Saving time saves lives

Global innovation in submarine rescue

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Abstract—**The world of the submariner is a hazardous one and will only become more challenging with the proliferation of submarine-capable navies especially in the Indo-Asia-Pacific region. More submarines means more submarine warfighting and potentially more submarine rescuing. JFD Australia, the provider of the submarine rescue system to the Royal Australian Navy, discusses its submarine rescue capability and the challenges and innovations that go with providing such a critical service to Australian submariners. In the event that a crew on board a disabled submarine requires rescuing, JFD can deploy its submarine rescue vehicle and, once rescued, submariners can be treated using JFD's transfer-under-pressure chamber (TUP) and hyperbaric equipment suite (HES). The new TUP and HES represented a $19.7million investment in submarine rescue in Australia and, following the launch of the equipment in April 2018, means that, for the first time, the entire crew of an Australian submarine could be treated simultaneously. Australia now has its safest ever submarine rescue system. JFD has designed and built submarine rescue systems for both Singapore (which it operates and maintains) and Korea – systems built in a parallel strategy as a result of innovative thinking which saw a reduction in risks to operators and equipment as well as significant savings in costs and delivery time. Most recently (2018 and 2019) JFD provided two complete air-transportable submarine rescue systems to the Indian Navy, including a deep search and rescue vehicle, launch and recovery system equipment, a transfer-under-pressure system and all logistics and support equipment required to operate the service.**

I. OVERVIEW OF SUBMARINE ESCAPE AND RESCUE

The very notion of rescuing a crew from a disabled submarine has long proven a highly technical challenge for engineers, who, over the decades, have had to create and innovate systems that can operate quickly and safely in what will always be a race against time to save lives. Time – to the first rescue and, importantly, time to the last rescue, when the final crewmember leaves the vessel, will always be the overriding motivation in developing a fast, safe and trusted submarine rescue system. Submarine rescue has been and will always be about keeping submariners safe. It is the insurance policy when all other systems designed to keep our submariners safe have failed.

The first successful submarine rescue was from the sunken USS Squalus off the coast of New Hampshire in 1939 when US Navy divers safely transported 33 survivors to the water's surface in a 40-hour operation using the newly developed McCann Rescue Chamber which was a large, steel rescue "bell". This bell, with two operators, transferred eight submariners at the one time to the ocean's surface. It was, by every measure, an historic moment for sub-sea rescue and little could those innovators know that when they were successfully moving that crew safely under pressure to the water's surface, they were also setting the global benchmark in submarine escape and rescue.

Fast forward 80 years and in 2019, many of the world's navies have a submarine rescue capability: Australia, the United States, Sweden, India, Singapore, Korea and the North Atlantic Treaty Organisation nations in a service provided by Norway, France and the United Kingdom. And, with more countries rushing to procure a sovereign submarine fleet, the demand for submarine escape and rescue systems will grow. It must be also noted that in the past two years, there have been two submarine disasters that have not only captured world attention but have demonstrated the importance of nations having a sovereign submarine rescue capability. In July 2019, 14 submariners died after a fire aboard a Russian research submarine, the Losharik AS-31 in the Barents Sea. The fire is thought to have started by a faulty lithium-ion battery and sadly, those who perished were trying to extinguish the flames, highlighting the acute risk of all submarine operations. In November 2017, the ARA San Juan with its crew of 44 vanished off the coast of Argentina while returning from a routine training exercise. It was this tragedy in potentially rescuable water (rescuable water is generally in water at depths of up to 600 metres, after which, the depth becomes too challenging due to many rescue vehicles only being certified to dive to 600 metres sea water), that immediately sparked the international submarine rescue community into calling the nearest submarine rescue system. In this case it was the US Navy's system based in California that was called upon to rapidly mobilise and get to the scene as quickly as possible although Australia's system was alert and ready albeit slightly further away.

Submarine rescue will always be about saving time to save lives and one of the most frequently talked about topics is the time to first rescue (TTFR) and the time to first intervention (TTFI) but crucially, the time to last rescue (TTLR) is equally important as the window for a safe and successful rescue diminishes as time goes by.

II. AUSTRALIA'S SUBMARINE RESCUE CAPABILITY

It was in Australia, in 1994 with the commissioning of the Collins-class submarines, that the Royal Australian Navy and the Federal Government of the day, decided that a submarine rescue system was required to support this new sovereign capability. This rescue system is housed and maintained at Bibra Lake, south of Perth where it is “rescue ready” at 12 hours’ notice to deploy to a disabled submarine anywhere in the world.

The Operating Concept for rescue of its crew from a disabled submarine (DISSUB) within the Royal Australian Navy consists of a two-ship capability; an intervention capability embarked on the Escape Gear Ship (EGS) whose task it is to speed off at immediate notice to the known location of the DISSUB and provide initial assistance to crew members whom may have escaped from the submarine and/or provide pre-rescue reports on the condition of the DISSUB through deployment of its Remotely Operated Vehicle (ROV) and exact location through the use of the EGS’ portable side scan sonar. The second ship known as the Rescue Gear Ship (RGS) has embarked on it JFD’s complete integrated rescue and hyperbaric treatment capability. Arriving after the EGS, the RGS and its capability will dive its submersible and affect the rescue of crew of the DISSUB and return them to the surface for treatment and repatriation. It is the synchronization of these two gear ships, the orchestration of their complementary capabilities and the integrated rescue/treatment capability of the RGS that saves lives through saving and minimizing rescue time.

It is the latter piece which is the main topic of this paper as the new rescue/hyperbaric treatment capability is a fully integrated system that is comprised of three main components: a submarine rescue vehicle, a transfer-under-pressure (TUP) chamber and a hyperbaric equipment suite (HES). The submarine rescue vehicle is a free-swimming (as opposed to tethered which is connected to the surface ship via an umbilical) ‘mini’ submarine that is fully air-transportable. Importantly, it has a pilot trained to steer the vehicle directly to the disabled submarine. The significance of having a person in this vehicle cannot be understated as human contact in what is one of the most life-threatening situations a submariner will confront, informs profoundly, that help has arrived.

The system is maintained by a team of highly-skilled engineers and tradespeople, supported by a large and experienced supply chain able to mobilise the vehicle, be it by road, sea or air to the closest available supply ship for the rescue to commence. Ideally, this process, from the initial call for assistance to the time to first rescue will take no longer than 72 hours. Once at the site, the rescue vehicle with its pilot, is launched into the water to locate the disabled submarine before attaching to its hatch. This is called mating and upon confirmation that this occurred, the submariners are moved through to the rescue vehicle which transports them safely to the surface and the deck of the ship. From here, the crew is moved through the transfer-under-pressure chamber ensuring that at no time, do they suffer the life-threatening effects that come from being rescued from pressurised water. The last stage of the operation is when the rescued personnel move from the chamber and into the hyperbaric equipment suite, a decompression chamber where those rescued can recover, and if needed, receive treatment from medical staff to combat any physiological issues that have come from being under pressure, under water.

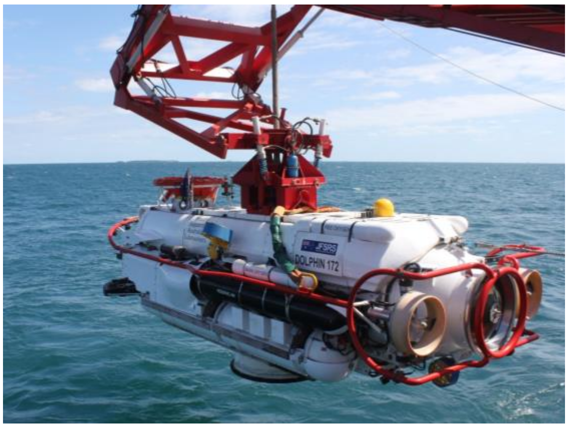

Figure 1. Australia’s submarine rescue vehicle

III. AN EXPLANATION OF THE HYPERBARIC EQUIPMENT SUITE

Australia’s hyperbaric equipment suite (HES) is an investment of $19.7m that was delivered to the Royal Australian navy in April 2018. Two years in the making, it is the final piece in a life-saving jigsaw that, very significantly, means Australia now has the full capacity and capability to treat the entire crew of a Collins-class submarine, 48-60 personnel, at the same time. It is, by every measure, a major enhancement to Australia’s submarine rescue capability, greatly reducing the time that submariners are in distress and importantly, as an operational requirement, it is maintained in a state of readiness at all times.

In a nutshell, the rescue system integrates and operates together to enable evacuation and hyperbaric treatment (planned and controlled decompression) of rescued personnel either through medical treatment following surface abandonment or evacuation using the submarine rescue vehicle. Of critical significance, the HES is air-transportable which gives it the flexibility to be mobilised to a disabled submarine anywhere in the world. The whole rescue system can be transported on numerous trucks, usually 19-20 and then flown by C17, AN24 or Boeing 747s around the world. It constitutes two recompression chambers (RCC), two sets of bellows to interface with the TUP, one 3-metre environment control system (ECS) and one 6-metre high pressure air compressor (HPAC) support container. The HES RCC is a three-compartment hyperbaric chamber with a maximum occupancy of 36 people. Recompression chambers RCC1 and RCC2 are operationally identical but have been configured to be a mirror of each other with control panels mounted on one side such that when installed side by side, the central access between the chambers functions as a chamber control room. When filled to capacity, the HES is capable of providing hyperbaric treatment to up to 88 occupants (by way of reference, a Collins-class submarine generally has a crew of 48-60). To support and treat rescuees and ensure flexibility of the chamber, several of the chamber’s occupants will be chamber attendants or medics. The HES system has been designed to maximise its flexibility and as such, the total occupancy of the HES across the TUP and RCC chambers at 88, allows for the number of chamber attendants and medics to be adjusted to suit the operational requirements of a rescue operation.

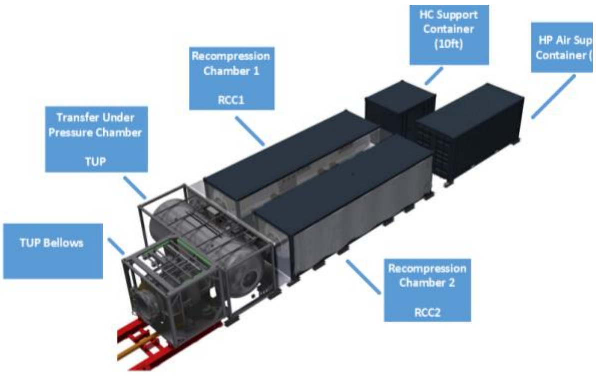

Figure 2. Australia’s hyperbaric equipment suite

TABLE I. RCC SPECIFICATIONS

RCC Specification		
Quantity	2	
Dimension	L 30’ x W 8’ x H 8’6” (ISO container)	
Volume	Entry lock	5.9 m^3
	Treatment lock	8.4 m^3
	Decompression lock	8.2 m^3
	Medlock	0.021 m^3
Estimated Weight	20t per RCC including ISO frame	
Capacity	Entry lock	8
	Treatment lock	14
	Decompression lock	14
	Medlock	36
Hatches	- 1 fitted to TUP manways - 2 internal - 3 Entry/Exit	
PD5500 vessel category	1	
Corrosion allowance	1mm	
Materials	Main shell, heads, nozzles, supports	Carbon steel
	Flanges, minor bosses (where possible)	Stainless steel
	Hatches	Aluminium alloy

For normal operation, the HES requires installation on to an approved vessel such as MV Stoker or an assessed Vessel of Opportunity (VOO) with the specific sea fastenings assessed by a suitably qualified naval architect. For installation on to MV Stoker, each of the system’s components are lifted onto the vessel and secured to the deck using specifically configured sea fasteners. Installation typically would require the creation of a deck grillage onto which the HES would then be installed and welded in situ. Such installations require engineering assessment and are evaluated as and when required. Installation of the HES onto a VOO is unique to the specific vessel and is planned and evaluated for each installation therefore the configuration of the HES onto a VOO can vary depending on the VOO’s design with optional configurations including Aft launch and Side launch. As the HES is installed as part of the overall submarine rescue system, it is integrated into the overall electrical system too. For manned operations, the HES must have two independent power supplies, typically from the vessel with a secondary supply from a deck mounted generator.

TABLE II. MAXIMUM OPERATIONAL SEA STATE

Maximum Operational Sea State	
Accelerations	
Significant wave height: 5m	Design loadings shall be defined IAW LR LAME
Maximum transit (un-operational) Significant wave height: 10m	Design loadings shall be defined IAW LR LAME
Design acceleration: IAW LR LAME & cargo securing arrangements	In accordance with AMTDU requirements
Pressure	
TUP and RCC operational: 0 to 5 bar (g)	Design loadings shall be defined IAW LR LAME
Test: 7.4 bar (g)	Test pressure will be calculated IAW PD 5500
Wind loading	
Operational	Up to 35 knots
Non-operational	Up to 60 knots

For provision of life support, the HES provides breathing quality air and oxygen to each of the chamber locks that is for use in maintaining a respirable atmosphere and provision of hyperbaric therapies such as breathing of 100% oxygen through the chamber’s in-built breathing system. The level of oxygen in the RCC atmosphere is kept within prescribed limits by adding oxygen as it is consumed metabolically. The required oxygen volume can be calculated for the transfer into the RCC assuming that each person breathing normally will consume 0.5L/min irrespective of pressure. It remains overwhelmingly the top priority that the safety and wellbeing of HES occupants and operators will always be the overriding factor in any rescue scenario. With such a technically advanced piece of equipment, there are some significant operational requirements. Obviously, only suitably qualified and experienced personnel may operate the HES system and JFD Australia has a team of approximately 80 highly experienced engineers and tradespeople as well as a strong and reliable supply chain familiar with all aspects of the kit. This team is put to the test each year in a series of gruelling simulated training exercises off the West Australian coast, Black Carillon, where, working in partnership with the Royal Australian Navy, JFD puts each component of the submarine rescue system through a range of scenarios designed to replicate a real-life submarine rescue emergency.

IV. THE FUTURE OF SUBMARINE ESCAPE AND RESCUE

There is constant and continual innovation and investment in the best possible technology to ensure that submarine escape and rescue systems can save as much time as possible to save lives. In early 2019, JFD delivered into the service of the Indian navy a 3rd generation submarine rescue system that marks a pioneering step-change in real world submarine rescue capabilities. Working in partnership with the Indian Navy and based at that nation’s submarine rescue unit in Mumbai, the submarine rescue vehicles, of which two have now been accepted, have been designed with a weight that optimises maximum payload while still safeguarding their transportability which as previously stated, is a critical factor in minimising the time to mobilise the system and the time to first rescue.

The submarine rescue vehicles are capable of operating at greater depths than most other comparable vehicles, giving the crew the reassurance they need that there is an effective and robust capability should an incident arise even in the most challenging ocean conditions. These vehicles demonstrate where the future lies, optimising speed and manoeuvrability. Speed, because it will always be about getting to the submarine as quickly as possible, that important time to first rescue and manoeuvrability, because while in an ideal world a disabled submarine would land the “right way up” on the sea floor, in the real work it is important to prepare for all types of logistical situations and to have the ability to mate with any submarine even those that might be subject to inclination or leaning on the seabed is a unique capability that further enhances submarine rescue around the world.

From the early innovators of the 1930s to today and the technological developments that continue to be seen around the world, the focus has never wavered, submarine rescue is and will always be about keeping submariners safe. Increasingly, submarine rescue has become a key sovereign capability and the importance of providing a trusted, fast and safe submarine rescue system can never be understated. Australia now has its safest ever submarine rescue system, a fully integrated solution that can save the lives of our submariners and, if called upon, the lives of submariners around the world.