● International Maritime Conferences ● ICC Sydney ● May 10th – 12th 2022

Novel portable penetration equipment to optimise naval indirect firefighting attack efficacy by simplifying systems and training.

Author, S.T. Battenally
Manderson Engineering Innovations Pty Ltd
Sarah@me-innovations.com.au

Abstract

We have designed a simple, safe portable penetration device and method to fight compartment fires at sea. It could be life-saving.

This novel system is designed to be utilised for indirect firefighting with gas-tight penetration into fire-affected compartments.

The accessory and method are designed to penetrate bulkheads and decks (vessel walls and floors) with a suppression capability that complements a range of sprinkling or atomiser nozzles. Once fitted the device can be operated unmanned, removing personnel from the vicinity of danger.

For the first time, instead of using prevalent naval containment methods - using either existing holes or cutting holes by exothermic methods to access fire - this system can penetrate into the fire with a gas-tight fitting. The system protects against extreme fire behaviour such as flashover, backdraft and fire gas ignition.

The system will likely reduce free surface flooding, human error and skill-atrophy. The device offers an alternative that not only simplifies procedures and training but also prevents firefighters from avoidable hazards.

A spring-loaded bias barb construction, anchors and locks device to secure the nozzle into the fireside of the compartment allowing it to be operated unmanned. The ability to apply a range of firefighting couplings or fire hose fittings on the inlet of the device supports the mariner or land-based firefighter to adapt fittings to the device as required. Providing any emergency team member with a portable compartment fire penetrator system.

This intuitive method could be life-saving and prevent future naval losses.

Keywords: Fire suppression; naval fire; fire at sea; indirect attack; human error; firefighting; novel technology; fire incidents; water mist

1) INTRODUCTION

Fires on ships can lead to the devastating loss of life, injuries, reduction in capability and loss of operational performance. As marine and naval technology evolves, damage control and safety systems also need room to adapt, to save lives, ships and bolster lethality. Accordingly, firefighting within a vessel is an area of increasing concern for mariners and people associated with maritime industries. Although various safety systems are required on most cargo vessels, commercial vessels and naval warships, there must be room for development and to address the gaps in prevalent seagoing and survivability operations. For that reason, the paper will propose a simple, safe portable penetration device and method to fight compartment fires at sea, that could assist in narrowing gaps in current fire safety procedures.

The procedural firefighting response onboard a naval ship can be separated into four phases, outlining the control and recovery defence-in-depth system that is consistent with the Royal Australian Navy Firefighting doctrine and validated by the Defence Science and Technology Group (Gamble et al., 2014).

1. *Manage* - Fire management starts from the instant smoke or fire is detected. It involves establishing a command-and-control communication line between the decision-makers and the crew, setting personnel boundaries and evacuating all other personnel from the affected area.
2. *Extinguish* - With the aim to extinguish the fire, the immediate response is to activate water mist systems where fitted or apply portable firefighting systems before persisting with direct tactics. If successful, a recovery of the affected compartment and systems will commence.
3. *Suppress* - If the fire is not extinguished, it is then managed by suppressing measures which include closing all ventilation dampeners and securing all doors and hatches. At this time, it is imperative that all personnel attacking the fire have been withdrawn.
4. *Containment* - These measures are applied once the fire is near to or has reached fully developed status within the compartment, and all fitted and direct firefighting actions have failed to control or extinguish the fire. The aim in the containment stage of a naval fire is to limit the growth of the fire within the compartment(s) and stop the fire from spreading to surrounding compartments. This requires establishing boundary cooling and smoke boundaries, with these boundary systems intended to starve the fire through a lack of oxygen.

In the containment stage, if a ship's emergency response team cannot stop the spread of the fire, heat or smoke to adjacent compartments, the fire can become uncontrollable and the crew will need to be evacuated. If uncontrolled the fire can progress and lead to extreme compartment fire behaviours such as flashover, backdraft and fire gas ignition. Such fire scenarios were examined and documented in the Command Investigation of the United States Ship (USS) Bonhomme Richard Fire (2020) and the US Navy Major Fire Review (2021).

Technologies for revised methods of indirect firefighting to regain control in the late stage of fires are very few. By proposing the novel firefighting accessory and method in offering the system as a portable sprinkling or water mist tool to optimise processes in the containment stage, it could increase fire incident management options. This is done by providing a temporary penetrator system to apply a gastight and indirect firefighting attack into a compartment from the deck above or an adjacent bulkhead.

This paper proposes a portable sprinkling/water mist penetration tool to reduce free surface flooding, human-error and aid in steaming out a fire. The methods and hardware have been initiated by two passionate maritime firefighters driven to develop firefighting accessories to increase preparedness in the naval, maritime and maintenance environments. The innovative approach could plug a gap in fire management systems and may present solutions to the options and recommendations highlighted in the USS Bonhomme Richard investigation and the US Navy Major Fire Review. Prior to this paper, the device has been referred to as Penetration Technology and identified as the Breach and Attack Tool, or BAT for short. This novel technology was reviewed by the Chief of The Royal Australian Navy, Vice Admiral Michael Noonan, and it has been recognised with the 2021 Chief of Navy Innovation Excellence Award.

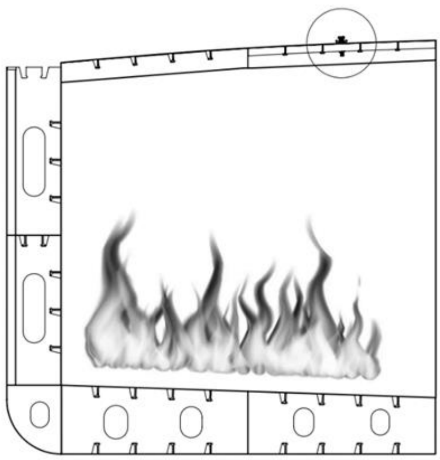

Figure 1: Cross-sectional view of a container ship with the BAT novel penetrator secured into the deckhead of a midships hull section.

Literature Review

The literature is unanimous in identifying the main cause of recent US major fire incidents as a combination of lack of preparedness and human factors. Many recommendations in the literature focus on the implementation of advanced damage control technology and training. They also highlight a need to increase training concurrency and champion a modernisation of damage control equipment to facilitate greater fire attack posture and consequently reduce major fire incidents.

The US Department of Navy held an investigation into the 12 July 2020 major fire onboard the USS Landing Helicopter Dock Bonhomme Richard (LHD 06) and found that the resultant naval loss was due to preventable causes and outlined four operational standard deficiencies leading to the result (United States Naval Institute News [USNI News], 2021).

This incident exemplifies that in maintenance environments, when at port or docking, personnel are transient between other core duties. Crew are intermittently away from the platform and fixed firefighting systems are often shut down. This increases the risk of an inefficient attack while also increasing the likelihood of fire breaking due to activities such as welding. Other factors include a lack of familiarity with platform-specific procedures with transient and new staff and procedural non-compliance which further compounds the risk of a fire.

In addition, The United States Fleet Forces Command released an Executive Summary of the Major Fire Review (2021). The (US Fleet Forces Command [USFF Command], 2021) literature presented an analysis of 15 separate major fires in the US Navy over a 12-year period from May 2008 to July 2020, not including the complete losses of USS Bonhomme Richard or USS Miami. Of the 15 major fire events investigated, 13 occurred during depot-level or unit level maintenance environments, 11 occurred outside of the normal workday, and only two incidents occurred while underway. The report concludes that the units were not fully prepared to fight fires in the maintenance environment. Major issues raised included lack of sufficient temporary systems for fire detection and suppression, lack of firefighting system redundancy, lack of knowledge of shipwide damage control conditions, and absence of a specific, detailed, and rehearsed firefighting plan for the maintenance environment including incorporation and interoperability with shore-based firefighters [USFF Command] p. 8.

Both investigations provide evidence that naval fires are more likely to occur in the maintenance environment. Vessels at sea have a higher level of readiness but need better assessments of preparedness to respond to fires while in port. This highlights the need to address non-compliance and training vulnerabilities in transient maintenance crewing. There is also an urgent necessity for incorporation planning with shore-based firefighters. Had the device and techniques offered by the BAT technology existed at the time, the device could have addressed these issues. The BAT could support a cross-platform readiness, provide a higher-level shipboard fire safety and assist in preventing such major fire incidences.

2) BREACH & ATTACK TOOL (BAT) COMPONENT DESCRIPTION

The undertaking in inventing and developing the methods involved applying learned experience, technical skill sets, and reviewing naval Incidents and command investigations. Experiencing an incongruity in the containment phase and personnel readiness inspired the development of solutions and equipment with a goal to minimise future naval damages or losses. This resulted in a Breach and Attack Tool (BAT) that is user friendly, simply instructed, and can assist in removing dangerous and complex steps in regaining tenable compartment fire access.

To assist in effective learning and reduce training shortfalls, the BAT is a one-system-fits-all approach. BAT may help in strengthening the emergency team's operational ability and efficient incident management through simple, portable and intuitive product design, and centralised training. The component-level design of BAT is unpacked below.

The inlet
On the rear of the device are fittings for connection to a source of fire extinguishing agent. This fitting can be changed to work with any required firefighting hose, or air fittings to mate with a pressurised cylinder of fire suppressing agent. For this example, a 38mm Storz fitting has been used.

The conduit
An internal passage makes up the central pipe extending between the inlet at the rear and the outlet nozzle at the fore-end. The internal pipe allows the firefighting agent to flow through the device to the nozzle.

Securing grapnel hook arrangement
The front-end incorporates a securing grapnel hook design. Acting between;

- *A retracted configuration:*
  The barbs are obtained within channels, allowing a smooth pass through the aperture.
- *A deployed configuration:*
  When the barb members fully penetrate the aperture, they are biasedly spring-loaded to the deployed configuration.

Closure and tensioning wing nut
The body has a threaded external feature complimenting the wing nut. The operation applies tension on the body between the closure and the deployed barb members. Ensuring gastight operation once the device is secured through the aperture in the bulkhead; allowing the device to be fitted in place and operated unmanned.

The outlet
For this example, the fore-end of the device is fitted with a full cone sprinkling nozzle. This nozzle can be interchanged to any design required. The components entering the affected compartment will be manufactured with considerably fire-resistant material, such as 316-grade stainless steel. Once tensioned the device is gastight, when charged it allows a fire extinguishing agent to penetrate the affected compartment to attack the fire and apply a cooling effect to the compartment.

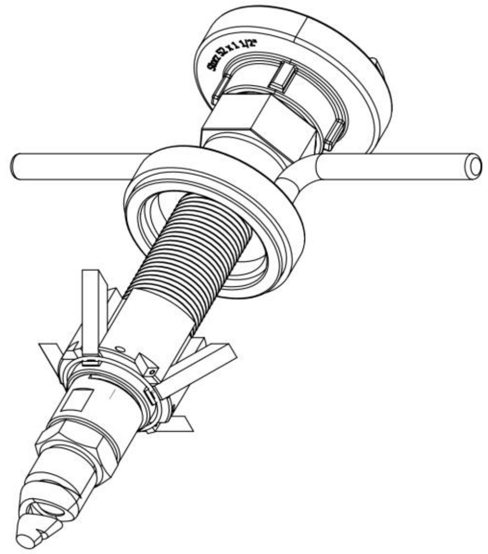

Figure 2: Spray nozzle adapted BAT.

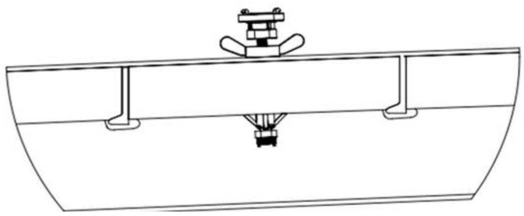

Figure 3: Water mist nozzle adapted BAT.

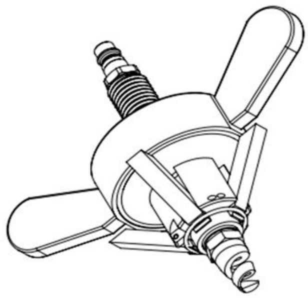

Figure 4: Shipping container adapted BAT.

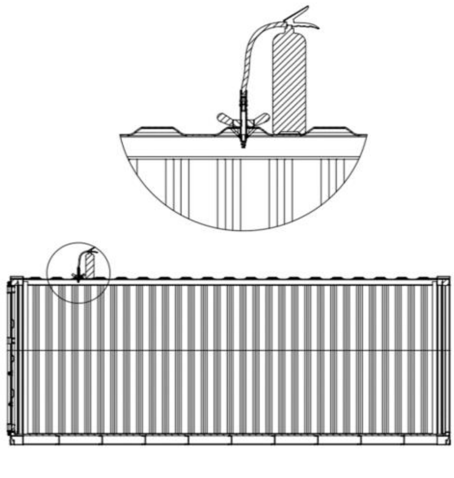

Figure 5: BAT penetrating a shipping container.

3) METHODS AND PROCEDURES

The steps in deploying the Breach and Attack Tool are:

a) Connecting the BAT device to the hydrant hose (Un-charged)
b) Preparing the aperture. - Using a high torque, low-speed cordless drill, arbor extended bar with a hole saw and nylon plug. [NOTE: A nylon disk (plug) is fitted on the extended arbor, it blocks the aperture when disconnecting the cordless drill from the hole saw, sealing the two compartments.]
c) Penetrating through the bulkhead, by drilling through the entire bulkhead/deck including any initialisation installed on the other side. [NOTE: Penetration points will be predetermined and marked-out to avoid severing electrical cabling, encountering pipework, I-beams, trunking etc.]
d) Disconnecting the drill leaving the hole saw and nylon plug within the aperture.
e) Directing the BAT towards the aperture inserting a fore-end and nozzle through the bulkhead. [NOTE: The nylon plug is tapered 1mm larger than the opening, under its own weight it will remain in the aperture. When pressure is applied both the hole saw drill bit and plug will transit through the hole and become sacrificial to the fire torn compartment.]
f) The firefighter should then attempt to retract the device to test the deployment of the barbs. In this step, a focus was placed on designing a robust and appropriate biasing operation that can support rapid incursion and securing. Its shape with the barbs encapsulated in channels mostly blocks the hole/aperture on entry. The minimalistic exposure reduces smoke, fire, or air regress on entry when married to an ideally sized penetration hole.
g) Engaging tension on the wing nut at the rear end of the device will fix the barb members against the fireside of the bulkhead. [NOTE: With bulkheads having many materials sandwiched between the inner and outer wall and of differing thicknesses, the BATs extended threaded body allows it to adapt variable penetration depths.]
h) Return to the hydrant and operate the valve at full pressure for 2 to 4-minutes.
i) Using thermal imaging or laser temperature sensors, assess the temperature of the compartment bulkheads for the desired cooling effect/ tenability before applying more cycles.

4) EXPERIMENTAL SETTING

Computational Fluid Dynamics (CFD) was conducted to understand the basic internal flow characteristics. ANSYS software supported a simple mathematical evaluation of the internal pipe designs' effect on freshwater flow velocity and pressure loss. As the device is centred around the delivery of water through a pipe the internal design could be easily tested. The CFD model supported a 38mm Storz hose connection at the inlet and compensated for the sudden contraction of a 1-inch N7 U.S Coast Guard approved nozzle at the outlet. This experiment did not include the K-factor of the nozzle as this component is interchangeable with any type of nozzle that is required to suit the fire incident and environment.

The experiment applied an assumed inlet flow rate condition of 400 litres per minute, of fresh water at 20 degrees resulting in an inlet flow velocity of 5.0352 m/s. This assumption was made considering friction losses to the point of penetration, Sydney wharf side fire hydrants and ideating the flow to volume characteristics to support a large compartment.

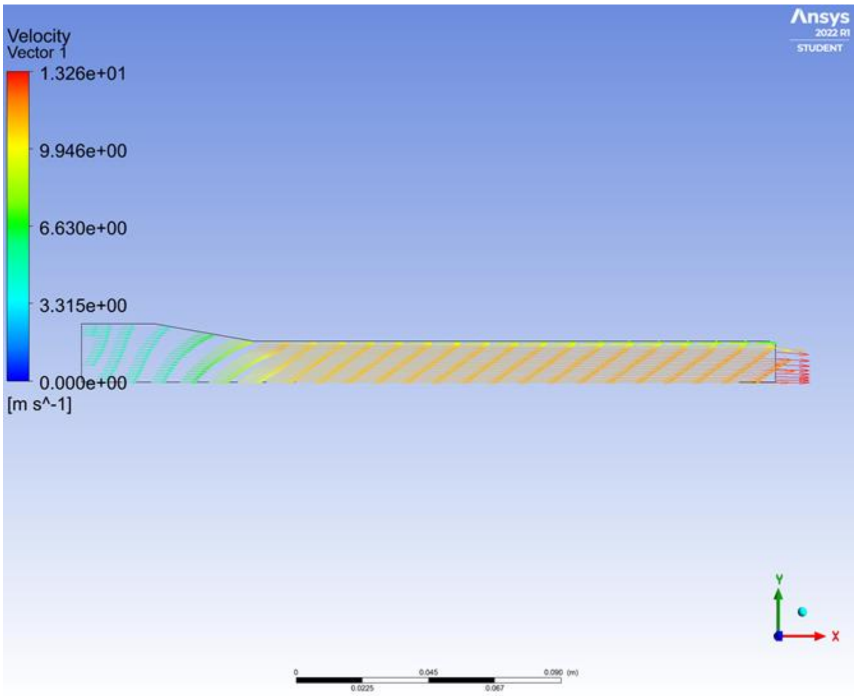

Figure 6: CFD streamline flow velocity contour with vectors.

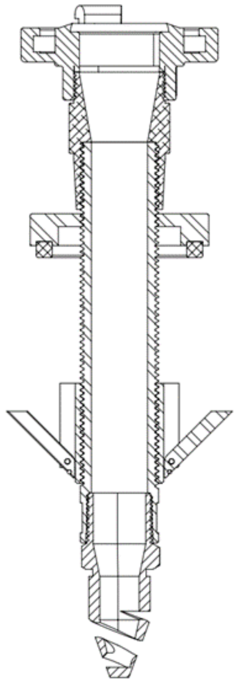

Figure 7: Sectional view.

The resultant CFD modelled the flow velocity, the vectors can be viewed by the streamline contour (left). The computational results found the velocity on the outlet of the pipe to be: 13.26 m/s equating to 47.736 km/hr. Applying a pressure and velocity coupling and defining absolute pressure on the outlet, returned a pressure differential over the pipe of 93.8 KPa or 13.6 PSI. These characteristics support the N7 nozzles manufacturers operating flow rate parameters for a 120-degree full cone fog to penetrate a fire and assist in steaming out a compartment fire. Further investigation, live testing and analysis are required to support this modelled evaluation.

To reduce the effects of free surface flooding, simulation and testing would be required to provide greater insight. A cautionary recommendation would be for the accessory to be operated in an on/off cycle of at most 2 to 4-minute intervals, with the firefighting team I/C ready with a thermal imaging camera to check for the desired cooling effect before conducting further cycles. Further CFD, platform analysis and live testing are needed to support this theory.

The accessory and method are designed to provide a through-bulkhead/ through-deck fire suppression system that can complement a range of sprinkling or atomiser nozzles. Allowing a platform engineer to model and equip the crew with a compatible firefighting nozzle for the

Platform-specific modelled fire situations. Alternately, the platform could have in emergency locations a ready use BAT as redundancy for any shipborne fire mishap.

5) PROPOSED SOLUTION AND FUNCTION

The Breach and Attack (BAT) Tool could comprehensively address the four operational challenges that led to USS Bonhomme Richard fire [USNI News]. The combination of operational factors pointed out in the report were: 1. Material Condition, 2. Training and Readiness, 3. Shore Establishment Support, and 4. Oversight. The ensuing paragraphs discuss how BAT could address these challenges.

1. Material Condition

In the USS Bonhomme Richard fire, 87% of the ship's firefighting systems were under maintenance and inactive. However, the BAT design circumnavigates the material condition of the vessel because it is completely portable and can be operated with or without the ship's fitted systems. The design will operate independently of ships' power or any external energy sources. It only requires a charged fire hose and a cordless drill fitted with an extended bar and hole saw. The system is portable and can be stored in a pelican case, meeting military shock grade. It is light, portable and transported simply by a single crew member in full firefighting attire. The BAT prototype housed within a pelican case, including the cordless drill and drill bit, weighs under 10 kilograms. Any sea fit crew member could lift and carry 10 kilograms to the scene of penetration.

Bulkhead/through-deck materials on ships vary and the BAT can accommodate for various depths and materials. The locking and securing mechanism can adapt to the varying thickness of ship bulkheads. The BAT is designed with a threaded wing nut and a hose connector at the back and expanding grapnel hook on the fore-end. BAT's design has locking strength to hold against the force of the spray and the length of the treaded body allows it to adapt to the varying thickness of bulkheads. The design considers the ability of the device to be removed after being exposed to heat. The components are made with 316-grade stainless steel with high durability in extreme temperature environments.

BAT could reduce the life-threatening issue of backdraft by having no open cavity when being used, this is achieved by simplifying the practice of rapid gas-tight procedures (as mentioned in method steps above a-i). The oversized wingnut houses a heat-resistant packing/O-ring with a larger circular footprint than the drilled hole. This material is sandwiched between the wingnut and bulkhead like a gasket creating a gastight seal. Having the single thread in the centre allows for an even crushing pressure to be applied to the sealing material, getting the full pressed capability out of the material in a single action. The circular relationship also helps to evenly control and dissipate the impulse and momentum forces when operated in cycles to discharge the firefighting agent. The ship's power was off during the initial hours of the USS Bonhomme Richard fire. It had Inactive, secured power conditions and unavailable fire-fighting systems. The BAT, if deployed, would have been totally accessible instrumental in overcoming these issues. It could have been an easy, portable, simple solution.

2. Training and Readiness

The investigation to USS Bonhomme Richard fire found major gaps in training:

"The training and readiness of Ship's Force was marked by a pattern of failed drills, minimal crew participation, an absence of basic knowledge on firefighting in an industrial environment, and unfamiliarity on how to integrate supporting civilian firefighters" [USNI News]

The BAT could address these issues. All Seafarers, Naval and Maritime personnel have to conduct training in shipboard survivability as a requirement of their duties onboard a seagoing vessel. Such training is delivered to international high standards. Mariners are instructed to perform steps and activities in relation to the lifecycle behaviours of fire. Training is proven to increase reaction timing and benefit the survival of the crew and platform.

The training and readiness of the BAT is based on natural instinctual processes and simplifies training and readiness. It leverages prior knowledge and to operate it is a right-hand thread. Like the rhyme, "righty tighty, lefty loosey" - the core operation is as simple as turning a tap. This simple survivability step could increase reaction timing. It could address the ***absence of basic knowledge***. The simplicity of operation, training and readiness could benefit the survival of crew and platform.

The basic familiarities to maintain human skill currency are a necessity to react swiftly and appropriately in these emergency situations. It could be said, current complicated processes need vast amounts of focus and bravery, intensifying the human factors that contribute to an inefficient attack, loss of compartment, or even loss of life and ship. If training is simplified, it is easier to practice and perform. The self-locking feature allows unmanned operations, removing crew from the scene and ***addresses the need to increase participation***. It takes one or two people to operate and they may feel safer knowing they can leave the scene of the hot spot.

Another hurdle for ***firefighting in an industrial environment*** is navigating the available fitted systems and containment of the fire. The BAT is a novel approach. Detailed cut marking could reduce human error when penetrating and could be clearly marked and learned. Personnel can clearly understand where to drill. These location markings could be marked onto the deck and bulkheads to locate ideal penetration points for all compartments. Drafted by a suitably qualified engineering naval architect to avoid the nozzle operation from being impeded by cabling, trunking or pipework etc. Also, ensuring minimal structural damage is incurred by the cut.

The Bonhomme fire found there were 14 consecutive ***failed drills.*** The BAT addresses this by providing an opportunity to build confidence for personnel in the attack party. The BAT can be inserted into the entry and could create a cooling effect when fire teams re-enter the fire impacted compartment. When applied to or adjacent to a scuttle, door or hatch with a water mist nozzle, the atomised mist can create a cooling wall effect, preventing a heatwave from exiting upon opening a compartment and assisting the fireteams' re-entry. The BAT could address the second issue of training and readiness in the USS Bonhomme Richard fire.

3. Shore Establishment Support

The BAT could address the third issue of shore establishment support in the USS Bonhomme Richard fire, by providing Interchangeable fittings for familiarity and sacrificial components. It's almost a set and forget device, similar to operating ships fitted system however it is independent portable and can be an integrated mutual aid asset. The device can be easily integrated to fit all maritime fire hoses or shore-based fire hose fittings.

''Of note, FEDFIRE hose fittings are not compatible with hoses and fittings aboard Navy ships. Both FEDFIRE and BONHOMME RICHARD personnel noted the differences in threading prevented FEDFIRE and BONHOMME RICHARD hoses from being connected." [USNI News]

Having the fire hose connector fitting interchangeable by a threaded connector by intermediate fitting rather than welded or swaged on the rear of the device gives an opportunity to support interoperability with civilian firefighting equipment. In supporting an interchangeable fitting on the conduit body, the device can be easily changed to comply with all hose fittings. The BAT supports the mariner or land-based firefighter to adapt fittings to the device as required. Providing any emergency team member with the complementary mechanisms of a portable penetrator to perform indirect firefighting tasks in a time-sensitive and critical environment, for any ship's staff or external firefighters.

The rear application of fittings creates a simple process of removing the device from its fixed position when reclaiming the compartment. By removing the hose connector on the rear and fully untightening the wingnut off the rear end, the firefighter can push the body of the device through the hole/aperture. It can be assumed the nozzle and fore-end components may become brittle after exposure to extreme heat and are sacrificial to fall into the compartment. This design not only addresses unfamiliarity with Navy vessels for shore-based and civilian fire crews but also readiness as explained in point 2 above. The USS Bonhomme Richard fire and structure of the response was unfamiliar to crews. The BAT on any ship is a mutual asset that can overcome the typography and mapping of complex onboard systems to better support shore-based firefighters.

4. Oversight

It could be said it is difficult to have oversight control in critical thinking emergency response environments. However, emergency drills are continually practised alongside and underway to ensure mariners conduct firefighting procedural competency. Ships' staff are encouraged to apply critical thinking within their ability to improve efficiency. Commanding Officers (CO) and Captains cannot always control critical thinking as firefighting is not the focused expertise of crew members. Therefore, oversight execution in fire emergencies is regularly managed by the categorisation of set roles and responsibilities.

In addition, firefighting drills are mostly designed and validated experimentally through CFD fire modelling of the platform configuration and crew reaction times. This evaluates the crews' ability to meet the fire challenges and employs event tree analysts to predict the suppression or spread of the fire, calculated on the crew's actions. The event tree analysis collates optimised crewing and procedural approaches to successfully attack a fire and builds on a culture of managed crew roles and responsibilities in fire emergencies. Maritime and naval oversight employee training programs advise the crew to follow these steps and procedures.

However, domestic firefighters encourage and prefer critical thinking by applying their extensive training and understanding of fire behaviour, COs and Captains of seagoing vessels cannot control or access the same aptitude standards and experience of their crew. The BAT is not aimed at changing current procedures but to provide an access route to an extra layer of protection in management options and could complement fire protection defence-in-depth architecture. Implementation of the BAT can support an access route to a level of critical thinking, as it can be adapted to any compartment. It could function as redundancy, or it can be applied as a directed manual firefighting tactic. The versatility to changing applications allows the BAT to adapt to different suppressant agents and compartments like switchboards, ammunition lockers, battery storage, hazardous chemical, paint storage, or warehouse doors. This could also support warfighting and damage control management in resource critical environments. The BAT could offer an increase in incident management options to the CO and command teams.

Oversight could be complemented by applying pre-set incursion mechanisms. For large machinery compartments with high fire risk equipment and storage, there may be a necessity for multiple penetration location markings. These markings can identify the equipment or machinery it is designed to protect. This would allow greater control to give crew specific commands.

On the fourth day of the USS Bonhomme Richard fire, the ship's stability was heavily impacted by free surface water. The warship gradually developed a starboard list after the introduction of firefighting water accumulated high in the structure. This required brave personnel to conduct active ballasting and dewatering techniques. As the fire raged, numerous parallel dewatering and stability actions were taken to counter the list to prevent the longitudinal bending stress and unstable conditions of the warship. The BAT operating methods could protect vessels from issues of free surface flooding by providing oversight control through the procedure to reduce the volumes of water in either a water mist or sprinkling and operating the system in short time intervals. The time intervals allow water droplets to displace oxygen by evaporating and creating a thermal management capability, assisting in suffocating the fire and reducing the temperature within the compartment. The stop interval provides an opportunity to inspect the bulkhead temperatures and assess if the cooling is effective. This approach can reduce free surface water, minimise overall water damage and reduce the risk of unstable conditions. The BAT could have been a solution to address components of the fourth issue of oversight in the USS Bonhomme Richard fire.

6) CURRENT STATE OF SOLUTION AND FUTURE RESEARCH

The current prototype could benefit from prototype testing and trials through engaging academic, naval, civil or industry collaboration to substantiate the discussed BAT potential solutions. This could be achieved through a collaborative, systems engineering approach. The possible testing may include a further spectrum of CFD fire and flowrate modelling, investigations into kinematics, mechanics of solids and would likely need to be supported by controlled fire tests and evaluations. To move the technology forward, focused academic, naval, civil or industrial relationships could benefit the BATs implementation through meeting applicable standards defined by legislation or client performance specifications. Planning thorough design analysis and functional testing could complement the BATs validation and assist in the processes of obtaining a certification baseline in Australia or internationally. The photos below (Figures 8 and 9) are examples of early prototype development. The following intentions are to draft a test and evaluation plan however, collaborative research and diligence would ultimately be required for the BAT to be employed in any engineering shifts to fire risk management.

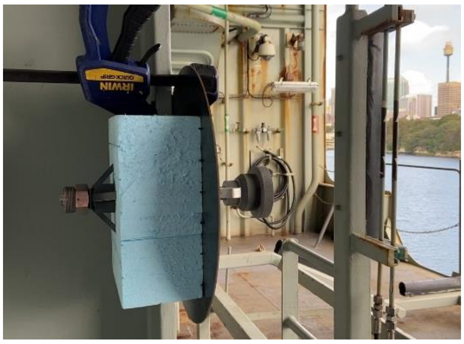

Figure 8: HP Jet Fusion 4200 3D printed BAT prototype to suit 3/8-inch atomising nozzle, penetrating a simulated bulkhead.

Figure 9: 316-grade Stainless Steel BAT prototype to suit 3/8-inch nozzle (nozzle not included) with drilling equipment in portable shockproof case.

There also needs to be research on current solutions such as US Navy Portable Exothermic Cutting compared to BAT drilling operations. The below photos (Figures 10 and 11) show the hot spots where exothermic hull cuts were made on the third day of the fire – requiring personnel to be sent in to make hull cuts [USNI News] p. 66. BAT drilling operations by design could be a safer alternative to hull cuts by exothermic processes at areas of extreme heat. The BAT design attempts to avoid opportunities for backdraft, flashover, fire gas ignition and escalation of fire which could happen in situations with exothermic cutting. The effects of exothermic cutting into hot spots are not divulged in detail in the reviewed literature.

Figure 10: "A standard photograph was taken by the drone." [USNI News] p. 65

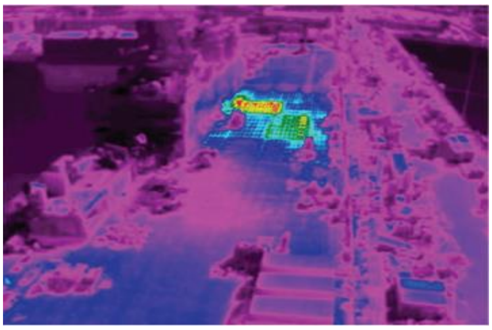

Figure 11: "Simultaneously by the same drone, a forward-looking infrared (FLIR) photograph was taken to identify hot spots for the targeted indirect attack via exothermic hull cutting." [USNI News] p. 65

7) CONCLUSION

This review has recognised the human factors related to an efficient attack on maritime fires specifically in the USS Bonhomme Richard fire. This case study highlights a need to reduce skill atrophy, improve preparedness and provide modernised penetration procedures. The BAT offers functional solutions and methods aimed to increase training readiness posture and provide a new level of individual preparedness. This proposed novel firefighting accessory could be held in emergency stations on every ship.

The BAT design is a novel technology inspired by preventing naval and maritime losses. It is a unique tool in the modernisation of damage control equipment with the aim to help combat preventable losses on vessels. It offers an alternative that simplifies procedures and training and prevents firefighters from avoidable hazards. It could save lives, ships and capability.

The method could improve emergency access to all compartment fires while increasing capability and speed in attacking any fire at sea, alongside or during maintenance. The system can work independently of the ship's power. It is portable, simple to use, requires basic training with previous common knowledge and is less than 10 kgs. Implementing the BAT procedure could provide more clarity around indirect attack methods and potentially increase survivability.

This new procedure with its optimised training practices to compliment survivability and ship safety is user friendly and training could be undertaken with ease. It adds a new layer of defence in fire safety that may give equivalent protection to mitigate those systems frequently shutdown or tagged out during maintenance. Penetrating compartment boundaries to attack a fire is imperative to keeping the crew safe and reducing the likelihood of fires in adjacent compartments. However, maritime firefighting practices as applied in the USS Bonhomme Richards fire use processes and equipment that exposed a high risk of human error and skill-atrophy that reduced the overall effectiveness of the response.

This paper proposes a better method of fighting a fire through indirect attack by identifying key points of failure. The BAT is a portable, rapid, and gastight penetration device and its various unmanned applications could improve practices in pre-set incursion mechanisms and extinguishing abilities by an interchangeable nozzle and hose fittings.

This is a basic technology to combat human error and explores methods to enhance usability, systems, and preparedness. Further investment and collaboration are needed to support the proposed novel firefighting accessory and its optimised training practices to complement survivability and ship safety.

8) REFERENCES

1) Department of Defense United States of America. (2021). *Command Investigation into the Facts and Circumstances Surrounding the Fire Onboard USS Bonhomme Richard (LHD 6) on or About 12 July 2020* (pp. 1 - 334, 375 -391). [Redacted]: [Redacted].

2) *For Release BHR Command Investigation (20 Oct 21)*. United States Naval Institute News. (2021). Retrieved 6 December 2021, from https://news.usni.org/2021/10/20/navy-investigation-into-uss-bonhomme-richard-fire-major-fires-review.

3) *For Release Major Fire Review (19 Oct 21)*. United States Naval Institute News. (2021). Retrieved 6 December 2021, from https://news.usni.org/2021/10/20/navy-investigation-into-uss-bonhomme-richard-fire-major-fires-review.

4) Gamble, G., Suendermann, B., Mathys, Z., & Woolley, A. (2014). *Fire Modelling and Event Tree Analysis for Naval Platform Fire Incidents*. Research Gate. Retrieved 15 February 2022, from https://www.researchgate.net/publication/327390980.

5) Manderson Engineering Innovations Pty Ltd. (2020). Firefighting accessory and Method Therefor (PCT/AI2020/051319). Retrieved 15 December 2021, from. Mr James Manderson.

6) United States Fleet Forces Command. (2021). *Major Fires Review Executive Summary* (pp. 1 - 57). [Redacted]: [Redacted].