THE SELECTION, INSTALLATION, AND OPERATION OF A MODERN CHEMICAL BASED TECHNOLOGY FOR THE DISSUB CO_2 REMOVAL SYSTEM IN ROYAL NAVY SUBMARINES

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ABSTRACT

Having identified a deficiency in the Royal Navy's present DIStressed SUBmarine (DISSUB) Carbon Dioxide (CO_2) removal system the Marine Environment Sustainability and Habitability (MESH) IPT has run a project to assess a number of candidate technologies for use as a replacement system. Three technologies were examined initially, and a competitive procurement activity has been completed. From this a CO_2 removal system was selected for installation and operation in current and future classes of RN Submarines. This paper reports the results of this procurement activity.

Introduction

Carbon Dioxide is a colourless, odourless and tasteless gas, which at high concentrations may cause vasodilation leading to circulatory collapse. These physiologically detrimental and potentially life-threatening levels are quickly reached in sealed environments, such as a submarine, from CO_2 exhaled by the inhabitants. In order to maintain a habitable environment it is therefore necessary to remove the CO_2 produced. In nuclear submarines CO_2 is routinely controlled by the use of a regenerable method, typically mono-ethanolamine packed tower scrubber plants. These plants require extensive power supplies and are generally located outside of the designated escape compartments. They are thus not suitable for use in a DISSUB scenario and an alternative method of CO_2 removal is required. At present, RN Submarines utilise an active (DC powered) CO_2 absorption system for life support in a DISSUB. The system comprises 4 Carbon Dioxide Absorption Units (CDAUs) sited in the submarines forward and aft escape compartments as shown at (FIG.1). The CDAUs are fundamentally fan units onto which 4 canisters filled with soda lime (a CO_2 absorbent) are placed. The primary DC power can be backed up, if required, by seawater activated batteries, or until recently a bellows foot-pump.

FIG.1 - CDAUS IN THE FWD ESCAPE COMPARTMENT OF A SSN. EACH CDAU HOLDS 4 CANISTERS

A deficiency in this system would force the surviving crew to attempt an escape well in advance of the 7 days specified in Def-Stan 07 260[1] and STANAG 1301[2] due to high CO_2 levels.

The CDAUs draw CO_2 rich air through the pre packed and sealed canisters, where the CO_2 is taken up by the soda lime in an irreversible reaction. As the soda lime is used up, its reaction rate decreases meaning that the CO_2 content of the atmosphere will begin to rise. When the CO_2 partial pressure (pCO_2) exceeds 2.0 kPa, the 4 canisters on a CDAU are changed for a fresh set. Evans and Loveman[3] established that with the present system, only 50% of the theoretical absorption capacity of the soda lime in a canister is typically used before the reaction rate falls below the estimated CO_2 production rate.

The shortcoming in crew endurance during the survival phase of a DISSUB scenario is further compounded by the poor performance of the current system under conditions of high pressure or low temperature. Recent studies[3] further demonstrated that at a pressure of 5 bar absolute, CDAU canister endurance falls by as much as 54%. Similarly, at a temperature of 5°C canister endurance falls by up to 58%. The study also verified that at conditions of high pressure and low temperature a cumulative effect occurs, causing a reduction in endurance of over 80%. This study estimated that, under the most adverse atmospheric conditions, the endurance of a full crew in the aft escape compartment on a Trafalgar Class submarine may be as low as 17 hours before escape would be required due to uncontrollable CO_2 levels.

In response to this deficiency and as the Equipment Design Authority for air purification equipment, the MESH IPT undertook a project to consider aspirant technologies to better meet the requirements of Def-Stan 07-260[1].

REQUIREMENT REVISION

The MESH IPT and the Standing Committee on Submarine Escape and Rescue (SCOSER) recognised that successive capability reviews had identified shortfalls in the requirement for CO_2 removal in a DISSUB. The most significant was the lack of an approved User Requirements Document (URD) and a formal gap analysis study that sought to identify capability gaps and assess their significance within the overall Escape and Rescue capability piece.

The aims of the URD[4], published later this year (2007), and the Submarine Escape Systems Safety Case Live File[5] written to meet the requirements of the Whole Submarine Safety Case, are to capture and catalogue the user's bounded needs for Submarine Escape Rescue and Surface Abandonment (SMERAS) in all Royal Navy submarines. The URD's aim is derived from the evolving need to modernise SMERAS governance and management across the submarine service. It is set within the context of NATO cooperation, but all requirements are aligned to UK needs. The live file was generated following a review of all extant support documentation, trials and defect data available reporting on voids as necessary. Following Hazard Assessment of these voids a priority list was generated to identify the most pressing concerns. One of those voids was CO_2 removal in a DISSUB.

TECHNOLOGY APPRAISAL

In June 2004 an internally published Options Appraisal[6] was produced by MESH IPT discussing the deficiency of the current CDAU system. The paper identified 3 alternative systems that appeared to offer the potential to increase the endurance of the crew up to the required 7 days. The 3 systems were:

- Molecular Product's self-powered carbon dioxide absorber, named the **CA**rbon dioxide **S**elf **P**owered **A**bsorber (CASPA);
- Micropore Inc's Reactive Plastic Curtain (RPC);
- The Battelle Curtain, as used by the United States Navy (USN).

This work further identified the requirement for limited testing of the CASPA and RPC systems, under both normal and extremes of pressure and temperature, matching earlier testing of the Battelle curtains[7] and enabled each of the systems to be compared in similar environments.

These trials allowed a conversant assessment to be made as to the feasibility of administering a procurement competition to seek a resolution that would meet the newly endorsed requirement[1]. Test data gleaned from the trials was used to develop a system specification requirement for use as the basis of the procurement competition.

Independent CDAU Replacement

The CASPA[8] is essentially a battery powered, standalone CDAU, as illustrated at (FIG.2). Each unit contains around 8 kg of soda lime, an integral fan and a battery pack selected to give 20 – 24 hour run time. Each of the units is approx.

12”x12”x6” and could be distributed amongst the DISSUB survivors as required to match CO_2 production. A series of trials at different conditions were carried out under a development contract with Molecular Products. Ambient trials were performed at their factory, whilst high pressure / low temperature trials were undertaken at the National Hyperbaric Centre in Aberdeen. A full description of the trials protocol and results are in the project report[9].

FIG.2 – CROSS SECTION OF THE PRE-PRODUCTION MODEL OF THE CASPA

Reactive Plastic Curtain

The reactive plastic curtain (RPC) consists of approximately 97% lithium hydroxide (LiOH), which is an efficient CO_2 absorbent. The LiOH is bound in a polymer, which makes up the remaining 3% of the RPC and allows it to be formed into strips. The RPC strips can be supplied rolled up in a canister, as illustrated in (FIG.3), which shows the rolled sheet as used in a diving re-breather set or as preformed sheets.

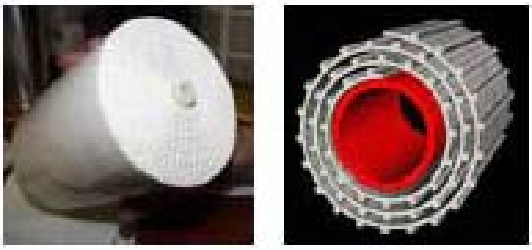

FIG.3 – PICTURE OF RPC REMOVED FROM STORAGE CANISTER; DIAGRAM OF A SECTION OF RPC SHEET, RIBBED FOR TUNED AIR FLOW

For passive use in a DISSUB these sheets must be unrolled or unpacked, cut to a manageable length, and deployed (hung up), as illustrated at (FIG.4). In order to assess the performance of the RPC under the influence of high pressure and low temperature, a series of trials were completed at the Deep Trials Unit (DTU) at QinetiQ Alverstoke, with the first set being conducted at 20°C and pressures of 1.2, 3 and 5 bar, and the second set completed at the same range of pressures but at 5°C.

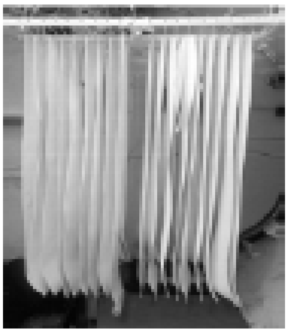

FIG.4 – REACTIVE PLASTIC CURTAIN CUT TO LENGTH AND HUNG IN STRIPS DURING A USN TRIAL

Battelle Curtain

Battelle curtains consist of a porous cloth material formed into a series of tubes. Each curtain is around 6 feet in length and is filled with the CO_2 absorbent chemical before being hung in the DISSUB, as illustrated at (FIG.5). It should be noted that (FIG.5) shows the curtains being used during a trial by the USN. In this trial, LiOH canisters were emptied into the curtain and then sealed in place, as shown.

FIG.5 - BATTELLE CURTAINS DEPLOYED DURING EARLY USN TRIAL USING LIOH CANISTERS. EACH CURTAIN IS APPROXIMATELY 6 FEET LONG

Each of the three technologies outlined above was subjected to a range of CO_2 removal scenarios (capacity checks and scaled DISSUB production levels/rates) over a range of pressures and temperatures.

Two products, namely the CASPA produced by Molecular Products and the Micropore Incorporated RPC utilising their ExtendAir® Absorbent technology were taken forward to present proposals[8 & 10] in support of the MESH Invitation to Tender[9] outlined below. Previously referred to as ExtendAir® RPC for reactive plastic cartridge or curtain, the ExtendAir® brand name is used to describe their current products.

The simpler the system, the more limited the changes would be to present stowage, and the quicker the change over between the systems, this would improve scoring at the tender assessment stage.

TENDER ASSESSMENT

Following review within the Commercial section of MESH IPT, companies were issued the Statement of Requirement (STR) and a copy of the formal tender assessment matrix was issued along with the STR; companies were then invited to clarify any questions they may have had with the Project Manager. Some of the key areas were amplified as below:

Background

It was articulated that key to the success of this project was a methodical and clearly communicated fitting out plan for the current classes of submarines. The successful bidder and the Project Manager needed to work closely together to ensure that the proposed fit plan dovetailed with the submarine maintenance programme (itself subjected to constant change).

Proposed Strategy

Each submarine would require two system fits, one forward and one aft. Ideally, both would be completed in one maintenance period, although there is capacity for the fits to be carried out over two consecutive periods if fitting was slower that expected or no maintenance period of sufficient size was available.

The limiting maintenance period is an SSBN Base Maintenance Period (BMP). For the purposes of this tender, companies were to assume that they had only ten working days access to the submarine, that they had to share that access (and the compartments in which they would work) with a number of other update and maintenance teams, and that military security would severely limit the freedom of the team to work in a flexible manner.

Performance

This is the measure of the systems' ability to remove CO_2 from the DISSUB environment for the 7-day period.

Load Management

This is the size of system that is required to be deployed at any one time and the practical demands on the survivors to manage it.

Space

The area within the DISSUB in which the system would be required to be stored and deployed.

Handling

The demands placed on the survivors to physically deploy the system; this includes the effects of any PPE that is required.

Environmental Impact

This qualifies the risk of respiratory irritation, temperature effects and air movement as a result of the system storage and operation.

Installation

This is the complexity of installation and fitting out with the replacement solution and the degree to which present stowage will be used. This is a measure of the risks associated with changing from CDAU to the replacement system.

To prevent any potential viable systems being ruled out prior to tender assessment, MESH IPT deliberately kept the STR as simple and open as possible. The Project Manager contacted prospective bidding companies regularly throughout the process to ensure that any queries were answered as soon as possible.

Tender Assessment Matrix

The Tender Assessment matrix[11] produced was to be completed individually by each assessing technical officer following a review of all tenders supplied. Reference in each of the criteria was made to the relevant section of the Schedule of Technical Requirements. The marking scheme was designed, in conjunction with individual weightings, to give an overall score to each proposed system. Scores were awarded in the range 0 – 10, with 0 denoting failure/inability to fulfil the requirement in the STR, 5 awarded for just meeting the criteria, and 10 for the presentation of an innovative response with performance far in excess of the requirement. Intermediate scores (1 – 4 and 6 – 9) were awarded for degrees of failure/excellence as judged by the assessment officer. These scores were weighted as Very High, High and Normal receiving multipliers of 3, 1.5 and 1 respectively.

The detail within each tender response drove the ability of the assessing officer to accurately assess the proposal. If statements in the documents were not clear/not present, the assessing officers were advised to contact the Project Officer. Each column in the tender assessment matrix was linked to a specific statement in the STR. For brevity the first criteria is below with the full criteria and weightings publicised at Reference 11.

REQUIREMENT	STR REF.	SCORE	Wgt
Control of CO_2 at/below 2kPa within DISSUB for at least 7 days.	5.A.a	/10	VH
Removal of CO_2 (hourly rate)	5.A.b (1)	/10	H
Removal of CO_2 (overall capacity)	5.A.b (2)	/10	N
Correct operation within defined environmental range	5.A.c	/10	H
	TOTAL 1	/70 (weighted)	

As part of the formal tender assessment process the individual technical assessments were moderated. During this moderation the key issues that resulted in differences in the system scores were discussed, a moderated score was agreed, and the discussion points that led to that score were noted. A critical section of this, like any other, tender was the commercial aspect; companies were to provide all system cost information to allow the following to be calculated:

- Fit costs for each submarine;
- Total fit costs for all current classes of submarine;
- Costs for replacement systems, and any price break information;
- Costs of any technical support outside of the provision of stores.

However it would be the technical aspects of the bid that would see the successful company through to achieving the contract as the individual assessing officers were not party to commercial information when making their assessment of the products.

EVIDENCE OF SYSTEM PERFORMANCE

Micropore's ExtendAir® LiOH CO_2 absorbents have been thoroughly evaluated by several of the world's leading military submarine atmospheric specialists, and have been proven to perform well, typically in both rate and capacity. Several nations have evaluated the product; below are cited some of the findings that document the 3rd party testing, and superior performance of ExtendAir® CO_2 absorbents for this critical emergency application.

Through trials conducted and funded by MESH IPT at QinetiQ, Alverstoke, UK, data presented[12] showed a higher efficiency when using ExtendAir® absorbents compared to CDAU sodalime systems and sodalime filled Battelle curtains. ExtendAir® absorbent efficiencies were as high as 99.8% as compared to 80% for the granule curtains under the same conditions; 1.2 bar, warm. For the 5 bar, cold trial, ExtendAir® absorbent efficiencies were approximately 90% compared to just 12% for sodalime-filled Battelle curtains.

FIG.6 – MICORPORE'S EXTENDAIR® LIOH CO_2 ABSORBENTS

For environmental concerns, it was also noted at no point in the trials were curtain surface temperatures recorded that would pose any significant risk of burn injury to the handler.

These trials were completed in two stages; warm and cold. Useful data was gathered during the warm trials showing the CO_2 content of the atmosphere in the Deep Trials Unit (DTU) with time (sampled every 10 minutes) and are illustrated at (FIG.s 7 and 8):

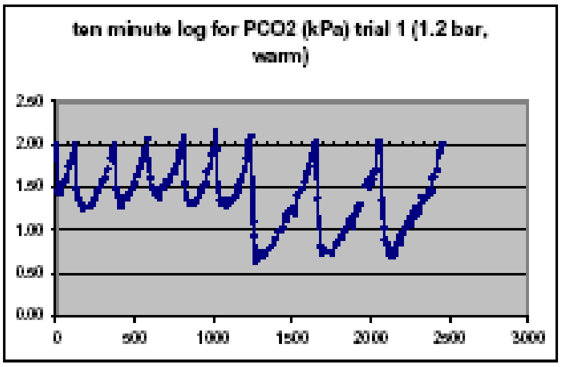

FIG.7 – PLOT OF CO_2 (KPA) AGAINST TIME (MIN) FOR 1.2 BAR / 20°C.
SAMPLE RATE: 10 MINS

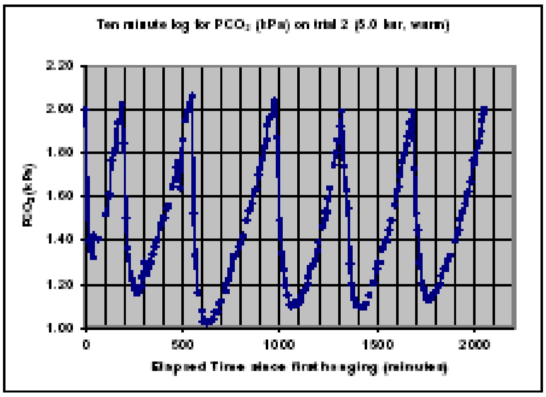

FIG.8 – PLOT OF CO_2 AGAINST TIME FOR 5.0 BAR / 20°C.
SAMPLE RATE: 10 MINS

The data from the trial carried out at 3.0 bar is not presented here, as it is consistent with that seen at 1.2 and 5.0 bar. The plots shown in (FIG.s 7 and 8) demonstrate the effective absorbent qualities. Each time batches of 12 sheets were hung, which equates to the contents of 2 canisters and it can be seen that the LiOH CO_2 absorbent effectively strips the atmosphere of CO_2, bringing the chamber content down to well below 1.0 kPa at 1.2 bar and between 1.0 – 1.2 kPa at 5.0 bar. This reaction takes place in a very short space of time and is a result of the design of the absorbent, which effectively exposes 25% more LiOH to the atmosphere per unit volume than for a similar granular system. The rapid absorption of CO_2 and then slow build up back to 2kPa suggest a very effective passive absorbent. Under all conditions, it was observed that an initial stabilising period was necessary during which a critical mass of sheets are exposed – in much the same way as a build up over the first day of use was required for the CASPAs during similar trials. Once a steady absorption rate was achieved, the average time between hangings for each batch of 12 sheets was measured. Analysis by QinetiQ showed that a 16% decrease in average hanging times was observed between 1.2 and 5.0 bar, evidence of the reduction in absorption rate that is expected at higher pressures. This suggests that at higher pressures, more canisters would need to be deployed over a 7-day period to counter the CO_2 production rate.

A second, cold set of trials was also completed at the DTU. These were carried out at the same pressures as the warm trials but at 5°C. It was clear from the data recorded that the LiOH CO_2 absorbent performed equally well at low temperature and at NTP. The absorbent offers a high capacity, truly passive absorption system that is capable of operation regardless of the internal conditions in the DISSUB. The performance of the LiOH CO_2 absorbent has been assessed over the pressure range 1.2 to 5.0 bar in both warm (~20°C) and cold (~5°C) conditions. In all ambient conditions tested it was possible to successfully control the carbon dioxide partial pressure below the desired level of 2.0 kPa. A report[9] concluded that the LiOH CO_2 absorbent offers superior CO_2 absorption performance to both CDAU and Battelle Curtains across the range of conditions tested. The Naval Submarine Medical research Laboratory[13] asserted similar conclusions.

At the 2005 Submarine Air Monitoring and Purification (SAMAP) conference COMSUBIN/NAVARM, the Italian Navy, reported on a Survival Exercise (Survivex) trial they had conducted.

The protocol involved 25 healthy volunteers (aged 25 - 46; mean 33) who were confined within the forecompartment (200 m^3) of the Sauro-class, second batch submarine L. Da Vinci over 48 hours. Micropore Incorporated RPC LiOH curtains were cut into sheets from the original roll and hung in sets of 6 about the forecompartment (6 x 1.5 m = 9 m roll). Three rolls at a time were opened. CO_2 was allowed to reach about 1 % (from initial 0.06 %) before activating the RPC. The curtains were left hanging as long as possible, after being substituted by another set; in fact the first two sets (out of four) would stay up approximately 24 hrs, then they were disposed of.

The results obtained show that RPC are a very effective and accurate CO_2 scrubbing system. Using four sets of three cartridges the submarine's CO_2 level stayed below their own predictions; this means that with a normal stock in the Sauro-class fore-compartment a survival of seven days (according to NATO STANAG) for 25 people under similar conditions is to be reasonably expected. (FIG.9) shows results from this Survivex.

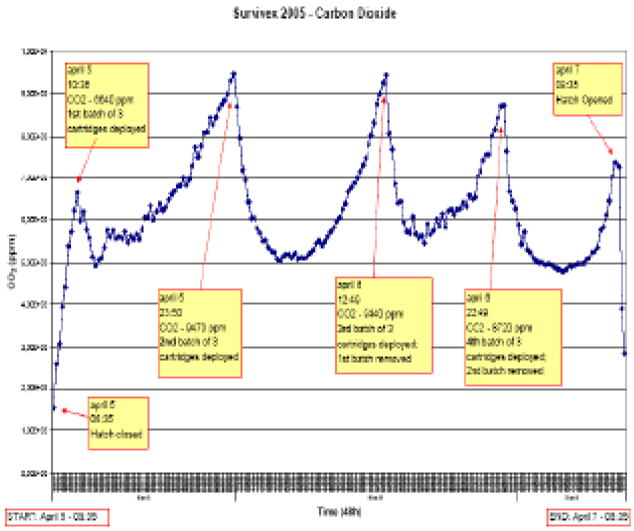

FIG.9 – CO_2 CONTROL USING EXTENDAIR LIOH ON-BOARD ITALIAN SAURO-CLASS SUBMARINE DURING A SURVIVEX

As a result of the individual scoring the technical officers selected Micropore's ExtendAir® LiOH CO_2 absorbent as the preferred solution and as a result MESH IPT and the Royal Navy were awarded Micropore Incorporated the contract to supply the Royal Navy with it's emergency CO_2 removal capability.

DEPLOYMENT TIMING STRATEGIES

It would perhaps be too constraining to produce one deployment approach that would serve all eventualities; a number of different approaches are outlined below and compared to criteria that indicate the quality of such protocols. Again this will allow other potential users to utilise a similar approach if deemed appropriate.

FACTORS THAT INFLUENCE THE DEPLOYMENT STRATEGY

CO_2 Volume

The single purpose of the system is to maintain a breathable atmosphere (in terms of CO_2 levels only) to support survival onboard a DISSUB for a period of up to 7 days, including the time taken to complete the escape phase. The greater the number of personnel that require environmental support, the more volume the system will need to support, as well as accommodating greater distribution between its sub systems (individual curtains). The better protocols will be able to accommodate alterations in CO_2 demand with minimal input by the submarine crew – a significant change in respiratory activity as a result of another submarine emergency could be one scenario that would deliver this.

Space Available

Although the Micropore system will deliver the survival requirement as detailed at STANAG 1301, a far greater deployment volume could be required in order to achieve this. If the full seven day requirement were to be all deployed at the start of the survival period then 1680 curtains would have to be hung within the survival volume, a considerable challenge where the available compartments might only be those forward of the first watertight bulkhead.

In addition, the survival volume will support a range of other activities; the crew will need sufficient room to access critical submarine systems, conduct surveys, sleep and eat, and maintain morale. Therefore, maximum deployment amount could be curtailed by the simple challenge of fitting multiple activities into a small amount of survival real estate.

Personnel Available

As a sub set of the total CO_2 clearance challenge outlined earlier, there is the issue of capability to deploy the system. The Micropore system is made up of a large number of sealed LiOH curtains, each requiring manual deployment. Given the actions involved, it is considered that initiating sufficient curtains that are capable of supporting the entire survivor complement of an SSN may take some time. Although it would be advantageous to deploy sufficient CO_2 clearance capability for at least 12 hours, the impact of limited personnel (especially if limited by injury, rather than absence) should be considered in the Senior Survivor's decision-making process.

Storage Locations

Given that the CDAU system required the use of fixed equipment, storage for the canisters was maintained within each escape compartment only. With the Lithium system, such focus is no longer required. Although all storage space currently available is within the escape zones, it would be possible to distribute a portion of the system to the main living/combat spaces as the majority of personnel will remain within these areas if possible. Indeed, distributing the system will mitigate the impact caused by damage to an escape compartment and the subsequent unavailability of the CO_2 removal equipment. This has two impacts in terms of deployment scenario; a potential reduction in the time taken to deploy the system, and a reduction in the proportion of that overall system that might be unavailable due to compartment damage – and thus the total CO_2 clearance capacity still available.

Achievement of Theoretical Performance

From the testing activity, detailed in the MESH IPT report[9], it is clear that there is a variance in performance based on the volume of curtains hung at one time. Notwithstanding the limitations of the test conditions (the test chamber was not sufficiently large to compensate for the scale effects of full size curtains within a reduced size survival volume), it is considered that the most efficient use of curtain capacity would be by individual positioning of curtains to meet individual person respiratory rates. Given that this would be impractical to achieve, it is important to understand that moving towards more limited distribution may increase the potential for insufficient clearance in areas of the survival volume.

MEASURING THE IMPACT OF A DEPLOYMENT PROTOCOL

To take a view on the most beneficial method of deploying the Micropore system, one needs to understand what criteria could be used to differentiate between the options. Some such metrics are detailed below:

- Speed of deployment (SoD). This is an indication both of the simplicity and use of the deployment method. It ensures that those methods that can start to have an impact quickly could be marked well;

- Response to compartment availability (RCA). This indicates the sensitivity of the method to changes in the survival real estate; those methods that are flexible or relatively insensitive to the compartments available for deployment will score more highly;

- Crew workload (CW). This is an assessment of the crew effort required to deliver the deployment method – it captures activity throughout the survival stage. It is expected that those methods that are more insensitive to using large groups of people at any stage will score higher;

- Performance (P). This is an assessment of the degree to which each method could impact on the theoretical performance (rate or capacity of CO_2 removal) of the LiOH curtains. It is suggested that those methods that are closest to the tested scenarios will score more highly;

- Ergonomic impact (EI). This is a 'catch all' assessment of the impact of the system once deployed in accordance with the potential methods. Again those methods that minimise impact on the submarine crew would score more highly.

POTENTIAL DEPLOYMENT PROTOCOLS

In presenting these protocols, the author has considered the front end of a UK SSN; one of the more challenging scenarios in terms of clearance volume, complexity of the deployment area, and relative probability of use.

The French way. The French Navy currently use soda lime granule filled curtains, hanging all curtains at the commencement of the survival phase equally distributed through the volume to allow optimal CO_2 clearance of the survival volume.

One man, one vote. This method would calculate the number of curtain each crew member would need for the seven days, issue them accordingly, and then require individual members of the crew to remain relatively static within the survival volume, deploying curtains on a time basis to match the theoretical rate and capacity of individual curtains.

Zonal protection. This method focuses on the need to keep the whole survival volume within specification, whilst allowing relatively free movement through those spaces. Groups of curtains are rigged throughout the survival volume to allow sufficient CO_2 clearance for between 12 – 24 hours; a regular monitoring regime will ensure that replacement curtain sets are hung to maintain CO_2 below the escape limit.

Let sleeping dogs lie. This specific method focuses on the need to support a probable crew management technique. Rather than hang throughout the survival volume, curtains should be grouped towards the areas of the volume that will accommodate that portion of the crew that will remain asleep/recumbent for a significant portion of the survival time – reducing respiratory demands on the emergency atmosphere systems.

Ready to go. As a subset of the above, the requirement would be to hang only within the escape areas of the survival volume. This would ensure that the system was deployed close to its storage sites, as well as ensuring that the crew could move seamlessly to the escape phase without compromising performance of the CO_2 removal system.

ROYAL NAVAL IMPLEMENTATION

Although not as yet fully implemented it is envisaged that the Royal Navy will implement a Zonal Protection system based on a set of look up tables created. The tables will give guidance on the number of curtains that should be hung within a 24-hour period for the number of survivors in the survival space available. As with the current CDAU, and indeed general guidance within the GUARD Book, initial actions will centre on the break out and checking of the Lithium system. A defined process for this has been created, including the quick checks that will give some measure of confidence that the system will operate as required. The Zonal Protection system will ensure the entire survival volume is maintained within specification, whilst permitting free access through those spaces. Groups of curtains will be placed throughout the survival compartment at regular intervals or to maintain below a predetermined CO_2 ceiling to allow sufficient CO_2 clearance for between 12 – 24 hours. The recurrent monitoring schedule will certify the maintenance of CO_2 below the escape limit.

CONCLUSIONS

Having identified a deficiency in the Royal Navy's present DISSUB CO_2 removal system the Marine Environment Sustainability and Habitability IPT ran a project to assess a number of aspirant technologies for use as the replacement system. A competitive procurement activity has been completed and within the criteria established at the outset it is considered that the project has successfully demonstrated that Micropore's ExtendAir® LiOH CO_2 absorbent best meets the identified requirement.

The flexibility offered by the ExtendAir® CO_2 absorbent allowed for a number of potential deployment methods to remove CO_2 from within the confines of a DISSUB. Several themes were identified in order to produce uplift to the guidance within the GUARD Book and a re-issue of emergency CO_2 clearance information within BR 241. A Zonal Protection methodology has been adopted to keep the whole survival volume within specification, whilst allowing relatively free movement through those spaces.

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ABBREVIATIONS/GLOSSARY

ASM: Astute Class Submarine

BR 241: Submarine Escape and Rescue Handbook

CASPA: The name given to the pre-production trials unit for CO_2 removal, developed by Molecular Products Ltd

CDAU: Carbon Dioxide Absorption Unit; the current system of CO_2 removal fitted to RN submarines

CO_2: Carbon Dioxide

DEFSTAN: DEFence STANdard; a series of documents that details key requirements of operation within the military context

DISSUB:	DIStressed SUBmarine; the term given to a stricken submarine. It implies that the submarine crew have to go through a survival and escape phase during which life support systems independent of submarine services will be required
DTU:	Deep Trials Unit; a hyperbaric chamber at QinetiQ Alverstoke that can model DISSUB CO_2, temperature and pressure conditions
Guard Book:	A waterproof book that contains survival guidance for the submarine crew in the event that they have to survive in a DISSUB
IPT:	Integrated Project Team; the organisational boundary that captures a range of people with differing roles/skills under the banner of one aim – the support of defined equipment/s or system/s
ITT:	Invitation To Tender; the contractual mechanism of eliciting formal tenders from a company
kPa:	Kilo Pascals
LiOH:	Lithium Hydroxide
MESH IPT:	The IPT that is responsible for all marine environmental/habitability systems
MoD:	Ministry of Defence
NTP:	Nominal Temperature and Pressure; set as 20°C and 1 bar absolute
O_2:	Oxygen
RN:	Royal Navy
RPC:	Reactive Plastic Curtain; the passive shaped chemical curtain for removal of CO_2
SCOSER:	Standing Committee On Submarine Escape and Rescue; they endorse the policy controlled by SMERAS
SMERAS:	A section within SUBIPT that is the MoD Subject Matter Expert and Design Authority for Submarine Escape, Rescue and Surface Abandonment
SUBIPT:	Submarine IPT: The IPT responsible for the support and provision of all in-service submarines
SURVIVEX:	An exercise that simulates DISSUB conditions within a submarine within a controlled environment
URD:	User Requirements Document; the key technical aspects of a system or equipment specification
USN:	United States Navy

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