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Dr David H Elliott was one of the guest speakers at the SPUMS 1998 Annual Scientific Meeting. He is Co-Editor of The Physiology and Medicine of Diving, which was first published in 1969, with the most recent edition in 1993 and is also the civilian consultant in diving medicine to the Royal Navy. His address is 40 Petworth Road, Haslemere, Surrey GU27 2HX, United Kingdom. Fax + 44-1428-658-678. E-mail 106101.1722@compuserve.com .

THE HISTORY OF AUSTRALIAN SUBMARINE ESCAPE AND RESCUE OPERATIONS

Robyn Walker

Key Words

Accident, bell diving, decompression illness, emergency ascent, history, hyperbaric facilities, rescue, surface decompression, transport, treatment.

Abstract

The Royal Australian Navy has developed and implemented a sophisticated submarine escape and rescue organisation. It includes not only the material hardware but a framework for review, accountability and progress. This paper outlines the development of the system looking historically at the events which initiated its formation.

Background

Australian submarine operations date back to WW1. The AE1 was commissioned in 1913 and was lost with all hands on approximately 14 Sep 1914 off New Britain. The submarine failed to return from patrol and the cause of its loss remains unknown. No trace of the AE1 has been found.

The AE2 was commissioned in June 1913 and was lost as a result of enemy action in the Sea of Marmora on 30 April 1915. The AE2 was the first allied warship to penetrate the Dardanelles and saw 5 days of action in these waters before being sunk by enemy fire. The entire crew survived. Rumours that the AE2 has been found off Turkey are yet to be confirmed.

During the period 1915-1922 Australia had a series of J boats, originally built for the Royal Navy (RN), but these do not appear to have seen much action. From 1918-1939 the Oxley and Otway were commissioned by the Royal Australian Navy (RAN), but again little action was seen by these boats.

It was not until the 1960s that the RAN purchased the Oberon Class of submarines from the RN and we became an active submarine nation. With this purchase came the corporate knowledge of the RN with respect to submarine escape matters: the single escape tower (SET), the built in breathing systems (BIBS) and submarine escape immersion equipment (SEIE). The RAN relied entirely on the RN for expertise in submarine escape, rescue and air purification systems.

During the 1980s there appears to have been a decrease in the flow of information coming from RN and policy changes were often "found" by accident with no information available as to how these decisions were made.

The 1990s saw the introduction of the Collins Class Submarines and, along with the requirement to build a unique submarine, came the requirement to develop and maintain in-house expertise in submarine escape, rescue and air purification matters. This resulted in the establishment of a department with a full time focus on submarine escape, rescue and air purification as they pertain to Australian submarines.

Why Maintain a SUBSUNK Organisation?

There are a number of reasons why the Australian government has directed the RAN to maintain a submarine escape and rescue organisation:

a it is morally difficult to place colleagues and subordinates in dangerous situations,

b one should attempt to reduce the danger to a level which is perceived to be acceptable,

c to maintain morale: few people are willing to place themselves in a totally unsurvivable situation, and

d to comply with OH&S frameworks: the RAN has an obligation to make every practicable effort to provide the safest work environment for its personnel.

It is acknowledged, however, that, in time of war, the deployment of resources to recover survivors other than in home waters is unlikely and possibly not even then.

Premise

There have been over 170 recorded peacetime submarine sinkings in the world since 1900 and no less than 10 in the last 10 years. It is said the most likely scenario for a submarine accident will be at times of transit through ports, channels and fishing grounds with collision and grounding the most likely mechanism.

The basic underlying premise that applies is that, once a submarine becomes disabled, at least one compartment remains intact or can be secured for long enough for survivors to decide upon and carry out a course of action. Therefore the sole aim is to save life.

Before the Collins Class

Until the early 1990s Australia's focus was on escape, via the single escape tower. This is where the survivor, dressed in submarine escape immersion suit (SEIS), leaves the submarine via the SET and makes a buoyant ascent to the surface. This is effective down to a depth of 180 m. We adopted the philosophy of the RN and accepted their system would work.

Compartment escape was provided to cater for the situation of rapid and uncontrollable flooding of a compartment when there would not be time to operate the SET. This is effective only down to a depth of 60 m, after which the risk of life threatening decompression illness (DCI) becomes too high.

While the RAN recognised rescue was the preferred method of leaving a submarine, logistic constraints virtually negated the possibility. The non-existence of rescue resources, the sheer size of the Australian submarine operating area and the logistic nightmare of deploying a foreign rescue capability conspired to prevent rescue being a serious option for SUBSUNK scenarios.

The dawning of a new era

With the advent of the Collins Class submarine further stumbling blocks became evident. Whilst the Collins Class SET is designed to the same parameters as the RN model, it is not the same in all respects and therefore required vigorous testing to provide both designer and user confidence that the system's capability was a known quantity and not simply implied.

Compartment escape in the Collins is an unknown commodity. Each Collins escape compartment is large compared to the Oberon and therefore time to flood the escape compartment is considerable, time under pressure increases and the risk of significant DCI increases. Secondly the battery compartments in the Collins are not pressure tight and are part of the escape compartment. Therefore a battery flood may result in:

a the production of oxygen and hydrogen gas by dissociation,

b the possibility of fire or explosion arising from sparking/high temperature in the vicinity of the gases produced,

c generation of chlorine gas, and

d the generation of a toxic atmosphere under pressure as a result of all the above.

Therefore, for a number of reasons, compartment escape in Collins is riskier than for an Oberon submarine.

A number of rescue vehicles were available, mainly in the northern hemisphere. The United States Navy Deep Submergence Rescue Vehicle (DSRV) is capable of pressurised rescue (up to 2 ATA or 2 bar) using the forward compartment of a submarine as a mass recompression chamber (RCC). If a country uses the DSRV the foreign government is financially responsible for all operating costs and total or partial loss replacement in the event of damage. The current cost of one DSRV is estimated to be in the vicinity of US$500 million dollars, which is a fairly daunting figure. The British LR5 is a commercial submersible and capable of road transfer only. It is not likely to deploy to Australian waters and has no surface transfer under pressure capability.

The air purification system within the Oberons was well researched and understood, operated in small compartments and within well trialled parameters. The Collins air purification system is different in design and has never been trialled as it does not exist in any other class of submarines.

The SEIS has undergone development and the MK 8 suit has been superseded by the MK 10 (Figure 1). This incorporates a number of changes including a change to a single skin with a life raft built into the pocket. Neither the MK8 nor the Mk10 had been trialled in a Collins submarine.

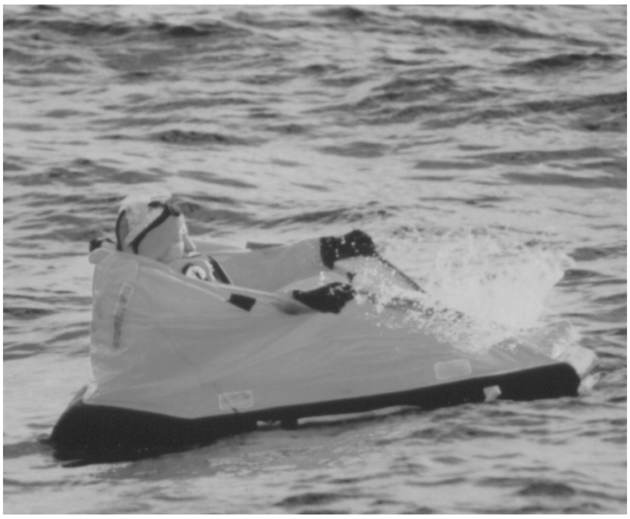

Figure 1. A "survivor" on the surface on the surface in the Mk 10 escape suit with the life raft inflated.

Warships in general can provide accommodation, secure communications, direction finding, underwater telephone, manpower and facilities for lifting patients off the ship by helicopter, however there is usually insufficient deck space and stability to mount and operate a rescue capability. There is insufficient deck space to mount and operate a sufficiently large RCC facility for either escape or rescue and warships usually have no dynamic positioning capability. It is therefore difficult to maintain accurate station over the disabled submarine and deploy a rescue vehicle or remote operated vehicle (ROV).

In summary there were a significant number of deficiencies in our submarine accident response plan ie:

a lack of facilities for escape (platform, medical team, RCCs),
b we could no longer rely on compartment escape as a viable alternative,
c lack of rescue capability,
d the installation of a untested air purification system: can the survivors survive until the rescue forces arrive?,
e the new escape suits had not been tested with a Collins and
f the lack of a platform for rescue.

SUBSUNK exercise 1993

For the first time in 1993 medical involvement in a SUBSUNK exercise occurred. Only 4 "survivors" were recovered but this was enough to highlight deficiencies in the medical management plan. It took over 11 minutes to retrieve the survivor from the water and transport to the triage area. Triage was difficult due to the small space allocated and due to the lack of oxygen stores in this area. Difficulties were encountered in transporting the patients around the ship and in securing the patients to the stretchers. The medical kit containing drugs and equipment was disorganised and difficult to use.

The way ahead

The Chief of Navy issued a directive in August 1994 instructing the submarine hierarchy to review all safety arrangements at all levels before the RAN had any active involvement in sea trials of Collins. Instructions were given that the RAN must be able to provide appropriate and timely medical treatment for those who escape, the numbers to be provided for were non-negotiable (55, maximum crew numbers for a Collins) and the contingency plan was not to be restricted to current national resources. There was also to be sufficient on board survival resources for maximum crew numbers to sustain life for 7 days while awaiting the arrival of the rescue forces.

In October 1994 the Submarine Escape & Rescue Project was established with the directive to produce the remedy prior to the start of Collins dived sea trials in February 1995.

The Australian Submarine Corporation was contracted to provide a submarine escape and rescue service (SERS) comprising:

a recompression facilities for 55 people,
b an extension of life support (ELSS) capability,
c a rescue submersible capable of operating in waters down to the crush depth of the submarine, and
d a transfer under pressure facility (up to 5 ATA).

Exercise Black Carillon I

Black Carillon 1 demonstrated the adequacy of the SERS for dealing with a mass escape. Fifty five survivors were rescued from the water, triaged and allocated to one of 4 broad medical treatment areas: immediate recompression, immediate resuscitation, medium priority and delayed priority. Twenty two survivors underwent simulated recompression therapy over the 8 hours of the "escape".

Exercise Black Carillon II

Black Carillon II demonstrated the successful mating of the rescue submersible Remora with an Oberon class submarine, Otama. The Remora was launched from the mother ship, successfully navigated its way to the submarine's position on the bottom of Jervis Bay and crew were transferred from the submarine to the surface.

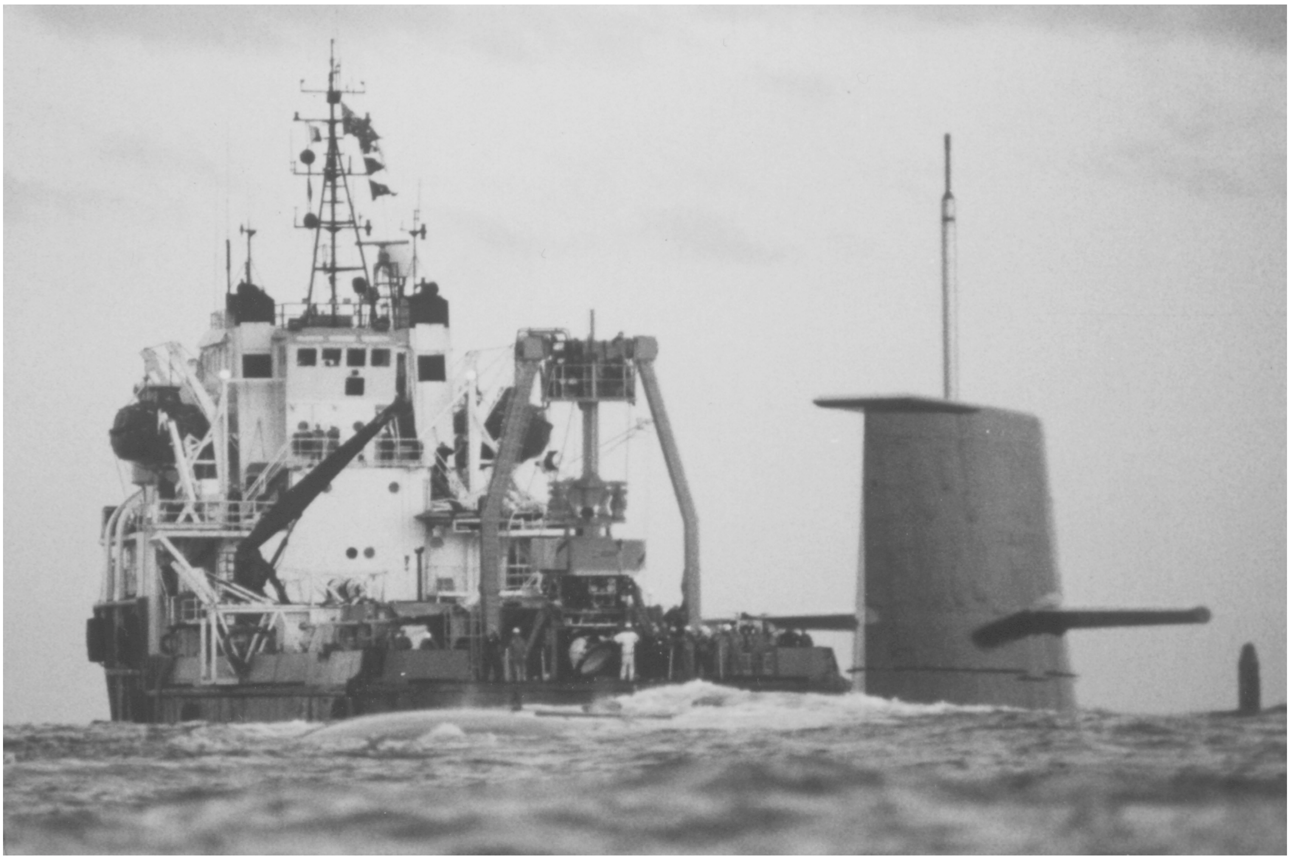

Figure 2. SEAHORSE SPIRIT (mothership carrying SERS), with HMAS COLLINS in the foreground, during Black Carillion 98.

Exercise Black Carillon 98

The logical progression of demonstrating the submarine escape and rescue capability continued. Black Carillon 98 had three broad aims:

1 ESCAPEX: to demonstrate, with minimal risk, the function of the single escape tower fitted to the Collins Class submarines for actual escape. This involved 9 instructors from the Submarine Escape Training Facility making a successful escape from the submarine which was bottomed in approximately 45 m. This is the ultimate proof that the SET will function as designed. Steps taken in the lead up to this exercise included tower functioning trials, to demonstrate the tower pressurisation rates were within acceptable limits and that the tower system operated as designed. Trials have also confirmed the SET performance with both the MK8 and MK10 suits at maximum operating depths. Trials have also verified the hood inflation system configuration for the MK10 suit.

2 RESCUEX: the second broad aim was to demonstrate the capability of the Remora to transfer, at atmospheric pressure (1 bar), crew from the Collins Class submarine to the surface recompression chamber suite. The ability to recover and transfer "injured" personnel from the submarine to the Remora and then to the RCC suite via a harness/pulley system was also demonstrated.

3 SURVIVEX: in order to demonstrate the Collins Class submarines can meet the 7 day survival requirement, the on board survival procedures were exercised as described in the Guard book (a set of cards providing escape and rescue instructions and held in each submarine escape compartment). The carbon dioxide level within the submarine was artificially raised to 2.5% and the crew were expected to follow procedures to measure the carbon dioxide and oxygen levels. Depending on the result, they had to decide whether to commence running the soda lime absorption units (SLAU), powered by 24 volt batteries in the event of a power failure, or burn oxygen candles. Trials to date have determined the SLAU meets the requirement for 46 men for 7 days; however the trials were not performed in accordance with guard book procedures and therefore not truly representative of an escape scenario. The SURVIVEX ran for 24 hours and calculations of usage rates of soda lime and oxygen candles will be extrapolated to 7 days. This should give accurate predictions of the stores required for 7 days.

The performance of Dräger tubes (used to measure carbon dioxide and oxygen levels) in the hyperbaric environment has been questioned in the past. Trials conducted led to a revision of practices and changes were made to guard book procedures. The SURVIVEX provided the opportunity to verify the guard book in a realistic situation.

The ELSS capability had not yet been conclusively demonstrated. Pods which weigh approximately 100 kg when fully laden with life support stores, food, water, medications etc. can be posted by ROV into the escape tower, providing extra time for the rescue forces to prepare. Difficulties have been noted when trialling the pods and a formal evaluation of the pod posting according to guard book procedures occurred during BLACK CARILLON 98.

Monitoring System

How does the RAN manage such a process? The RAN has implemented an internal 2 stage certification process addressing the material, engineering and operational aspects of the SERS with an additional annual audit of the system addressing these issues. The Remora is certified by the classification authority, Det Norske Veritas (DNV) for material safety with the recompression chamber suite currently undergoing this certification process.

The SUBSAFE Board Submarine Escape and Rescue Subgroup (comprising operational, medical and engineering representatives) is responsible for ensuring no hazard items represent an unacceptable risk prior to the conduct of these trials and in future operations.

Australian Defence Medical Ethics committee approval has been sought and granted for each phase of the exercises.

Summary

The RAN has developed and implemented a sophisticated escape and rescue organisation, the concept of which is being adopted by other major submarine nations around the world. The organisation includes not only the material hardware but a framework for review, accountability and progress. The Black Carillon exercise series will be followed by future exercises planned to maintain the momentum and in-house expertise in submarine escape and rescue.

LCDR Robyn Walker, MBBS, Dip DHM, is Officer in Charge, Royal Australian Navy Submarine and Underwater Medicine Unit, HMAS PENGUIN, Middle Head Road, Mosman, New South Wales 2088, Australia. Phone +61-(0)2-9960-0333. Fax +61-(0)2-9960-4435. E-mail Robyn.Walker.150150@navy.gov.au .

MILESTONES OF THE DEEP DIVING RESEARCH LABORATORY ZURICH

J Wendling, P Nussberger and B Schenk

Key Words

Decompression, deep diving, history, hyperbaric facilities, hyperbaric research, mixed gases, research, tables.

Abstract

Between 1959 and 1963 the deep diving pioneer Hannes Keller performed a series of depth records using heliox. He was assisted by the lung physiologist Professor A A Bühlmann of Zurich University. In 1961 application of a modified multi-tissue, perfusion limited, decompression algorithm for nitrogen and helium enabled an open sea dive to 305 m at Santa Catalina Island off California. However the price was a fatality. This dive was a break through for commercial diving, proving the feasibility of deep diving with helium.

A research contract with Shell, to develop decompression tables for offshore work, allowed the restructured research team at Zurich to construct a 100 ATA hyper- and hypobaric, multichamber, research and treatment facility, planned and directed by one of the authors (BS), an engineer. Experimental dives were continued down to 220 and 350 m at Alverstoke, UK, in 1969, and to 575 m in Zurich in 1981. The original decompression tables were empirically modified and became widely used. The problems of calculated tables and true reality will be discussed.

Altitude dive tables for scuba bounce diving were produced to meet the needs of military and police divers in Switzerland. Dive tables using the same algorithms as used for the deep dive experiments were calculated and tested for different altitude ranges. Bühlmann postulated a linear relationship of his supersaturation tolerance coefficients to the external pressure. In 1972 the first altitude table was produced using a 12-tissue model and in 1986 the actual set of tables was produced based on 16 tissues.

In a period of general rejection of any diving practices using computers as on-line dive planners, Bühlmann supported the adaptation of the Zurich tables for diving computers. The 1986 model has been further adapted to take into account workload, temperature, respiratory rate and inadequate decompression procedures specially considering the bubbles load of the lungs during certain phases.

The actual activities of the hyperbaric facility can be divided into the development of deep dive breathing apparatus and research into clinical hyperbaric oxygen (HBO) therapy.