SAMAP

Submarine Air Monitoring Air Purification Conference

Resurgence in Submarine Shipbuilding

4th - 6th November 2019

Crowne Plaza Newcastle, Newcastle, UK

Sponsored by

SAMAP

ANALOX

CONTENTS

WELCOME LETTER

On behalf of the organising committee, it is my pleasure to invite you to join in the 12th Submarine Air Monitoring and Air Purification conference 4-6th November 2019 in Newcastle upon Tyne, in the heart of Geordie country. A city with a long and varied history synonymous with the 19th century Industrial Revolution, coal mining and shipbuilding. It also prides itself with a rich cultural heritage, flourishing liberal arts and a first-rate university. It is the eighth most populous city in the UK situated 166 km south of Edinburgh.

The SAMAP conferences are held every second year, alternating between Europe and North America. The aim of the conference is to bring together advances in research and technology related to the maintenance of a physiologically acceptable atmosphere in submarines and other enclosed environments. This involves a multidisciplinary approach encompassing analytical chemistry, toxicology, physiology, human performance and engineering. In this eclectic context, where possible the presentations are grouped according to the categories: air monitoring, air purification or health effects.

Historically, there has been some collaboration between submarine atmosphere research and air quality management in manned space vehicles due to the requirement for long-term isolation in an enclosed environment. Therefore input from space programs is relevant and always welcome at SAMAP.

The detailed organisation of each SAMAP conference is voluntarily undertaken by a local organisation or business with a long history of association with SAMAP. This year Analox and Sonistics, Ltd have undertaken the arduous task of organising this year’s conference, providing staff and financial resources to ensure a successful meeting. Thus we are particularly indebted to Vicky Pigg and Michelle Wilson of Analox, Stokesley UK and Sam Hopkins of Sonistics Ltd, Bath, UK.

Wally Mazurek, Australia.

(Convenor)

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KEYNOTE LECTURE

Tom Limero

Wyle Laboratories Inc., JSC, Houston, USA.

Thomas Limero hails from Springfield, Massachusetts and he received a Bachelor of Science degree in Zoology from the University of Massachusetts in 1969. He earned a Ph.D. in Analytical Chemistry from the University of Houston in 1988, where his doctoral work centered on development and characterization of a non-radioactive source for electron capture detector. Tom was the supervisor of the Toxicology Laboratory at JSC for 28 years. Under his guidance the laboratory developed new samplers, adopted EPA analysis protocols for archival samples, and developed, with commercial partners, real-time monitors to measure combustion products and volatile organic compounds aboard spacecraft. Over the past 3 years, Tom has taken on the role of subject matter expert (SME) in chemistry and continues investigate technologies for use aboard spacecraft, which now include nano-HPLC for biomarker detection.

OPENING ADDRESS

Waldemar Mazurek
CV Sept 2019

Waldemar (Wally) Mazurek joined the Department of Defence, Defence Standards Laboratories, DSL (subsequently renamed as the Materials Research Laboratories, MRL and later, the Defence Science and Technology Organisation, DSTO) in 1967 and worked in many chemistry disciplinary groups including textiles, paints, sealants and general chemistry. In 1991 he was appointed as the head of a new group on submarine atmospheres and in the same year he spent 13 months on attachment to the UK (DERA) MoD at Holton Heath, UK in the Submarine Atmospheres Group headed by Paula Dibben.

On return to the Australian Department of Defence he developed a research program in submarine atmospheres as well as collaborative research and information exchange programs with the USN, RN, the French Navy, Swedish MoD and the Netherlands MoD. In 1994 he organised the first Submarine Atmosphere Monitoring and Air Purification (SAMAP) conference in Adelaide, Australia and subsequently acted as convenor for SAMAP conferences in Europe and North America in collaboration with local colleagues and defence organisations.

During this period his group hosted two visiting scientists (UK and Sweden) as well as providing training for the USN in submarine diesel exhaust measurements.

In addition to the submarine atmosphere research, his group was also involved in air quality issues in surface ships, military aircraft and armoured military vehicles. He has published in the open scientific literature as well as internal publications and reports.

In 2014 he retired from DSTO but has maintained an active interest in the SAMAP conferences.

He holds an MSc and a PhD degree in chemistry, from La Trobe University, Melbourne, Australia.

PROGRAM OF EVENTS

Sunday 3rd November

13:00 - 17:00	Registration desk

Monday 4th November

07:30 - 08:30	Registration desk and refreshments
08:45	Welcome address by Cpt Martyn Boyes Royal Navy and Wally Mazurek
09:00	Keynote speaker Dr Tom Limero, Johnson Space Center, Houston USA
10:00 - 15:30	Speaker sessions

17:00	Coach leaves for Evening reception Boat Ride along the Tyne
17:30	Boat boarding
18:00	Sail time
20:00	Return to hotel

Tuesday 5th November

09:00 - 13:00	Speaker sessions
14:00	Bus departs for HMS Trincomalee Visist
16:00	Return to host hotel, evening at your own leisure

Wednesday 6th November

09:00	Speaker sessions
14:00 - 15:00	Closing comments and finish

ABSTRACTS

SUBS IN SPACE

Tom Limero

Wyle Laboratories Inc., JSC, Houston, USA

The collaborations between NASA and the U.S. Navy date back to the very beginnings of NASA in 1958. This presentation provide a time line of activities and collaborations from the earliest days to the present. Joint projects ranged from rockets to environmental controls, monitoring equipment, and air quality standards. Also, starting in the early 1990s NASA began discussions with the U.K. Navy and by the early 2000s, a joint project was initiated that involved NASA, the U.K. Navy, and the U.S. Navy. SAMAP has provided a forum by which NASA and the navies of the world have an opportunity to exchange ideas and innovations that have led to continued discussions and sea trials. NASA and the navies of the world face some similar issues with their partial closed environments and although differences in operational scenarios and logistics do exist, there is still good reason to share ideas and collaborate now and in the future.

ATMOSPHERE MONITORING –
ASSESSING FUNCTIONAL LIMITS OF DETECTION

Mr Alan Chapman
Maritime Life Support, QinetiQ, Haslar Marine Technology Park,
Gosport, Hampshire, PO12 2AG, UK.

The UK Ministry of Defence has developed its own regulations for atmosphere control in submarines (BR1326). The UK Health & Safety Executive, and the European Union, continues to drive down chemical exposure limits for Industry and these are published in The Health & Safety Executive UK EH40 guidance document. Submarine Maximum Permissible Concentration (MPC) action levels for atmosphere contaminants must be reviewed when revised evidence of the risk to health of exposure becomes available.

Understanding the Limit of Detection (LoD) and Limit of Quantification (LoQ) achievable by on-board monitoring techniques is particularly important for Royal Navy submarines because continuous MPC action levels are typically lower than Workplace Exposure Limits and consequently are more challenging for monitoring techniques to achieve. Typically the upper limits of detection and quantification are less critical in the submarine environment and these are not addressed in this paper.

A number of alternative methods of assessing the lower operation limit of analytical techniques are routinely used. For direct reading toxic gas monitors sold in Europe this is most commonly performed to EN 45544:2015 [1] whilst retrospective analysis techniques are typically based on the in-house quality requirements of the individual laboratories. Eurachem Method Validation Working Group give guidance on how to determine LoDs and LoQs in their guide, The Fitness for Purpose of Analytical Methods [2]. This paper looks at the process used in both the EN 45544 and Eurachem methodologies and how this affects the confidence in the lower operating limit. It is especially important to use a single methodology for assessing the functional limits of methods when comparing real-time monitoring techniques against retrospective methods to allow a fair unbiased assessment.

NOVEL APPROACHES FOR THE INVESTIGATION OF SUBMARINE AIR QUALITY

A.V. Qualley[1], B Vaught[2], L.A. Beardslee[2], D.M. Fothergill[2] & H.M. Rubenstein[3]

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[2] United States Navy Naval Submarine Medical Research Laboratory, Naval Submarine Base, Bldg. 141, Trout Ave, Groton, CT 06349, USA
[3] United States Air Force 711th Wing – Air Force Research Laboratory, 711th Human Performance Wing/RHMO, 2510 Fifth Street, Area B, Building 840, Wright-Patterson AFB, OH 45433, USA

Introduction: Current passive dosimeter methodologies require the use of several different types of media and multiple analytical strategies for sampling and measuring airborne volatile organic compounds (VOCs). Here, the use of two non-traditional dosimeters, silicone wristbands (SWB) and mesoporous silica (MPS) tokens, were evaluated as universal passive dosimeters for contaminants present in the isolated atmosphere onboard a US nuclear submarine. The data presented describes our initial steps in exploring the technical feasibility of conducting individual longitudinal exposure monitoring for submariners using a universal passive dosimeter.

Methods: Surveillance sampling of airborne contaminants was conducted onboard a fast attack US Navy submarine using the new SWB and MPS dosimetry media and a currently used sorbent sampler produced by Assay Technologies, Inc. All media were exposed at eye level at 6 locations for a period of 22 days while the submarine was underway. Control media were brought aboard and remained isolated from the atmosphere for the duration of the study. Off-line thermal extraction with conventional thermal desorption gas chromatography/mass-spectrometry (TD-GC/MS) was used to measure 16 VOCs of interest adsorbed to the novel sampling media (MPS, SWB). Additionally, newly acquired modified off-the-shelf (MOTS) instrumentation (SIFT-MS) was investigated for the ability to expand the analyte range for each individual analysis.

Results: We were able to detect 13 out of 16 VOCs in the SWB and 11 out of 16 compounds in the MPS that were above the background levels measured on the control media. The amounts of the various VOCs measured was generally higher in the aft compartments (engine room) compared to the forward compartments but showed consistency in the relative amount between the different media except for benzene which was higher in the Assay badges. Our preliminary findings indicate that the MOTS SIFT-MS is capable of analyzing all of the 19 target VOCs simultaneously and that both MPS and SWB samplers can be used to introduce analytes into the SIFT-MS, albeit with differing levels of background interferences.

Conclusions: Novel media (SWB and MPS) demonstrated the ability to differentiate between separate compartments onboard the vessel based upon the spectrum of collected VOCs and showed good agreement between SWB, MPS and a legacy sorbent sampler produced by Assay Technologies, Inc. for most of the VOCs measured. We also demonstrated that SIFT-MS is capable of analyzing all of the target VOCs simultaneously. Preliminary findings indicate that both MPS and SWB samplers can be used to introduce analytes into the SIFT-MS via an automated TE step, albeit with differing levels of background interferences. Future experiments will determine sampling rates for the novel sorbent materials and evaluate the SIFT-MS as an alternative to TD-GC-MS based strategies.

(Funded by the U.S. Defense Health Agency, US Navy J9 Restoral and Joint Program Committe-5 Military Operational Medicine Research Program)

CONTAMINANT DETECTION IN THE SUBMARINE ENVIRONMENT

M. Leist, Defence Science & Technology Group

506 Lorimer St, Fishermans Bend, Victoria 3207, Australia

Submarine extended underwater endurance places a significant limitation on the ability to exchange contaminated air with fresh air. To ensure submarine operations do not pose a risk to crew health or damage to the platform, a thorough understanding of the levels and types of contaminates present is essential.

The measurement of contaminates within the submarine environment can be a complex task. The chemical composition of the submarine atmosphere can differ significantly from other industrial workplaces thereby creating unique analytical challenges. In addition, any chemical sensors installed must also be sufficiently robust and reliable to avoid increasing the workload of the crew, or the maintenance schedule of the submarine. The challenges facing the measurement of both gas and particulate matter will be discussed.

Originally at the request of the Royal Australian Navy (RAN), the Defence Science and Technology Group commenced a program to develop a prototype Tunable Diode Laser (TDL) sensor for the detection of Carbon Monoxide. Carbon Monoxide has been historically challenging to detect due to the elevated levels of hydrogen present in the Collins Class Submarine atmosphere. An update on the development of the sensor that is aimed to meet both the analytical and environment challenges will be provided and compared with current alternatives.

While the international Agency for Research on Cancer (IARC) have concluded that there is sufficient evidence for the carcinogenicity of engine exhaust, it is also important to be able to determine Diesel Particulate exposure to minimise lesser non-malignant potential health effects such as cardio vascular effects and inflammation effects in airways. The ability to determine crew exposure to diesel particulate matter in the submarine will also be discussed and atmosphere data presented.

ACUTE EXPOSURE TO DIESEL EXHAUST EMISSIONS: IRRITANTS

W. Mazurek

Australia

Diesel exhaust emissions are a major source of pollution in conventionally powered submarines in terms of both fugitive emissions from the engine and intake of exhaust emissions through the snorting tube. Exposure monitoring is largely confined to diesel particulate matter (DPM) measurements in real-time and retrospectively in addition to CO and NO_x measurements under steady-state engine running conditions. In the case of submarines, the engines are run at constant speed and constant load during battery charging with little variation in combustion conditions. However engine starts represent entirely different combustion conditions which affect the composition of the exhaust emissions. This is true of all combustion engines and where engine loads and speeds are variable the composition of the exhaust emissions is also likely to vary.

During the course of measuring engine exhaust emissions from a variety of military platforms, it became apparent that personnel exposure during engine idling resulted in eye nose and throat irritation. It is well known that the combustion process can produce lachrymatory compounds such as formaldehyde, acetaldehyde and acrolein. However, these compounds are not mentioned in exhaust emission regulations nor are they generally measured. This is generally because modern engine management technology has resulted in a significant reduction in the emission of these compounds. Unfortunately, military platforms tend to retain their engines for up to 20 years or more and the configuration of the exhaust may enhance exposure to personnel compared to civilian applications. Furthermore, in the case of submarines, the engines are custom built and are not covered by engine emission regulations.

The aim of this presentation is to illustrate the nature and concentrations of irritants produced by diesel combustion engines and the sampling and analytical techniques that can be deployed for the monitoring of these compounds.

CARBON MONOXIDE RELEASE FROM WHOLE BEAN ROASTED COFFEE IN STORAGE

Alan McCarrick and Benjamin Letter
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Shannon O'Dwyer
Naval Surface Warfare Center Philadelphia Division, Phila, PA
and Drexel University, Phila, PA

Matthew Knighton
Naval Surface Warfare Center Philadelphia Division, Phila, PA
and Rowan University, Glassboro, NJ

Sara Jane Neal
Naval Sea Systems Command, Washington, DC

The process of roasting coffee beans produces carbon monoxide (CO) and carbon dioxide (CO_2) as unwanted byproducts along with the multiple flavor and odor compounds that become trapped within the coffee beans as they cool from the high roasting temperatures. After roasting is complete, these gasses begin to diffuse out of the beans. Roasted beans are normally kept for several hours to days to "temper" by releasing some gases before packaging. Coffee beans packaged in flexible, sealed bags with one-way vent valves slowly release these gases to the surrounding storage area. As the gasses diffuse out of the beans and the vent valve opens, all gaseous components are released into the surrounding atmosphere. Our data indicates that storage of roasted coffee beans in non-ventilated spaces can potentially raise concentrations of CO to dangerous levels. The Navy has an interest in determining the CO off-gassing rate and total capacity as it applies to shipboard storage involving large quantities of bagged coffee in order to ensure the safety and wellbeing of Navy sailors. An environmental chamber was configured to mimic the chamber volume to coffee mass ratio of storage aboard some US Navy ships. Increases in CO and CO_2 concentrations were measured over time for three different nominal temperatures: 40°F, 70°F, and 100°F. Off gassing rates were capable of generating hazardous levels of CO at rates significantly affected by temperature. Diffusion occurred more rapidly with increasing temperature. A second test at room temperature released CO at much higher rates than the first test. Further investigation indicated that the beans used for the second room temperature test had been shipped significantly closer to the roasting date than the manufacturer claims. This confirms that the rate of CO release is substantially higher immediately soon after roasting.

AN EVALUATION OF MONOETHANOLAMINE (MEA) DEGRADATION AND MITIGATION UNDER THE CONDITIONS USED IN SUBMARINE CARBON DIOXIDE REMOVAL PLANTS

Charles Cummings, Timothy Taylor

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The current carbon dioxide (CO_2) removal technology utilised on Royal Navy submarines is based on the amine, monoethanolamine (MEA). This reversibly binds CO_2 under ambient conditions and releases it when heated. However, this amine degrades within the plant yielding hazardous compounds such as ammonia (NH_3). In this study a laboratory test apparatus was used to evaluate MEA solutions containing a range of inhibitor additives to determine which experienced the least degradation. A series of additional experiments were carried out to optimise the sorbent used to remove reaction adducts and metal impurities from the MEA within the system. These investigations concluded that the existing inhibitor additive was the most appropriate based on performance, cost, and exposure hazard but improvements could be achieved by using alternative sorbent media. The methodology presented can be applied to new CO_2 removal technologies including solid amines which also degrade to release NH_3.

VOLATILE ORGANIC COMPOUNDS (VOC) INTERACTION WITH HIGH AND LOW TEMPERATURE CARBON MONOXIDE/HYDROGEN OXIDATION CATALYSTS

Gareth Toft[1], Charles Cummings[1] & Tina Goodall[2]

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Under its duty of care the UK Ministry of Defence (MoD) must ensure that Royal Navy (RN) submarines maintain a safe breathable atmosphere. A key component in this is the high-temperature carbon monoxide (CO)/hydrogen (H_2) burner. This employs a bed of Moleculite®, a copper oxide/manganese dioxide oxidation catalyst at elevated temperature. Although the primary function of the burner is the removal of H_2 and CO an important secondary role is the removal of Volatile Organic Compounds (VOC). This paper presents the finding of an investigation to determine the removal performance of Moleculite® for several submarine atmosphere VOC. Removal of between 61 and 76 % total VOC content was found, suggesting that the CO/H_2 burner has a significant impact on the level of atmospheric VOC. Whilst Moleculite® has been the catalyst of choice for many years, other materials which operate at lower temperatures are of growing interest. Use of these alternatives would provide significant power savings. Low-temperature catalysts have the potential to be poisoned by submarine atmosphere contaminants. The laboratory evaluation of two Johnson-Matthey precious metal catalysts is reported. Results showed that VOC had only a minimal effect on CO and H_2 oxidation performance and that these catalysts had an average VOC removal of 78.5 %. Low-temperature catalysts have potential to replace the currently used high-temperature catalyst with no adverse effect on either CO/H_2 or VOC removal performance.

DESIGN IMPROVEMENTS TO THE MPOG OXYGEN GENERATOR

Pete Hutchinson

Air purification, Survival in disabled submarine

Molecular Products is a world leader in the design and manufacture of life critical devices for the treatment of breathable gases and the filtration of hazardous or harmful emissions. Where there is a finite quantity of air, Molecular Products' leading-edge technologies will sustain human life independently, or collectively, to maintain a breathable environment

Over the past decade Molecular Products has developed the newest additions to their oxygen portfolio; the MPOG and EO2-30. These oxygen generators are used globally to provide breathable oxygen in closed environments; primarily submarines, mines and safe havens. The subtlety of the technology comes from the concentrations of iron and sodium chlorate in the chemical formulation to control the rate of the reaction and the oxygen volumes produced. Sodium chlorate chemistry has been commercially proven over decades of use and has been relied on in some of the harshest environments to generate breathable oxygen since the early 1900s.

In the MPOG and EO2-30, Molecular Products has designed intrinsically safer through-life products, driven by an extensive development programme and a comprehensive understanding of their lifecycle. But design and development are a continuous process that relies on consistent feedback and collaborative relationships with customers. And it is these two things that are pivotal in ensuring that Molecular Products remains at the forefront in the manufacture of life support devices for some of the world's most inhospitable environments.

When launched in 2011, the MPOG was a new evolution of oxygen generator that offered improved user experience and better protection. In this presentation, Molecular Products will discuss how a close working relationship with users and honest feedback has led to design improvements to the product. Including changes to chemical classifications that resulted in replacement material being sourced, to ensure a safe product is supplied. We will talk through the test regime, performance criteria and design changes that have led to the MPOG Mk2.

MONITORING THE CO2 LEVELS WITHIN A CO2 SCRUBBER TO GIVE AN INDICATION AS TO WHEN TO CHANGE THE SCRUBBER MEDIA

M. Richardson

Analox Sensor Technology, 15 Ellerbeck Court, Stokesley Business Park,
Stokesley, North Yorkshire, UK, TS9 5PT

Active CO2 scrubber systems using CO_2 canisters or CO_2 scrubbing packs, operate by forcing atmosphere through multiple scrubber media, often installed in parallel. This means airflow from a drive pump/fan is branched, with each branch passed through a set of scrubber media, following which the branches are recombined before the scrubbed atmosphere is distributed to the vessel.

In general these systems are operated by changing out the CO_2 scrubber media in the system at a set time period calculated previously from information of the usage rate of the scrubbers. This may result in a situation that some of the media still have usable life left due to the possible differences in flow distributed to each scrubber medium installed in parallel and the variation of usage rates due to activity within the boat. This situation may be further complicated by a boat having multiple active scrubber systems installed in different areas of the boat, with each system potentially being exhausted at a different rate.

The early replacement of scrubber media means that more need to be carried on a vessel than are necessarily required, or with a given stock the ability of the submarine to stay submerged without taking in fresh air, by snorting, is reduced.

Analox proposes that the efficiency of the scrubber media use could be improved by the instrumentation of the scrubber system, to check in real time the usable life left in each scrubber media. To test this hypothesis we intend to instrument an active scrubber system to measure the relative usage rate of scrubber media to determine the magnitude of the efficiencies that could be gained by fully utilising each scrubber medium and replacing them only when they become exhausted, rather than replacing all scrubber media onboard when the CO_2 level across the vessel reaches a set level or a predetermined estimated time expires.

This measurement of the potential benefit of fully utilising each scrubber medium will then be used to build a set of proposed actions that could be taken to improve submarine active scrubber system performance.

TEST RESULTS OF TWO NEW NON-REGERNERATIVE CARBON DIOXIDE SCRUBBERS

Peter Row[1] and Thomas Daley[2]
[1]TPG Maritime Ltd. UK
[2]Micropore Inc. USA

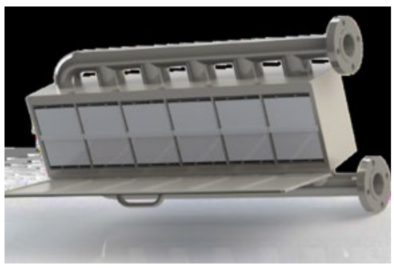
Micropore has teamed with TPG Maritime to develop a new series of non-regenerative carbon dioxide (CO_2) scrubbers. These units are intended for atmosphere control applications such as submarines, hyperbaric chambers and small submersibles. TPG maritime has a long history of design, build and support of submarine atmosphere control systems. Micropore developed and manufactures a proprietary CO_2 adsorbent that encapsulates fine alkaline powder into a solid sheet. Integrating Micropore PowerCube® adsorbent into a family of custom designed scrubbers allows for optimal utilization of adsorbent in a space and power optimized design.

The first commercially available scrubber was the single cube CO2RE (Carbon Dioxide Removal Equipment) scrubber. This scrubber has an installed fan (AC or DC powered) and the option of inlet and outlet infrared CO_2 analyzers for automated operation. The power requirement is low (several watts) due to low airflow resistance through the scrubber and adsorbent. This paper will report on the performance test results over the typical range of submarine ambient CO_2 concentrations.

The second scrubber offered by TPG Maritime is a 6 cube unit with multiple arrangements. This scrubber is intended for back-fit or new construction diesel electric submarines. These scrubbers offer 6 cubes in either two banks with parallel flow or all 6 cubes in parallel. Due to the low pressure drop, airflow can be provided by existing ventilation system or by a dedicated fan. Performance test results for these cubes is reported in this paper.

CO2RE Single Cube

6 Cube Scrubber for retro-fit



Inline 6 Cube Scrubber

A HISTORY OF CO_2 SCRUBBING ON BOARD WALRUS CLASS SUBMARINES

Toon Mariën

Ministry of Defence, NL

An overview of CO_2 scrubbing on board Walrus class throughout the years.

During the build of the Walrus class, 8 scrubbers for scrubbing CO_2 were build and implemented. Two scrubbers were installed on each Submarine, positioned in Wardroom and Torpedo storage room. These scrubber made use of canisters filled with Sodalime Granuals.

Already during the first few years it became clear that the scrubbers were not performing as expected. So throughout the years RNLN made small changes, as air flow rate and internal cannister changes by OEM. In 2007 there was a study upon improving CO_2 scrubbing, one of the conclusions was that more volume of adsorbing material was needed, even with 100% use of the canisters in the two existing scrubbers. **This resulted in a 3rd scrubber**. The third scrubber gave a slight but not sufficient improvement so further research was done.

From start of operating Walrus class until 2013/2014, the MAC values of CO_2, were a maximum level of 1.5% (no designated time limit), and a 24 hours maximum level of 2%.

With a new POR for new canisters the responsible department of the Defence Material Organization was triggered on the MAC levels. At the end of 2013 a research was initiated on admissible CO_2 levels, this resulted in new MAC levels for CO_2 on Netherlands submarines

After a study on values to be in forced on submarines RNLN decided that we had to go down with .5% on our values now resulting in a CO_2 operational maximum for 1%, and a 24 hours maximum level of 1.5%.

During 2014 and 2015 RNLN did several tests, first test (Power cube test) was presented at SAMAP 2015. This made RNLN switch from granual canisters to the Power cube adapter and the CaOH power cubes. A other test was ("The Nesquick" test) on the internal airflow on the original two scrubbers. Also presented at SAMAP 2015 (by Barend van der Giesen)

RNLN, together with manufacturer of the Power cube adapter and the 2 different Power cube blocks wanted to perform an on board test. So in 2014 RNLN performed a test on board submarine Dolfijn. During the power cube test RNLN made use of the Power cube adapter and 2 different kinds of scrubbing material blocks (CaOH- and LiOHPowerCube). This was presented at SAMAP 2015

Continued overleaf

The combined conclusions of these test were:

- Install a third scrubber
- Use the Micropore powercube adapters in combination with the Micropore calcium hydroxide blocks (Powercube)
- Improve airflow through the two existing scrubbers

After implementing the first two conclusions the CO_2 levels on board submarines improved and even became lower than expected. Although RNLN did not perform an endurance test up to this moment.

The third conclusion is work in progress. In 2018 a company performed CFD analysis on both old scrubbers and were asked for suggestions on improving the internal airflow, after some modelling and calculations the conclusion was that a suggested small change, would make a big difference and was the best solution for both scrubbers.

With this small change on a part of the scrubber the airflow could be improved to get an almost evenly airflow through all power cubes.

The average deviation on the torpedo storage room scrubber changed from 5.44% to 0.53%. The Ideal airflow is 16.67% through each of the six power cubes.

The improvement on the Wardroom scrubber was significant less than the improvement on the Torpedo storage room scrubber. Never the less RNLN made the change on both scrubbers.

The Average Deviation on the wardroom scrubber is under 1%. No graphs or pictures on the Wardroom scrubber about air flow are available in this presentation.

RNLN implemented this improvement on one of the submarines and is looking for an opportunity for testing.

What now?
So RNLN has mounted a third scrubber (final design) and made the changes to the two existing scrubbers on one of our submarines. This coming fall RNLN will implement the changes to the two scrubbers on the second submarine and have to plan and perform a quayside - and sea trial.

PLAN:
1st, Perform a static quayside trial, like RNLN did before, find a few a bit crazy guys, Put these guys in a closed down submarine, give them fire extinguishers, have them discharge aprox 2.8 kg CO_2 /hour into the submarine for simulating a crew of 62 and let them measure: CO_2, O_2, temperature, humidity and 2nd Perform sea trial to look at the performance under real life submarine conditions.

WHY USE A DSVDS FOR SUBMARINE RESCUE?

Jos Bogaert
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Every scenario of distressed submarine is different, but critical parameters that may limit survivability of the crew are always the same:
- Pressure rise
- Toxic atmosphere
- Loss of life support capability
- Time

In an ideal world, it should be possible to undertake:
- Fast mobilization of rescue elements
- Fast localisation and environment assessment
- Safe & fast rescue intervention
- Immediate medical treatment for sub's crew

A lot of rescue systems like NATO NSRS (or equiv.) are available.
Most of these systems have the following functions :
- Transportable full rescue system
- TUP facilities
- On-board decompression chambers & medical experts

In some cases, SRS intervention may be difficult, or even impossible:
- System not available (maintenance…)
- Longer mobilization of system
- Technical failure before or during operation
- Bad sea conditions
- Sub/SRS interface unreachable by SRS or damaged
- Sub/SRS interface unreachable by sub's crew

In such situations ADDITIONAL TIME is needed

To increase significantly preparation and intervention time, the following problems must be addressed :
• Avoid toxic atmosphere inside Sub by regeneration/ventilation
• Continuous monitoring and control of inside pressure
 Ventilation and Depressurization System (DSVDS)
• Ensure life support for the ELSS Pod posting

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Background
A DSDVS provides the means of remotely de-pressurising and / or ventilating a DISSUB compartment that is subject to elevated internal pressure, or has an atmospheric specification beyond breathable limits.
A DSDVS therefore has two purposes; firstly to control pressure /de-pressurise, and secondly to ventilate.
The former would either be able to maintain pressure within survivable limits (against for example a rising pressure gradient) or to lower the pressure to reduce the surface decompression obligation.
The latter would supply air and remove waste gases.

DISSUB Internal Pressure
Of all the factors influencing the system capabilities, the target pressure (and airflow) in the DISSUB is arguably the most critical. It is from this point that the rest of the system must be matched and sized
When looking at a system that supplies breathing air, too high a DISSUB internal pressure demands a high flow to provide sufficient refreshing of the atmosphere to accommodate the submariner's life support consumption rates – whilst the higher internal pressure aids recovery of the exhaust gasses, the size of the recovery hose this may entail on the recovery side could hamper system mobilisation.
The consequent increase in supporting equipment quickly adds to the overall size of the rescue spread.
Too low a target pressure reduces the differential available to exhaust spoiled air at the surface.

Flow Rate Limitations
The flow rates required to maintain the atmosphere within habitable bounds are a function of:
- the consumption rates of the submariners
- the pressure of the chamber
- the size of the chamber
- any contaminated air to be removed and production sources of contamination
- the smallest restriction in the line

It is also worth noting that the flow rates may produce problems at entry to the DISSUB –there is a physical limit to the velocity with which air may enter and exhaust through a salvage point. A restriction at this point, should be investigated with respect of orifice size and internal layout. This will then have an impact on the system. Although it is possible to increase mass flow rate with pressure, the velocity shall remain constant, the point at which this occurs on a submarine requires understanding ahead of purchasing a system as it may affect internal pressures

Transportation
The system has to be air transportable, and the items specified comply with JADTEU guidelines.
It is worth noting however that standard 20ft ISO specified size of shipping container disqualifies use of certain common 747 transport planes. These planes have historically been the most readily available means of air mobilisation and form the basis of many designs.
If a specific set of air transport guidelines or the details of the most readily available air transporter were available, the design may be specifically tailored to this.

Continued overleaf

Medical Air / Oxygen

A system capable of introducing oxygen, coupled with ELSS pod posting of LIOH Curtains or similar would offer additional system flexibility at extremes of operation.
Integration of such facility is a relatively small cost when considering the purchase of a system but adds an additional layer of capability and the ability to extend the habitable environment in certain scenarios.
A system capable of supplying oxygen must be designed with this in mind at the outset and material and safety considerations applied throughout as standard.

Umbilical System Deployment

The means of deploying the umbilical, requires thoroughly integrated and must be considered as the system develops. Historically this is one of the most challenging aspects when providing a rescue ready DSDVS.
Regard for factors such as deck handling, splash zone transition, submarine interface, ROV and diver interface and surface ship stability are critical. Whilst a large diameter umbilical facilitates the flow rates, were it also load rated, its stiffness would demand a winch of such dimensions that it would severely limit deployment and mobilisation.

DSVDS Exercises

- Although there are several systems in use with different Navies, knowledge of the working of the systems is minimal
- Every exercise a successful coupling of the hoses is performed and when air is flowing the exercise stops
- All these exercises take place at limited depths while the real challenge is to do it deep
- Also not much thought is given how to deal with partial pressure of oxygen / CO2 and what mixture to supply to the submarine

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