MILITARY DIVING: OPERATIONAL CHALLENGES AND THEIR INFLUENCE ON TECHNOLOGY

INTRODUCTION

We are living in the Information Age where we are driven by the latest technological developments and diving, like all pursuits, has seen significant advancements in the available equipment and utilisation of information. Technology has enabled technical divers to push the barriers of rebreather diving, and the military sphere is now on the brink of a similar capability leap as they begin to adopt these new developments. The focus of militaries has been on terrestrial warfare, the current geo-political landscape has dictated this effort, but we are entering a moment where the maritime sphere is receiving progressive attention. We have seen extraordinary progress in diver propulsion devices (DPD) developments, and alongside the introduction of innovative electronics in rebreathers, divers have the capability to run extended duration and deeper dives without compromising on personal safety. The outcome of bringing maritime capability in line with terrestrial is that we are now in a position where the human body is being outperformed by the available equipment. The question is how technology can advance to enable the human body to perform as well as the machine. Our experience has identified the **five** immediate challenges holding back the evolution of diving.

THERMAL STRESS

Thermal problems in diving are often associated with cooling, and the risk of hypothermia due to water typically being colder than the human body. Secondly, water requires more energy to heat than air and with the effects of movement and conduction, the body will cool quicker in water than in air (Ornhagen, 2004). This process is the same even in warmer water, where the diver will eventually cool as the core temperature reduces, just over a longer duration. This is not to say that over- heating (hyperthermia) is also not an issue. In a dry suit the cooling effect of evaporation is void and when diving in warm waters it is possible for divers to over-heat, with this issue only counteracted by some form of cooling.

Compounding the natural effects of water on the human body, military divers constantly have to compromise between wearing the appropriate passive protection for the water temperature and what is operationally suitable, for example combat swimmers operating in cold water environments may choose to wear less passive protection in order to allow a very high intensity work rate (which will keep them warm for a period), whilst allowing flexibility both on the dive and on target. However, any delays or issues sub surface will leave then highly vulnerable to rapid heat loss and thermal stress, which will undoubtedly affect their operational performance.

There are many solutions available on the market to heat and/or cool the body and lessons have been learnt to develop these into safety critical pieces of equipment. Early active heating suits operated by simple on/off switches led to major fluctuations in operator body temperatures and the onset of decompression illness to varying degrees. Industry developments have since accounted for this issue and evolved the concept of heating a body underwater (and maintaining a diver's core temperature) using temperature controlling elements. By doing so the diver always operates within an optimal thermal envelop.

OXYGEN TOXICITY MANAGEMENT

To date combat diving has been conducted on pure oxygen rebreathers, and in recent years with DPD's to support shallow water transit. Divers on pure oxygen can carry much smaller amounts of gas when operating on closed-circuit systems (Wilmshurst, 1998). However, pure oxygen dives are limited by depth and time because at higher partial pressures oxygen causes acute toxicity leading to convulsions and other symptoms (Ran, Tzippora & Yochai, 2006), which underwater are typically fatal due to drowning (Wilmshurst, 1998). The MCM100 overcomes this by operating on mixed gases, customisable depending on the dive plan, and maintaining a fixed partial pressure of oxygen (PPO2 Setpoint) throughout the dive profile. The setpoint can be controlled to minimise the risk of oxygen toxicity over a wide depth range.

OXYGEN DURATION

Dives are also limited by the volume of breathable gas carried. With the implementation of propulsion equipment e.g. Jetboots/DPDs etc., which have enabled divers to transit further with minimal exertion and remain subsurface for longer durations, the efficiency of the breathing equipment becomes essential to further extend the duration of a dive.

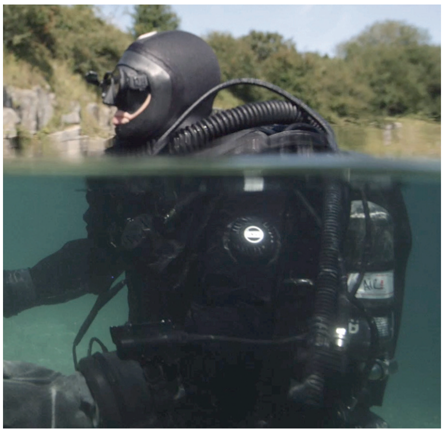
Traditional front mounted mechanical O2 rebreathers may not be the most appropriate apparatus in this new extended discipline given the diver is typically limited to only a couple of short deep excursions to depth as they risk the onset of central nervous system oxygen toxicity (convulsions due to high PPO2) and over long exposure to lower PPO2's, pulmonary toxicity. Semi-Closed Circuit Rebreathers (SCRs), with additional extended range gas supplies, have historically been an alternative however, the constant flow addition of oxygen is wasteful, and a less covert way of maintaining PPO2 due to the regular expulsion of gas from the loop. The technology in today's Electronic Closed-Circuit Rebreathers (ECCRs) makes them the ideal solution for long endurance, multi-level diving. By removing the issues associated with pure oxygen and SCR systems, through a combination of smart sensing that ensures a constant maximum PPO2 throughout the dive (at all depths) and by diluting the oxygen concentration therefore extending the available exposure time, the total mission time can be extended.

CO2 ABSORBENT DURATION

Real time oxygen setpoint and toxicity tracking is well established in modern rebreathers; however, carbon dioxide is largely ignored and is a hidden danger which can not only incapacitate the diver but also exacerbate central nervous system oxygen toxicity. CO2 can rise quickly in the breathing loop for several reasons including:

- Empty cartridge
- Poorly packed cartridge leading to CO2 channelling,
- Damaged sealing system
- Exhausted Absorbent,
- Out of date absorbent,
- Flooded absorbent,
- High intensity work and the associated high ventilation rates resulting in too much CO2 produced to be effectively removed by the absorbent.

When tested and certified in accordance with the CE EN14143 standard, commercially available rebreathers all achieve differing CO2 absorbent cartridge (scrubber) durations due to factors such as cartridge design, absorbent capacity and type of absorbent. In recent years some manufacturers have incorporated CO2 tracking solutions to estimate remaining



absorbent life and to improve diver safety however, this typically is based on a rudimentary method of tracking the thermal reaction front (a by-product between CO2 and the absorbent material) through a cartridge. In addition, some units deploy simple gaseous CO2 sensors based on non-dispersive infra-red sensing technology which are prone to inaccuracy as a result of humidity.

Without an accurate way to monitor CO2 and the subsequent scrubber endurance military divers, often alone or in pairs, working at moderate intensity for long periods, can only rely in their own preparation of the CO2 scrubber cartridge and 'worst case' data available from the manufacturer. Any issues with preparation can lead to serious problems sub surface. Problematically, the physical signs and symptoms of elevated CO2 in the loop can drastically affect a diver's ability to identify and rectify the issue. With the advent of accurate CO2 sensors and high pressure (HP) gas sensor and monitoring algorithms, new methods of tracking CO2 and scrubber endurance are available. One example is that real time scrubber endurance can be monitored by calculating theoretical CO2 production based on oxygen usage, the CO2 value can be deducted from the tested scrubber canister absorbent capacity to give the diver an indication of mission time remaining. Digital CO2 sensors also warn the diver if any of the previously listed issues occur, removing the serious risk that elevated CO2 presents to the diver and therefore operations.

NUTRITION

Current operational methods for diver nutrition on long endurance missions is through the consumption of liquidised food via a port within the full-face mask. There have been limited developments in improving this method. However, for most dive operations nutrition is not an issue. Short to medium length dives will not require the diver to eat, and in the case of long endurance dives, food may also not be a consideration. However, it is only until dive plans attempt to push the equipment to its maximum whilst also requiring the diver to maintain full operational effectiveness, that the issue of nutrition becomes prominent. With advancements in underwater vehicles divers could realistically be underwater for in excess of 8 hours, at which point their physiological and mental effectiveness is inhibited by a lack of nutrition.

Avon Protection keeps these challenges at the forefront of our developments ensuring we always consider how can we improve the safety and comfort of the diver and therefore how can we extend their operational capability.

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