organization, and not only put them in a tool box, the new method has to be amended or introduced thoroughly. If the method is considered disruptive or radical, and therefore requires new ways of approaching a problem, either within existing procedures or by adding new procedures, the organization needs to be prepared and ready for such endeavor.

Such organizational change need to address a number of parameters, and/or have a general understanding for the innovative process. Combining the results of (Nonaka & Takeuchi, 1995) and (Kulve & Smit, 2010) with the experience of Swedish Navy, the parameters of the project are suggested to include:

- Combined strong senior level support; at technology, method and organizational (development as well as applied) levels
- Understanding the cost cutting pressure, but accepting rational investments
- Finding and empower middle management heroes in the knowledge creating process
- Adding technology and method, rather than replace, for organizational acceptance
- High focus on method development and training, supported by a
- Center of excellence in training and concurrent method development, and a
- Highly dedicated implementation plan

Fire hazards and incidents are of great concern to all types of vessels. The impact on crew, ship and mission could be disastrous. New constructions, new assignments and societal change have triggered the Royal Swedish Navy in searching of safer and more efficient firefighting.

Requirements in cost efficiency while maintaining the readiness and capability levels with decreasing number of crew available, has been an issue of great importance on the agenda for the supplying

[38] (SERF in collaboration with SP Technical Research Institute of, 2010)
[39] (Robert Averin (FMV), 2014)

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agency. Safety and mission focus have also played a role of great magnitude while evaluating tools and methods.

Research made by the Royal Swedish Navy and others has found that the cutting extinguisher and it methods supplies or contributes extensively with the following features:

- Safe and rapid re-entry procedure at shipboard firefighting through mitigation of backdraft and flash overs, as well as rapid cooling of fire gases
- The concept require much less crew than standard firefighting procedures alone, which leaves more crew available for the mission
- Boundary cooling from inside the “thermos”
- It is a complement to traditional firefighting equipment, and is easily introduced to present procedures
- In comparison with traditional boundary cooling, the cutting extinguisher concept uses minimal amount of water – which decreases stability issues and collateral damages
- The concept is easy to understand, and is easy to train
- When the concept is trained, the method is easily practiced onboard
- Excellent system for redundancy on breach of fixed installed fire suppression systems
- The cutting extinguisher can be used where fixed installed fire suppressive systems and other measures don’t reach; void areas, cofferdams and containers for transportation
- Can be used as a clearing tool, especially on composite vessels
- Retrofitting to comply as an equivalent to new classifications/standards are possible and very cost effective
- Increasing parallel method development in civil firefighting enhance possibilities to benchmark and cross-fertilize.

In addition, the cutting extinguisher could be used for third party fires, as a fire and rescue tool.

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References

Averin, R. (2004). *Report on trials with the cutting extinguisher, FMV VO SJÖ 38 150: 48280/04 (English translation).* Stockholm, Sweden: FMV - Swedish Defence Material Administration.

Averin, R. (2011). Säkrare arbetsmiljö i Somalia - Safer work environment in Somalia. Uppsala: FMV - Swedish Defence Material Administration.

Carlsén, T., & Winkler, H. (2000). *Skärsläckaren som röjnings och släckverktyg för fartyg av kolfiberkomposit.* Engineering, Department of Fire Safety Engineering. Lund, Sweden: Lund University.

Carlsson, L. E., & Lundmark, L. (2011). *Fire Protection on Board.* Göteborg: Jure Förlag.

Dahlberg, S. (2001). *Report on Completed Tests with Cutting Extinguishers.* Karlskrona, Sweden: Royal Swedish Navy, Sea Safety School.

FMV - Swedish Defence Material Administration. (2012, 01 16). *Korvett Visby - flexibelt fartyg med stor uthållighet.* Retrieved 04 15, 2015, from FMV: http://www.fmv.se/Projekt/Korvett-Visby/

Försth, M., & Möller, K. (2011). *Absorption of heat in liquid droplets, SP Report 2011:75.* Borås, SE: Fire Technology, SP Technical Research Institute of Sweden.

Gottuk, D. T., Peatross, M. J., Farley, J. P., & Williams, F. W. (1999). The development and mitigation of backdraft: a real-scale shipboard study. *Fire Safety Journal 33*, 261-282.

Gsell, J. (2010). *Assessment of Fire Suppression Capabilities Of Water Mist - Fighting Compartment Fires with the Cutting Extinguisher - PhD thesis.* Belfast, UK: Faculty of Art, Design and Built environment, University of Ulster.

Holmstedt, G. (1999). *An assessment of the cutting extinguisher advantages and limitations.* Lund, SE: Department of Fire Research, University of Lund,.

Johan Lindström, M. F. (2014). *Using the Cutting Extinguisher to Fight Fires at Sea.* London, UK: The Royal Institute of Naval Architects.

Johansson, H. (2012). Fire protection o flight weight composite structures. *LIWEM.* Gothenburg, SE: Kockums Thyssen.

Kulve, H. t., & Smit, W. A. (2010). Novel Naval Technologies: Sustaining or Disrupting Naval Doctrine. *Technological Forcasting & Social Change*, 999-1013.

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McGeorge, D., & Høyning, B. (2002). Fire Safety of Naval Vessels made of Composite Materials: Fire Safety Philosophies, Ongoing Research and State-of-the-Art Passive Fire Protection. *RTO-MP-103, RTO AVT Specialists' Meeting on "Fire Safety and Survivability".* Aalborg, DK: NATO Unclassified.

NFPA. (2010). *NFPA 750 - Standard on Water Mist Fire Protection Systems.* Quincy, MA, USA: National Fire Protection Agency.

Nonaka, I., & Takeuchi, H. (1995). *The Knowledge Creating Company.* New York, N.Y.: Oxford University Press, Inc.

Osbäck, M. (2012). Presentation of Swedish Naval Warfare College. *NATO SG7.* Karlskrona, Sweden: Swedish Naval Warfare College, Royal Swedish Navy.

Robert Averin (FMV), J. L. (2014). Swedish Naval Shipboard Firefighting. *Naval Damage Control.* Portsmouth, UK: SP Swedish Technical Research Institute, FMV Swedish MoD.

Royal Swedish Navy. (2003). *Örlogsboken, M7742-730002.* Karlskrona, Sweden: Swedish Armed Forces.

Royal Swedish Navy. (2010). Fartyg och deras utrustning. i *Regler för militär sjöfart.* Karlskrona, Sweden: Swedish Armed Forces.

SAAB Kockums. (2014). *Visby Corvette Class - Defining Stealth at Sea.* Retrieved 04 15, 2015, from SAAB Group: http://www.saabgroup.com/en/Naval/Kockums-Naval-Solutions/Naval-Surface-Ships/Visby-Class-Corvette/

Schürmann, S. (2002). *Droplet sizing and characteristics of water mist fire protection spray nozzles.* Metzingen, Germany: Lechler GmbH.

SERF in collaboration with SP Technical Research Institute of. (2010). *Cutting Extinguishing Concept – practical and operational use.* Borås, SE: MSB.

SP - Measurement Technology Department. (2009). *Dielectrical test of a cutting fire extinguisher.* Borås, Sweden: SP - Technical Research Institute of Sweden.

Svensson, R., Lindström, J., Ochoterena, R., & Försth, M. (2014). *CFD simulations of the Cutting extinguisher.* SP Technical Research Institute of Sweden, Fire Research. Borås, Sweden: SP Technical Research Institute of Sweden.

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This paper was presented by Anders Trewe of Cold Cut Systems Svenska AB (CCS) and Robert Averin of Swedish Defence Material Administration (FMV) at MAST Asia Conference 2015. Further information about the coldcut™ cobra may be obtained by contacting CCS. The coldcut™ cobra cutting extinguisher is patented – please contact CCS for further information.

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