Efficient and Safe Shipboard Firefighting – More Cooling with Less

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Abstract

Mitigation of austerity has recently closed upon the level of importance of mitigation of fire among naval forces. Budget cuts combined with demands to keep the naval fleet's operational levels intact have created new opportunities of cooperation and thinking outside the box in extending present vessels' life span. Investing in new technology could not only add lifetime, but enhance the safety of the crew and the ability to stay focused on the mission with less effort.

Fires onboard naval vessels will not only impact the vessel, but threaten to compromise the mission as a whole. Traditionally, shipboard firefighting on steel hull vessels engage a lot of crew members, consumes a lot of water and takes focus off of the mission.

Modern composite light weight material structures require immediate intervention in the fire compartment, less the supporting structure will be damaged. In addition, societal changes impose alignment to civilian work safety regulations.

High pressure water mist has been scientifically proven a very efficient extinguishing agent; cooling and inerting combustible smoke gases with less water than otherwise. It rapidly cools the fire room, mitigates backdrafts and makes the re-entry procedure safer for the BA-crew.

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 crew and water consuming, high risk tasks, thus mission compromising.

A mobile, versatile high pressure water mist system with cutting/penetrating abilities would add the redundancy necessary to handle a breach in the fixed installed systems. It would also add efficient and safe fire protection to compartments not protected by other systems.

The Swedish Navy has invested in cutting extinguishing systems to effectively enhance safety and comply with RMS 2010/NSC; for redundancy on their new Visby Class Composite Stealth Corvettes, as well as retrofitting on steel hull vessels for cost effective and enhanced bulkhead fire protection. Of course, the overall argument is securing the ability to succeed with the mission.

Key words

Shipboard Firefighting, Cutting Extinguisher, Safer Firefighting, Efficient Firefighting, Water Mist

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Introduction

Pooling and sharing and *Smart Defence* has become the buzz words of the day among authorities such as the European Defence Agency and NATO. The recent cuts in budgets all over the lines require new ways to entangle old problems: Not only are the budgets decreasing in an increasing pace, ability to retain capability are an undisputed demand from the funders. In addition, demands on military operations with respect to safety and security are closing in to the demands of the civilian society.

For most operations, this could imply prolonging the life span of present equipment, finding disruptive and groundbreaking technologies and methods for doing more with less and work more safely and efficiently with the means at hand. Naval operations are not exempt.

Fire onboard can ruin a good day, someone said. Traditionally, shipboard firefighting on steel hull vessels engage a lot of crew members, consumes a lot of water and takes focus off of the mission. Fires onboard naval vessels will not only impact the vessel, but threaten to compromise the mission as a whole.

In addition, modern composite light weight material structures require immediate intervention in the fire compartment, less the supporting structure risks to be damaged or collapse.

New disruptive technology for applying water mist to shipboard fires has recently been developed: the cutting extinguisher. The cutting extinguisher method is proven by on shore firefighting and a number of scientific reports. In the naval setting, the efficiency of water mist introduced to a compartment with a fully developed fire has also been documented in scientific reports, such as *The development and mitigation of backdraft: a real-scale shipboard study* (Gottuk, Peatross, Farley, & Williams, 1999).

This paper discusses the features of water mist and ways to apply it safely and to swiftly combat shipboard fires. It also presents the experiences of the Royal Swedish Navy concerning the cutting extinguisher, the rationale behind the investments, and how it has introduced the cutting extinguishing concept to their standard shipboard firefighting procedures.

Vessel constructions and shipboard firefighting

Steel Hulls and Light Weight Construction Materials

Traditionally, a naval ship is constructed with a steel structure. In terms of combustion, this it 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 (McGeorge & Høyning, 2002).

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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. I 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 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 (Johansson, 2012).

Shipboard fires onboard ships, or ships with superstructures, constructed with composite systems; traditional boundary cooling has no effect 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 crew and water consuming, high risk tasks, thus mission compromising.

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 Halons, Argons 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 (Schürmann, 2002).

Water Mist

Water mist is generally interpreted as sprays with water drops of a size up to 1000 microns, or 1 mm (NFPA, 2010). Recently, research has shown that water broken up into small 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. At a droplet size of 1 mm, one liter of water covers the area of a third of a soccer goal (6m2). At 1 micron, one liter of water covers an area of

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approximately 6000 m2, 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 (Gsell, 2010). 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 (Försth & Möller, 2011).

Given we have a method to transform water to micron size droplets and applying this to firefighting, we have a theoretical possibility to increase the efficiency of water used by up to approximately 1000%. Suppliers of fixed installed firefighting systems such as Hi-Fog® (Marioff, 2011) and Ultra fog® (Hanje, 2012) are getting close to these levels. Adopting this feature to a hand held lance with the possibility to penetrate virtually any construction material, and you will have a tool that adds safety, swiftness, redundancy and accessibility with a minimal use of water to shipboard firefighting.

Methods and Procedures

Standard Naval Shipboard Firefighting

Pre-action preparations and 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, standard procedures for firefighting tactics onboard conventional vessels include four main actions:

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

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.

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, is 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.

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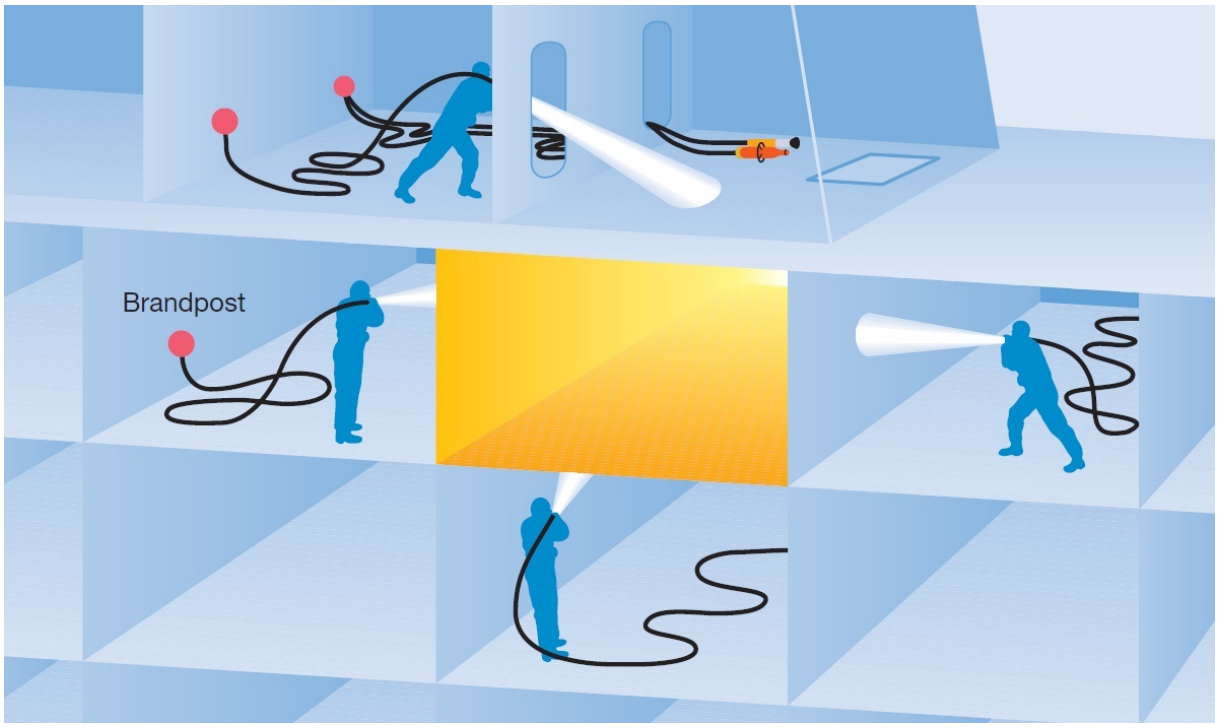

Fig. 1 Boundary Cooling[1]

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. 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 lapsed time to get in control of the fire. During this time, boundary cooling must be applied continuously (Royal Swedish Navy, 2003).

Mission critical situation

In a 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 (Carlsson & Lundmark, 2011).

[1] (Royal Swedish Navy, 2003)

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Composite vessel shipboard firefighting

The tactics for shipboard firefighting on composite ships are initially similar to standard procedures. However, 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.

The Cutting Extinguisher and its Method

The Cutting Extinguisher

The Cutting Extinguisher is a mobile high pressure water jet system with penetrating and cutting capabilities. The system ejects approximately 30 to 60 liters water through a nozzle mounted in a hand held lance at approximately 250 bar and 200 meters per second.

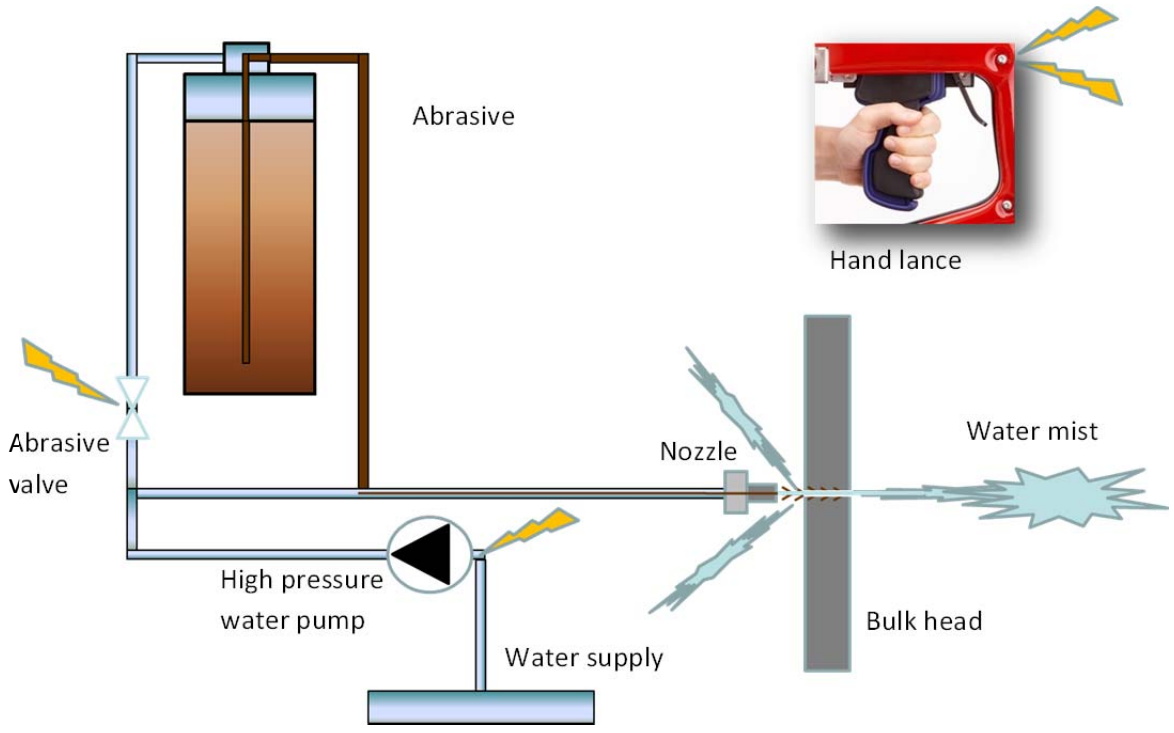

Fig. 2 Cutting Extinguisher Schematics

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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 (Holmstedt, 1999).

Fig. 3 Advantages of the Cutting Extinguisher

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. It also cools the fuel surface, and by time, shields the fuel from the surroundings (Gsell, 2010). If the cutting extinguisher is utilized with a Class A detergent, the shielding is even more apparent (Dahlberg, 2001).

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

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between the water mist and the fire, eventually sucking in the water mist into the flames and choking itself.

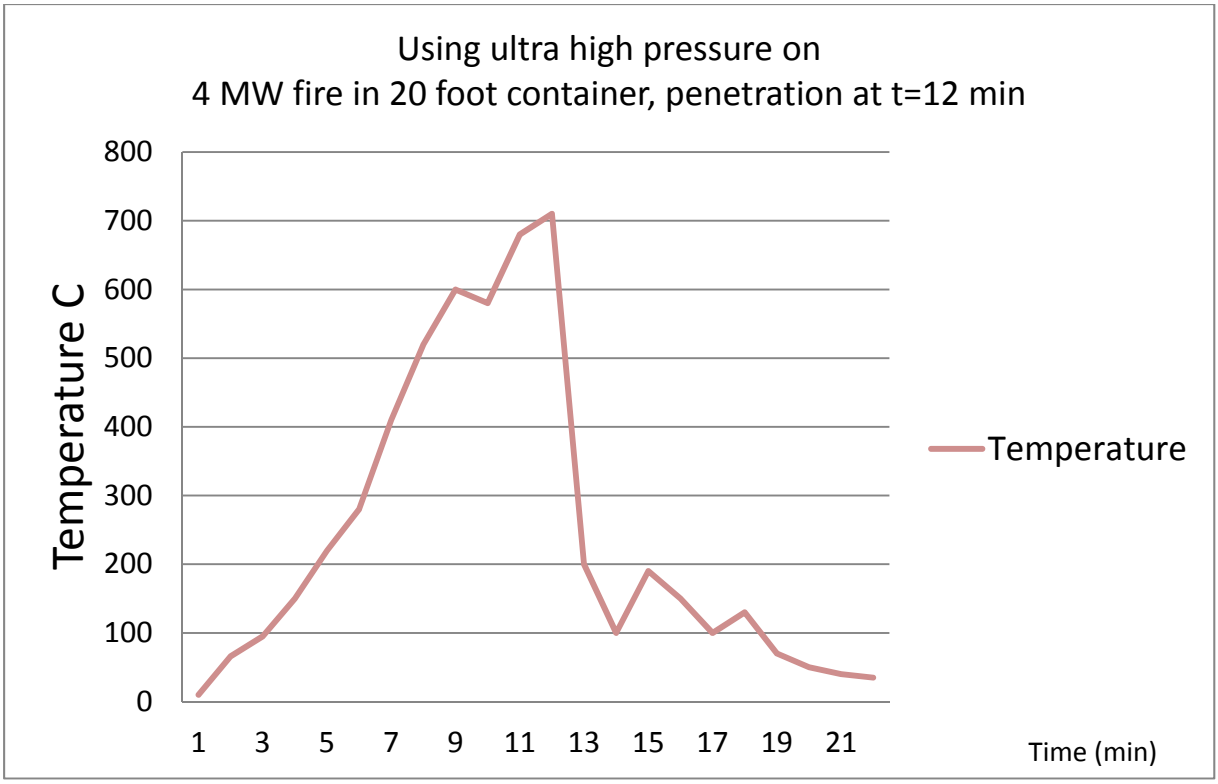

Fig. 4 Rapid Temperature Reduction

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 (SERF in collaboration with SP Technical Research Institute of, 2010).

Examples of penetration abilities are tested and described in various reports. FMV conducted tests at early stages (Dahlberg, 2001):

- 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.

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

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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 (SP - Measurement Technology Department, 2009).

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 (SERF in collaboration with SP Technical Research Institute of, 2010).

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.

The Royal Swedish Navy and the Cutting Extinguisher

Societal change, decreasing funding and new challenges

Funding for solving the military assignments and duties has been steadily decreasing over the past decades. At the same time new international missions have emerged into the arena. For the Royal Swedish Navy and FMV, the Swedish Defence Material Administration, in order to maintain fast responses to new missions, this has implied doing more for less: including more efficient strategies and tactics, bilateral procurement initiatives, life cycle extension, etc.

Societal changes have introduced a more uniform legal situation, comparing civilian and military sectors of the community. Among other things, change in the recruitment process, going from a draft organization to professional sailors and soldiers, more civilian regulations were brought in to the military organizations. Civilian work environment regulations and other jurisdictions were to be enforced throughout all military levels. Exempts of these regulations and/or military rules were not accepted in the same extent as earlier. Areas where equipment and crew were exposed to high risks, such as vessels' fire resistance/protection and shipboard firefighting were rising on the priority list.

The change in global politics and Sweden's membership in the European Community introduced new joint missions to be completed at virtually any place around the globe. These brought forth yet new challenges for crew and equipment.

As more sophisticated equipment had been introduced onboard Swedish naval vessels, the Royal Swedish Navy has found itself spending a larger fraction of resources on training. Sticking to traditional solutions, crew would soon find themselves to be occupied with constant training of handling the equipment, leaving little or none of the time and resources to sail the ship, less carrying out missions and assignments. Adding more crew was of course not an option, requirements from HQ and funders rather opted for reducing crew.

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Requirements like *more for less* and *thinking outside the box* permeated the whole organization, including the Naval Procurement Command and the Sea Safety School (Averin, Säkrare arbetsmiljö i Somalia - Safer work environment in Somalia, 2011).

Cutting extinguisher traced

In 2001, fairly parallel by ordering a number of composite Visby Class Stealth Corvettes from Kockums Naval Shipyards, the Royal Swedish Navy and the Swedish Defence Materiel Administration, FMV, sought methods for offensive and efficient firefighting from a safe defensive position, to meet the demands of firefighting onboard composite vessels. In addition, the main target was to find systems supplementing and adding redundancy to traditional onboard systems; with high efficiency in suppressing fires, water usage and crew staffing. The system should also be easy to use, understand and train.

Shortly, a contingent from the Navy Sea Safety School paid SERF a visit. SERF is a regional Fire and Rescue Service with headquarters in Borås, Sweden. At the time, SERF was involved in developing tactics for a new firefighting tool – the cutting extinguisher – together with the Swedish Rescue Service Agency. The Navy became interested and decided to obtain a unit for further tests and evaluations.

Numbers of tests and evaluations were conducted and the results pointed out the Cutting Extinguisher as a reasonable candidate for firefighting onboard composite vessels as well as adding enhancing features to shipboard firefighting on traditional steel hull vessels (Dahlberg, 2001).

The cutting extinguisher was found to fill the gap of time between the initial attack and the BA-attack, providing the shipboard firefighting crew to (Averin, Report on trials with the cutting extinguisher, FMV VO SJÖ 38 150: 48280/04 (English translation), 2004):

- 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

In addition, the cutting extinguisher may be used as a clearing tool by itself or by adding a guided cutting frame.

Atalanta Operation

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 costal corvettes, they had to undergo fire zone classification according to *Regler för Militär Sjöfart*[2]*/Naval Ship Code* prior to introduction to the operation fleet at open sea. Compared to insulating zones,

[2] (Royal Swedish Navy, 2010)

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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*.

Fig. 5 Operation Atalanta - Escort by HMS Stockholm[3]

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.

Visby Class Stealth Corvettes

By 2009, FMV and the Royal Swedish Navy had specified the requirements for the cutting extinguisher to be installed onboard the Visby Stealth Corvette Class. The 73 meter corvettes were equipped with dual cutting extinguishers for redundancy; one installed at the bow and one aft. The systems are driven by hydraulic motors, supplied with power from the onboard hydraulic system.

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

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Fig. 6 Visby Class Stealth Corvette

Each of the system reaches to all areas of the ship, thus the redundancy. To complete the systems, a cutting frame unit, with the ability to cut man holes in the composite construction material within 2 minutes, was installed onboard (Averin, Säkrare arbetsmiljö i Somalia - Safer work environment in Somalia, 2011).

Royal Swedish Navy Shipboard Firefighting

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 bright red S on a white field. Hatches and doors are also considered pre-defined attack points, but are not marked – since they open, they usually don't have obstacles on opposite side (Osbäck, 2012).

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.

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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.

Fig. 7 Cobra Attack – Second Attack onboard Visby Corvette

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-designated 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.

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.

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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.

Conclusions

Naval ship applications

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 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 standard firefighting equipment, and is easily introduced to present procedures
- In comparison with 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
- 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
- Self-contained diesel engine system works independently of main power systems
- 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

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

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This paper was presented by Anders Trewe of Cold Cut Systems Svenska AB (CCS) at MAST (Maritime Systems and Technology) Europe Conference 2012. 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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