SAMAP

Submarine **A**ir **M**onitoring **A**ir **P**urification

Human Life Beneath the Waves

29th April - 2nd May 2024

Naval Establishment, Amsterdam, The Netherlands

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INTRODUCTION

Since 1994 the SAMAP series of international symposiums have provided a technical forum for the submarine community to discuss all aspects of Submarine Air Monitoring and Air Purification. A select group of industry and government professionals from around the world gather to present and discuss their work and new technologies related to sustaining a physiologically acceptable submarine environment. This symposium offers delegates a unique opportunity to share research and technical endeavours plus offering obvious collaborations.

Delegates are offered the opportunity to present papers on topics concerning aspects of a submarine's atmosphere, indoor air quality related topics and medical, physiological and Submarine Escape and Rescue research. In addition there are opportunities for commercial exhibits and sponsorships.

As the social events sit alongside the conference, SAMAP also offers a great opportunity for networking and the sharing of ideas outside the formal platform.

This year the SAMAP conference will be held in Amsterdam, Holland. The conference will be held on the Marinekazerne Amsterdam, just next to the centre. The area was an old marine shipyard. It was founded in 1655 when the government of Amsterdam the admiralty allowed starting a shipyard on that place. On the side of the centre it is bounded to the 'Land's Zeemagazijn', originally a warehouse and office of the admiralty and now a maritime museum which we will visit Wednesday afternoon.

Figure 1: The former warehouse and office of the admiralty, now the Maritime museum. On the background of the conference area.

PROGRAM OF EVENTS

Monday 29th April

13:00 - 18:00	Open registration

Tuesday 30th April

08:00 - 09:00	Registration desk & refreshments
09:00 - 09:30	**Welcome address by Cpt Danny van den Bosch**, Royal Netherlands Navy
09:30 - 10:00	Keynote Lecture: **Submarine Life Support Applied Respiratory Physiology,** Jos Bogaert
10:00 - 10:30	Presentation 1: **Transition From Oberon to Collins Class Submarines: Air Quality Issues and Lessons Learned,** W Mazurek
10:30 - 11:00	**REFRESHMENTS**
11:00 - 12:00	Presentation 2: **Lithium Hydroxide Reactive Polymer Curtain Removal of Chlorine and Carbon Dioxide in Distressed Submarine,** Charles Cummings, QinetiQ
12:00 - 12:30	Presentation 3: **The Design, Construction and Testing of A New Cartridge Scrubber for Small Submersibles,** Tom Daley, Micropore
12.30 - 13:30	**LUNCH**
13:30 - 14:00	Presentation 4: **Comparison of Wet Amine vs. Dry Amine,** Nathan Stevenson, Analox Group
14:00 - 14:30	Presentation 5: **Integrating Chemical Oxygen Generators into Existing Platforms,** Emma Knight, Molecular Products
14:30 - 15:00	**REFRESHMENTS**
15:00 - 15:30	Presentation 6: **SARS-CoV-2 Pandemic and the Submarine Service,** Lucio Ricciardi, University of Pavi
15:30 – 16:00	Presentation 7: **Research into Alternative Adsorbents for Atmospheric Control of Monoethanolamine and Ammonia on Royal Navy Submarines,** Edward Harris, QinetiQ
16:00 - 16:30	Presentation 8: **Setting Appropriate Limits for Atmosphere Control, to Protect Submariner Health,** Tina Goodal, DEA
16:30 - 17:00	Presentation 9: **Li-ion batteries in Submarines: Gas Monitoring & Handling. Current Knowledge and Outlook,** Viola Nilson, Saab
17:00 - 20:00	Evening reception in conference centre

Wednesday 1st May

09:30 - 10:00	Presentation 10: **SEAL Gas Air Purification using Metal-Organic Frameworks,** Patrick Fuller
10:00 - 10:30	Presentation 11: **Towards A Universal Passive Dosimeter for Monitoring Submarine Air Quality,** David M. Fothergill
10:30 - 11:00	**REFRESHMENTS**
11:00 - 11:30	Presentation 12: **The Review of ANEP/MNEP 86. Technical and Medical Standards and Requirements for Submarine Survival and Escape,** Tina Goodal, DEA
11:30 - 12:00	Presentation 13: **Discussion on Anep 86,** Jos Bogaert
12:00 - 12:30	Presentation 14: **History of the Naval Baracks in Amsterdam**
12.30 - 13:30	**LUNCH**
13:30	Return to host hotel
14:00 – 17:00	Visit Maritime Museum
17:30 - 19:00	Boat Trip from Naval Establishment
19:00 – 22:00	Dinner at conference centre

Thursday 2nd May

9.30 - 10.30am	Presentation 15: **Detect and Protect: The Pathway to Atmosphere Detection and Control of the Future,** Nathan Stevenson, Analox Group
10:30 - 11:00	**REFRESHMENTS**
11:00 - 11:30	Presentation 16: **Retaining Corporate Knowledge & Embracing Lessons from the Past, to Enhance Future Submarine Air Purification and Monitoring Design,** Tina Goodall, DEA
11:30 - 12:00	Presentation 17: **CEPEDA,** R Jolly
12:00 - 12:30	**Open forum discussion on the future of SAMAP beyond 2024** Facilitated by W Mazurek , Jos Bogaert and Vicky Pigg
12.30 - 13:30	**LUNCH**
13:30 - 14:00	Location next SAMAP in 2026
14:00 - 15:00	**Closing speeches**, W Mazurek

KEYNOTE LECTURE

SUBMARINE LIFE SUPPORT

Jos Bogaert

The first submersible of whose construction there exists reliable information was built in 1620 by Cornelius Drebbel, a Dutchman in the service of James I of England.

The Turtle (also called the American Turtle) was the world's first submersible with a documented record of use in combat. It was built in Old Saybrook, Connecticut in 1775 by American Patriot David Bushnell as a means of attaching explosive charges to ships in a harbour. Both these submarines were propelled by man Power.

Plongeur (French for "Diver") was a French submarine launched on 16 April 1863. She was the first submarine in the world to be propelled by mechanical (rather than human) power. The submarine used a compressed-air engine, propelled by stored compressed air powering a reciprocating engine. The air was contained in 23 tanks holding air at 12.5 bar(1.25 MPa, 180 psi), taking up a huge amount of space (153 m^3/5,403 ft^3), and requiring the submarine to be of unprecedented size. The engine had a power of 60 kW (80 hp), and could propel the submarine for 5 nmi (9 km), at a speed of 4 kn (7.2 km/h).

The first practical steam-powered submarines, armed with torpedoes and ready for military use was the Nordenfelt I, a 56 tonne, 19.5 metre (64 ft) vessel), with a range of 240 kilometres (150 mi, 130 nm), armed with a single torpedo, in 1885. Nordenfelt I operated on the surface by steam, then shut down its engine to dive. While submerged the submarine released pressure generated when the engine was running on the surface to provide propulsion for some distance underwater.

The Irish inventor John Philip Holland built a model submarine in 1876 and a full scale one in 1878, followed by a number of unsuccessful ones. In 1896 he designed the Holland Type VI submarine. This vessel made use of internal combustion engine power on the surface and electric battery power for submerged operations.

The diesel submarines are still in use with many nations but in 1954 the USA launched the first nuclear propelled submarine, the Nautilus. About half of the submarines in Operation are now nuclear.

Early history Dutch submarine Service

The Royal Netherlands Navy Submarine Service (OZD) was established on 21 December 1906. In this year the Royal Netherlands Navy commissioned its first submarine, HNLMS O 1. The OZD was tasked with taking care of the equipment of the submarines and the training of the crews.

At this time there were still doubts about the usefulness of submarines. Royal Netherlands Navy officers did indeed see an "interesting and ingeniously constructed mechanism in the vessel, but were hesitant about their practicality.

World War II
During World War I and the interwar period, the Royal Netherlands Navy ordered and built many submarines. As a result, at the start of World War II, the OZD had more than 20 submarines at its disposal.

The Dutch O 21 series was operating a device named a snuiver (snorcle). The Dutch navy had been experimenting as early as 1938 with a simple pipe system on the submarines O 19 and O 20 that enabled them to travel at periscope depth operating on its diesels with almost unlimited underwater range while charging the propulsion batteries. The system was designed by the Dutchman Jan Jacob Wichers.

After 1945, the OZD had eight submarines, but due to intensive use in the war these were in a bad condition. Also the fact that the fleet consisted of different classes was a problem. It made maintenance and exercise of crews very pricey. Due to the economic malaise and the high costs caused by operations in the Dutch East Indies, there was no money left for new construction. In the end the navy managed to take four submarines on loan from the British and the Americans. In 1946, the Netherlands still had a total of eight operational submarines in service: HNLMS O 21, O 23, O 24, O 27, Dolfijn, Zwaardvisch, Zeehond, and Tijgerhaai.

For the OZD, this period just after World War II meant depending on Dutch pre-war submarines and second-hand British and American submarines. The commissioning of the Dolfijn-class submarines in the early 1960s was an important milestone. The four boats formed the backbone of the OZD during a large part of the Cold War; they were in service from 1960 to 1992.

The Dutch submarine fleet never reached the size it had before World War II again. The new global power relations also generated a new package of tasks. In cooperation with other NATO countries, these are mainly non-attack tasks. Since the Dutch submarines were ideally suited for unnoticed explorations, the OZD was mostly focused on gathering intelligence during the Cold War. This happened, for example, during the West New Guinea dispute in the early 1960s, when three Dutch submarines patrolled the Indonesian ports to warn against possible invasions of West New Guinea.

In the period from 1970 to the 1990s, the crew of the six Dutch submarines secretly gathered information about the Soviet Union. Most of the missions the OZD carried out remain secret to this day.Although the cold war was not a real war, but there were certain dangers of operating in hostile waters During this period there was not much attention for survivability or escape.Basic life gases were monitored but the standards for carbon dioxide (CO_2) were high as the limit for oxygen (O_2) was very low.

It was only after the Kursk accident and the fire on board Chicoutimi that RNLN started investigating in 7 days survivability and modern ways of escape and rescue. It was only in 2006 that RNLN did their first survivex who was briefed at SAMAP in 2007, because Mattijn is working as an Anaesthesiologist he looked at figures of air consumption and CO_2 production differently and he took more factors in consideration. In the following slides the calculations for DISSUB survival and other factors to consider for 7 days life support.

My presentation will take you through these factors based on the Walrus Class Submarines.

ABSTRACTS

PRESENTATION 1

TRANSITION FROM OBERON TO COLLINS CLASS SUBMARINES: AIR QUALITY ISSUES AND LESSONS LEARNED

W. Mazurek, Australia

During the late 1990s the Royal Australian Navy (RAN) transitioned from British-designed Royal Navy (RN) Oberon class submarines to a more modern, enlarged Swedish-based design, Collins class submarine. The Oberon class submarines, although adopted by many navies, were essentially RN, WWII designs with diesel-electric propulsion and a keel for surface running, a snorkelling capability and a capacity for relatively short deep dive times.

Although fitted with a conventional diesel-electric propulsion system future plans included the retrofitting of Air-Independent Propulsion (AIP). Consequently, in the absence of a suitable AIP model, the RAN adopted the air quality management from the RN and USN nuclear-powered submarines to facilitate the extended dive times envisaged for AIP. Restrictions were placed on products allowed on-board, cigarette smoking, deep fat frying and other activities and materials which may have a detrimental impact on air quality. Some of these measures were resisted by the crew while the air quality and air purification management imposed an additional work burden on the crew however, the benefits of improved air quality were welcomed.

The aim of this presentation is to describe the differences in air quality and air purification technology between the two classes of submarines, the benefits and how the RAN and particularly the crew adapted to the changes over time.

As most navies are transitioning to new submarines with extended dive time, the lessons learned from the RAN are becoming more relevant.

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PRESENTATION 2

LITHIUM HYDROXIDE REACTIVE POLYMER CURTAIN REMOVAL OF CHLORINE AND CARBON DIOXIDE IN DISTRESSED SUBMARINE

Charles Cummings, Edward Harris, Geoff Loveman and Gareth Toft

QinetiQ, Maritime Life Support, Haslar Marine Technology Park, Gosport, Hampshire, PO12 2AG

A constant danger to all submariners is an incident which can lead to a distressed submarine (DISSUB). DISSUB encompasses a range of potential scenarios including loss of power and atmosphere control. In such a case, the atmosphere quality must be monitored and maintained so that service personnel can make informed decisions including escape or wait for rescue. During DISSUB consumable atmosphere control equipment is deployed to ensure life gases (oxygen and carbon dioxide) are maintained within specified limits. Chlorate oxygen candles are deployed to generate oxygen for crew consumption. To control carbon dioxide, lithium hydroxide reactive polymer curtains (LiOH-RPC) are used. These react with atmospheric carbon dioxide to form lithium carbonate. QinetiQ has extensive background in testing of LiOH-RPC to quantify removal rate at both laboratory and large scale trials.

An unquantified aspect is the removal of other hazardous gases with LiOH-RPC. Toxic gases can be produced from fire and electrolysis of sea water and need to be controlled within specified limits. This includes the generation of carbon monoxide, chlorine and hydrogen chloride amongst many others. Chlorine gas is highly reactive and hydrolyses to form a mixture of chlorine and hydrogen chloride. Reported herein is the removal of chlorine and carbon dioxide via the LiOH-RPC. An inert test chamber was constructed and filled with chlorine gas from a permeation device. Upon inserting an unused LiOH-RPC sample, chlorine concentration decreased. Kinetic equations that quantify the removal rate were extrapolated and will be presented.

The removal of carbon dioxide in both the presence and absence of chlorine was also studied. In both cases, comparable removal rates were observed. Removal experiments on in-date and out of date LiOH-RPC were carried out to understand if sample age had an effect. Chlorine removal with used (carbonated) LiOH-RPC was also observed, suggesting that chlorine control can be achieved with carbon dioxide saturated Li-RPC. In addition, comparison to historical large scale trial data for carbon dioxide removal was conducted and chlorine control estimated.

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PRESENTATION 3

THE DESIGN, CONSTRUCTION AND TESTING OF A NEW CARTRIDGE SCRUBBER FOR SMALL SUBMERSIBLES

Millie Rutherford, Submarine Products LTD; Tim Davies, Submarine Atmosphere Control Equipment LTD; Tom Daley, Micropore Inc

Introduction
Traditionally small scrubbers (2 to 5 people) used in research, rescue and tourist mini submarines are fan powered with baskets of granular calcium hydroxide to absorb carbon dioxide. Micropore has partnered with SubACE and SMP to incorporate ExtendAir® solid sheet absorbent in a purpose built carbon dioxide scrubber. Micropore has manufactured a new cylindrical cartridge expressly for a powered mini submarine scrubber. SubACE has designed and built and tested a prototype scrubber and SMP has refined the design, built the first article and conducted first article testing.

Aim
This paper will review the design considerations that must be employed to take advantage of solid sheet (structured absorbents) including flow, pressure drop and computational fluid dynamics (CFD). The prototype scrubber design / build / test will be reported in detail by SubACE. The first article redesign and testing will be explained by SMP.

Methods
The scrubber is custom designed to accommodate ExtendAir® cylindrical cartridges. The flow modeling uses standard CFD tools that are specially modified to take into account the small rectangular flow passages through the cartridges. The testing was conducted both open loop and in a closed chamber. The detailed test methods will be reported and results discussed.

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PRESENTATION 4

COMPARISON OF WET AMINE VS. DRY AMINE: ADVANTAGES AND DISADVANTAGES, ALONG WITH GAS DETECTION FOR RISK MITIGATION

Nathan Stevenson, Systems Architect

Analox Group

Modern submarines are highly complex platforms. The functionality of the atmosphere monitoring system plays a pivotal role in the ability of the crew to remain submerged for long periods while maintaining the high levels of alertness and cognitive function required throughout the patrol. A key requirement of atmosphere control is the capture of Carbon Dioxide produced by the crew.

In many submarines, an amine-based system is employed to extract CO_2 from the atmosphere. There are two primary types of systems: wet amine and dry amine. In the wet amine system, air from the submarine is exposed to a wet amine spray, effectively capturing CO_2 and forming an amine/CO_2 solution. Subsequently, the amine/CO_2 solution is heated to release the captured CO_2. The heated amine is then cooled and recycled in the capture process. Dry amine has the amine suspended in a honeycomb material through which the atmosphere is circulated, allowing the capture of CO_2. Once the material is saturated, steam is utilised to release the CO_2 from the material. Following this, the material is dried out, enabling the cycle of CO_2 capture to begin anew. These intricate processes ensures an efficient and continuous removal of carbon dioxide from the submarine’s atmosphere.

Both wet amine and dry amine processes are extensively utilised on submarines globally, each with its distinct set of advantages and drawbacks. Notably, wet amine faces a particular challenge where the amine, such as MEA (Monoethanolamine), can escape with the captured carbon dioxide, potentially leading to MEA release into the submarine’s atmosphere.

Analox believes monitoring the release of MEA from the CO_2 scrubbing plan needs to be implemented to best protect the crew. This detection capability serves a dual purpose: first, to identify if the MEA levels are approaching a hazardous threshold, and second, to ascertain when the filters have been compromised. This proactive approach to monitoring and detecting MEA release contributes to the overall safety and efficiency of the submarine’s environmental control systems.

Speaker Biography:

Nathan joined Analox in 2014, progressing from Systems Engineer to System Architect in eight years. Leading the Systems team, he spearheaded major defence projects, including Analox’s largest-ever contract. Recognized with Incorporated Engineer Status in 2022, Nathan’s excellence earned him a nomination for IET’s Engineer of the Year in 2023.

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PRESENTATION 5

INTEGRATING CHEMICAL OXYGEN GENERATORS INTO EXISTING PLATFORMS

Emma Knight

Molecular Products

Over the past few years several nations have integrated MPOG and EO2-30 chemical oxygen generators into their existing platforms. This is either as a direct replacement for outdated technology or to provide supplemental oxygen capability onboard for operational and tactical use.

The Royal Norwegian Navy is the latest nation to deploy MPOGs across their Ula-class fleet. This session will share how the partnership developed between Molecular Products and the Navy is supporting the platform-wide conversion from obsolete aerospace oxygen generators to chemical O_2 designed for submarine use.

The session will also discuss chemical oxygen generators as a supplemental oxygen source onboard Class 209 submarines.

Molecular Products manufactures mission critical air purification technologies that protect people, processes and environments in enclosed spaces. Specialising in highly technical chemical media solutions for the treatment of breathable gases, our global customer base is served from our two primary manufacturing facilities in the US and UK.

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PRESENTATION 6

SARS-COV-2 PANDEMIC AND THE SUBMARINE SERVICE: A SURVEY

Lucio Ricciardi

Dept. Forensic and Experimental Medicine, University of Pavia, Pavia, Italy

The COVID-19 pandemic has officially spanned the period between December 31st 2019 and May 5th 2023 (cases about 765 . 106; casualties about 1% WHO).

Media and scientific Literature report the time course of naval and submarine reaction to this sudden and lethal illness. At the very start, a French naval spokesman would talk about "blissful ignorance" of the nuclear submarine crews with respect to the virus, as most of them were engaged in their underwater patrols, lasting months (same for RN, Russian Federation Navy and USN). There was obvious bewilderment, when back home, but infection started spreading among crews, thus worsening their health, their working capabilities, hampering routinary activity. Subsequently primary countermeasures have appeared, such as setting up quarantines prior to deploying (USN) and implementing all measures as per WHO advice. When facing new cases, they would be immediately isolated, while searching for asymptomatic subjects by means of swabs that started to be distributed on board. In this phase (2021), a former USN commanding officer compared the submarine to a giant Petri dish: "If someone gets sick, lots of people get sick", while submariners had their first casualty. At the same time the Inspector General, US Dept. of Defense, issued a publication: **"Evaluation of the Navy's Plans and Response to the Coronavirus Disease-2019 Onboard Navy Warships and Submarines".**

In 2022, a review article reported a 50% virus attack rate aboard a nuclear submarine over 11 days, with one crewmember hospitalised and 6% infected, but asymptomatic sailors.

One of the protections against the spreading of the virus has been, ever since, the Six-Foot-Rule, which, together with the use of a face mask, proved safe enough to avoid infection, but, unfortunately, this was not always the case on board submarines, where distance among people is often much shorter.

Therefore, guidelines as to how to limit indoor airborne transmission of COVID-19 started to appear in Literature: airborne transmission is the primary route of transmission of the virus that arises through the inhalation of aerosol droplets exhaled by an infected person. Studies carried on within confined workspaces and university classrooms have allowed to develop a safety guideline stating the relation between time of room occupancy and carbon dioxide level, that is related to airborne pathogens concentration. Prior to these papers, another one was published about biosensors (air samplers etc.) for monitoring airborne pathogens.

As nuclear submarine patrols are likely to be prolonged, a strong preventive approach is required, to contrast airborne transmission of different pathogens.

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PRESENTATION 7

RESEARCH INTO ALTERNATIVE ADSORBENTS FOR ATMOSPHERIC CONTROL OF MONOETHANOLAMINE AND AMMONIA ON ROYAL NAVY SUBMARINES

Edward Harris, Charles Cummings and Gareth Toft

QinetiQ, Maritime Life Support, Haslar Marine Technology Park, Gosport, Hampshire, PO12 2AG

Royal Navy submarines use monoethanolamine (MEA) in their carbon dioxide (CO_2) removal plants to maintain acceptable CO_2 levels on-board. During the operation of these plants, MEA and its breakdown product ammonia (NH_3) can be carried over in the plant outlet air and enter the submarine atmosphere. MEA and NH_3 are hazardous to health and are also a significant source of on-board oxides of nitrogen (NOx). To minimise carry-over, bags of ion-exchange resin are employed within the air purification assembly of the CO_2 removal system to capture MEA and NH_3. Findings are presented of research into alternative adsorbents for MEA and NH_3 removal in this application.

Initial laboratory studies were undertaken using commercial off-the-shelf activated charcoals and ion-exchange resins. This work concluded that MEA adsorption was greatest for adsorbents with high porosity and NH_3 adsorption was greatest for adsorbents functionalized with acid groups. Building on these findings QinetiQ have prepared novel adsorbents with optimised physical properties and chemical functionality for the removal of both MEA and NH_3. Laboratory tests showed that these materials had enhanced removal for both compounds compared to the currently used ion-exchange resin. If these results can be realised at full-scale, this technology could reduce MEA and NH_3 emissions from the CO_2 removal plant and thereby lower atmospheric concentrations of NOx.

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PRESENTATION 8

SETTING APPROPRIATE LIMITS FOR ATMOSPHERE CONTROL, TO PROTECT SUBMARINER HEALTH.

Tina Goodall
MSc (Occupational & Environmental Health and Safety management)
CMIOSH, MRSC, DE&S / SDA Senior Fellow

Naval Authority Group - Submarine Atmosphere control / Escape Evacuation & Rescue
Abbey Wood Bristol, BS34 8JH, United Kingdom.

In order to maintain operational capability, it is of paramount importance that submariner health is not compromised by atmosphere contamination whilst deployed. There is a growing desire within submarine operating nations, to remain under the water for longer periods of time especially with the move away from diesel operated platforms and the wish to remain covert from hostiles. To fulfil this aspiration, additional health risks from prolonged exposure to atmosphere contaminants should be considered by the operating nation to protect the submariners acute and chronic health effects.

Each operating navy will need to consider the following areas at outset of a submarines design.

- The appropriate setting of atmosphere contaminant limits.
- The ability to be able to remove contamination by chemical or mechanical interaction, without introducing other contaminants of concern.
- The ability to accurately monitor contaminants of concern at the pre-defined health limits.
- The management and control of materials used onboard to reduce avoidable health effects from the use of those materials in closed boat operations.

This paper will concentrate on the process the UK Royal Navy (RN) has adopted to support the generation of appropriate atmosphere control limits for continuous exposure in the submarine operating environment, and discuss the considerations given to setting those limits to fulfil its duty of care under UK law.

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PRESENTATION 9

LI-ION BATTERIES IN SUBMARINES: GAS MONITORING & HANDLING. CURRENT KNOWLEDGE AND OUTLOOK

Viola Nilsson

Saab Kockums

Introduction

Lithium-ion batteries (LIB) are becoming increasingly common on the electrical vehicle market. From land to naval transport, submarines may be the next step. With a high energy density and good performance, one can see the benefits for submarine application. However, the safety of LIBs have been questioned. LIB can experience a thermal runaway (TR) which can cause catastrophic fire. A TR is an accelerating self-heating process which expels flammable and toxic gases. In submarine applications this could possibly lead to a DISSUB-situation. To prevent and warn for the early signs of TR, gas monitoring systems are needed. If a TR occurs, the question remains how to handle the toxic and flammable gases which will be discussed. Additionally, the presentation discusses which gases can be present in a TR.

Aim

The aim of the presentation is to summarise the current knowledge in the scientific community regarding:

- Factors impacting thermal runaway gas composition (battery chemistry, state of charge, trigger method, atmosphere)
- How early signs of TR can be detected with a gas monitoring system (target gases, sensing methods)
- Handling of gases expelled in TR

Method

The method used is a literature study of scientific research papers and studies in this field.

Results

The main factors of the TR-gas composition are according to the research battery chemistry; state of charge, trigger method and atmospheric condition. Where battery chemistry is the main contributing factor. For all common type of battery chemistries, the main gases found were CO_2, CO, CH_4, H_2, and different types of VOCs. In some cases where the electrolyte contained Fluoride compounds, TR could cause them to react with binding agents and form HF, PF5, POF3 and other extremely toxic gases.
A higher state of charge was found to impact the amount of gas generated in TR heavily. Some research suggested that a higher SOC could cause more oxygen to form in the chemical reactions, causing more CO and CO_2 to form. For early gas detection, some studies show that the gases released in the safety venting (also known as first venting) which happens before TR could be vital.

The most suggested target gases, i.e., the gases that should be monitored in a battery pack should be CO, CO_2, VOC and H_2. For gas handling, the suggestion is to have a gas evacuation system in place with ventilation ducts to each battery pack for exiting the gas from the submarine.

Conclusions
The research is very much in active development with comprehensive studies only a few years old. The literature suggests different target gases and sometimes have contradictory results. However, all research points to gas monitoring as the essential system for early detection of TR.

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PRESENTATION 10

SEAL GAS AIR PURIFICATION USING METAL-ORGANIC FRAMEWORKS

Patrick Fuller, Brian Hashiguchi, Conrad Roos

Numat, 1358 N Kostner Ave, Chicago IL 60651, USA

Breathable air is required for an acceptable submarine environment. Toxic Submarine Escape Action Limit (SEAL) gases such as ammonia, nitrogen dioxide, and chlorine gradually build up, limiting air breathability even with effective oxygen and carbon dioxide control.

What are absorbents?
Absorbents are porous materials used for filtering toxic chemicals out of air Metal-organic frameworks (MOFs) are premium sorbents capable of removing 5-20x more SEAL gas than the best available alternatives. Better sorbents give design flexibility to air purification systems, enabling decreased system size, reduced power, and/or increased filter lifetime.

What are MOFs?
MOFs are high-performing sorbents made my mixing metal and organic reagents MOFs are created by mixing metal salts with organic linkers, self-assembling into a three-dimensional crystal with exceptional porosity. By changing the metal salt or organic linker, the resultant MOF structure can be tailored for specific applications.

Why do MOF's perform so well ?
Most absorbents waste as much as 80% of their space , a well-designed MOF does not When performance matters we can Use MOFs it provides clean air for those who need it most MOFs protect workers against toxic electronic gasses, first responders angsinst toxic industrial and warfare gasses MOFS can also filter CO_2 and other pollutans at their source Under "N211-034 - Submarine Atmospheric Contaminant Scrubbing Technology", US NAVSEA is exploring MOF-based emergency SEAL gas scrubbers. Moving forward, trade-space decisions on performance, size, and cost must be made and system-level test methods must be agreed upon.

Numat seeks community input to guide product qualification, if you are interested in supporting, please email pat@numat.com.

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PRESENTATION 11

TOWARDS A UNIVERSAL PASSIVE DOSIMETER FOR MONITORING SUBMARINE AIR QUALITY

David M. Fothergill[1], Sarah Pfahler[2] & Mitchel H. Rubenstein[3]

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Introduction
Current technologies for monitoring air quality in U.S. Navy submarines involve mass spectrometry and infra-red spectrophotometry by the Central Atmosphere Monitoring System (CAMS). While these technologies enable real time monitoring of 18 gases/contaminants, they do not provide information about many other volatile and semi-volatile organic compounds (VOCs) that may be present in the submarine atmosphere and could pose a health risk. Consequently, the Submarine Atmosphere and Health Assessment Program (SAHAP) at the Naval Submarine Medical Research Laboratory has an ongoing mandate (Chief of Naval Operations (N871) Memo Ser N87l/5U660109 dated 9 Mar 1995) to employ technological advancements in constituent measurement and identification to maintain a long-term analysis of submarine atmosphere constituents. To that end the SAHAP deploys multiple passive dosimeters to provide retrospective time-weighted average concentrations of an additional 29 gasses and VOCs/semi-VOCs that are not monitored by the CAMS. In this presentation, we describe the test and evaluation of a new commercially available universal XCel+ Passive Dosimeter (XploSafe LLC) that can monitor up to 19 of the 29 SAHAP compounds in a single low-profile badge.

Methods
The XCel+ badge was compared to the current SAHAP media during a 56-day deployment aboard a Virginia (VA) class submarine. Both media were placed next to each other at six different locations throughout the submarine and exposed to the submarine atmosphere over the first 28 days of the deployment. In addition, one of the riders assisting with the study wore an XCel+ badge over the same 28-day period. After the deployment, the XCel+ badges were examined by thermal desorption (TD) gas chromatography-mass spectrometry (GC-MS) at the Air Force Research Laboratory. The SAHAP media (Assay Technology badges) were examined by Assay Technology, Inc. by dual column analyses employing GC-Flame Ionization Detection (FID) and liquid chromatography. Statistical analysis (Pearson product moment correlation and analysis of variance) comparing the SAHAP

media to the XCel+ media was limited to those compounds detected on both media that were above the limit of detection by the respective analytical techniques.

Results

None of the compounds detected on the different passive media exceeded the submarine atmosphere control manual 90-day exposure limits. Eight contaminants were detected on the XCel+ media while six contaminants were detected by the SAHAP media. The compounds uniquely detected on the XCel+ media were acrolein, methyl isobutyl ketone, and toluene while those uniquely detected on the SAHAP media included ethanol and 2-butenal. Both media detected acetaldehyde, acetone, 2-butanone, and isopropanol. Statistical analysis comparing the results of the SAHAP media to the XCel+ media for the later four compounds revealed a significant correlation in their levels across the submarine ($r=.505$, $p<.05$, $n=24$ paired samples). The levels of the different compounds detected on the XCel+ badge worn by the rider closely matched the average values across the six XCel+ badge fixed locations. When the air concentrations of the four contaminants were calculated using the mass collected on the media together with previously determined sample rates, the average concentration for the detected compounds was significantly greater for the SAHAP badge compared to GC-MS analysis of the XCel+ media ($F_{1,41} = 8.37$, $p<.01$).

Discussion and Conclusions

An initial submarine trial of the XCel+ media to detect trace contaminants in the submarine atmosphere showed promise in detecting low levels (ppb range) for most of the compounds currently monitored by the SAHAP using multiple media. The advantage of the XCel+ badge is that the smaller size opens the possibility that the exposome of individual service members could now be obtained in operational environments. Current ongoing laboratory dosing work with the XCel+ badges is aimed at defining the equilibrium point for 19 of the SAHAP compounds of concern to better define the maximum time that the badges can be exposed to the atmosphere before reaching saturation. Provisional analysis of the extended duration dosing trials for acetone and aldehyde with the XCel+ media indicated that these compounds have a linear uptake rate only over the first 10 days of exposure, with levels reaching equilibrium by the 15th day of exposure. This implies that the lower levels for these compounds found on the XCel+ badge compared to the SAHAP media during the submarine trial may have been due to the XCel+ badge reaching equilibrium well before the end of the 28-day exposure period. Our next step is to deploy the XCel+ badges again to verify the current results with a shorter exposure period based upon the results of on-going equilibrium experiments, and to expand data collection to individual monitoring for comparison with area measurements using both the XCel+ and SAHAP Assay badge passive dosimeters.

Acknowledgements and Disclaimer
This work was supported by funding from Joint Program Committee 5, Military Operational Medicine Research Program. The views expressed in this report are those of the authors and do not necessarily reflect the official policy or position of the Department of the Navy or Air Force, Department of Defense, nor the U.S. Government. Dr. Fothergill and Dr. Rubenstein are employees of the U.S. Government. This work was prepared as part of their official duties. Title 17 U.S.C. §105 provides that 'Copyright protection under this title is not available for any work of the United States Government.' Title 17 U.S.C. §101 defines a U.S. Government work as a work prepared by a military service member or employee of the U.S. Government as part of that person's official duties.

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PRESENTATION 12

THE REVIEW OF ANEP/MNEP 86. TECHNICAL AND MEDICAL STANDARDS AND REQUIREMENTS FOR SUBMARINE SURVIVAL AND ESCAPE

Tina Goodal

DEA

Abstract
ANEP/MNEP 86 is a NATO standard which contains three chapters directly relevant to support survival from a distressed submarine (DISSUB):

Chapter 1 - details the minimum physiological and environmental considerations that may be faced in a DISSUB prior to Escape and Rescue (ER).

Chapter 2 – provides details on the requirements that must be considered for Submarine Escape and Surface Survival personnel equipment.

Chapter 3 – provides details on medical constraints for fitness to serve on submarines and attend Submarine Escape Training (SET).

The NATO Submarine Escape and Rescue Working Group (SMERWG) Technical Panel, were requested to review the contents of ANEP 86, and comments were received from SQEP nations for consideration and development of the document.

From the NATO winter panel, it was decided that chapter 1 and Chapter 3 will stay in ANEP 86 and be fully reviewed by the Technical and Medical panels, and that chapter 2 will move to ANEP 85 - Material Interoperability requirements for Submarine Escape and Rescue.

Recommendations on amendments to Chapter 1 & 3 will be made to the NATO Tech Summer Panel Amsterdam 2024.

Work is still ongoing on the development of this document, and it is hoped that the SAMAP community will wish to input into development of guidance specifically related to chapter 1. It is also hoped that there will be some useful discussions on physiological and environmental considerations for DISSUB and monitoring capability/requirements to enhance submariner decision making.

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PRESENTATION 13

DISCUSSION ON ANEP 86

Jos Bogaert

ANEP 86 is a publication used by all NATO Countries who operated Submarines.

The ANEP 86 consist of three chapters:

Chapter 1 - Minimum conditions for survival in a distressed submarine (DISSUB) prior to escape or rescue

Chapter 2 -Submarine escape and surface survival personnel equipment (SESSPE)

Chapter 3 - Medical standard for sumarine esccape training tank candidates

For us here at the SAMAP conference chapter 2 and 3 are not relevant as they have nothing to do with Air monitoring or Air purification. However Chapter 1 is relevant to us as the minimum conditions for survival in a distressed submarine are laid out here. The document in itself is useful to give standards for air inside the submarine during normal operations, but also, what kind of gases should we monitor during submerged operations, but also, what kind of gases are released during a fire and what are the safe limits for these gases to breathe in without emergency breathing equipment. At the moment there are three types of submarines in operation:

1. The traditional Diesel submarines
2. The air independent Submarines
3. The nuclear Submarines

For Diesel submarines the atmosphere on board is important but because they have to snort regularly the atmosphere on board is replaced during snorting and limits go back to normal conditions.

Air Independent Submarines can stay submerged between 8 to 12 days, They have to pay more attention to their atmosphere as it is not replaced as regularly as in a diesel submarine and there also could be more contaminants in the air from the air independent power plant.

Nuclear Submarines stay submerged for more than 90 days and rely heavily on their Nuclear Power plant to produce Oxygen by hydrolysis from Seawater and scrub the air with Amines. Both processes produce unwanted gases like for instance Hydrogen that you have to ventilate outside the submarine.

During a DISSUB situation conditions in all three submarines are probably the same, they have no power and have to use Non-Powered means like Oxygen Candles or LioH curtains to scrub the air inside the DISSUB, To monitor the air they probably have to use battery powered equipment like the Analox MKlllP or Drager test tubes.

The document gives advice to monitor the following gases:

a.	Oxygen	O_2
b.	Carbon Dioxide	CO_2
c.	Carbon Monoxide	CO
d.	Chlorine	CL

The ANEP 86 also advices that consideration should be given to monitor the following gases:

a.	Hydrogen chloride	HCl
b.	Hydrogen sulphide	H_2S
c.	Ammonia	NH_3
d.	Oxides of Nitrogen	NOx
e.	Hydrogen cyanide	HCN
f.	Hydrocarbons	CxHx(X)
g.	Hydrogen	H_2
h.	Humidity	H_2O
i.	Refrigerant gases	

The ANEP86 gives the Safe limits for the gases normally present in a submarine and dangers if you exceed these limits and what the symptoms are if you exceed these limits.

However the document is vague about the safe limits for other gases and what other gases could be in the atmosphere after a fire or accident. How easy is it to measure these gases and is there equipment available that could be used on submarines?

Although there is some literature and studies mentioned in the ANEP, these studies are hard to find and most of them are more than 30 years old.

What I hope to achieve during this conference is to find some answers to the question: ***What should we measure, decide on safe limits for these gases and is there equipment available to measure these gases and can they be operated by submariners?***

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PRESENTATION 14

HISTORY OF THE NAVAL BARRACKS IN AMSTERDAM

The area known as Marine Land has existed for more than 350 years. It was founded in 1655 and laid out as a huge ship-building yard on the island of Kattenburg. “This is historic ground” declared Willem Bijleveld, former director of the National Maritime Museum. “The Admiralty of Amsterdam, the forerunner of the Royal Marines, built here the great warships which protected the merchant ships of the VOC fleet”.

The Golden Age
In the Golden Age, Amsterdam was the largest harbour in the world. VOC ships sailed across the globe bringing herbs, spices and materials back to the Netherlands. These sea voyages could be very dangerous. The Admiralty’s warships, intended to protect the VOC fleet from pirates, were constructed in the Land’s Dock, the largest and most innovative shipyard in the country and one of the biggest employers in the city of Amsterdam.

“The ringing of the bell”
The Gatehouse with its old entrance is one of the few remaining 17th Century buildings in Marine Land. Hundreds of workers, carpenters, mast-makers and painters came to and fro daily through the gate. At that time, a bell hung above the gate and was rung to announce the start of work. The same bell can now be seen in the Maritime Museum.

The Marine Land’s Warehouse
The National Maritime Marine building also reminds us of the Golden Age as it was built in 1656 as the central storehouse for cannons, sails, flags and other equipment for the rapid furnishing of the new warships. The building was designed by Daniel Stalpaert, the architect who also designed the Royal Palace on the Dam square.

The End of the Shipyard
Warships were built in the Land’s Dock for 260 years, from the wooden Ships of the Line for Michiel de Ruyter to the armoured cruisers for Queen Wilhelmina. In 1828 a dam or a dike was built between Amsterdam and the river IJ to protect the city from floods. As a consequence there was a lock, the Eastern Dock Lock, between the shipyard and the Zuiderzee which provided access to the North Sea. However, the entrance to the lock proved to be very narrow and too difficult for the bigger ships to navigate.

The building of the new railway station on the harbour front and the lane of railway lines over the Eastern Dock Dike also resulted in the closure of the yard. It closed its gates in 1915.

The slipways in the yard have gone, but the memory of the Land’s shipyard must be cherished, said Willem Bijleveld.

“Michiel de Ruyter made history when he sailed into battle from the yard and helped establish a strong Dutch Republic. This history you must always feel as you walk over the grounds”.

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PRESENTATION 15

DETECT AND PROTECT: THE PATHWAY TO ATMOSPHERE DETECTION AND CONTROL OF THE FUTURE

Nathan Stevenson, Systems Architect

Analox Group

Submarines, as intricate platforms operating in hostile environments, necessitate advanced technologies to ensure crew safety and operational efficacy. This paper presents an in-depth analysis of the evolution of atmosphere monitoring systems aboard submarines, emphasising the limitations of traditional detectors and introducing the Analox DAMS as a groundbreaking solution.

With prolonged submersion increasing the need for frequent atmosphere monitoring due to contaminant accumulation, understanding the significance of monitoring key gases such as Oxygen (O_2), Carbon Dioxide (CO_2), Carbon Monoxide (CO), Hydrogen (H_2), and refrigerants becomes paramount. These gases collectively represent a comprehensive approach to submarine safety, addressing various potential risks and ensuring crew well-being.

Challenges in measuring gases on submarines are outlined, including rapid and unpredictable environmental changes and the complex interplay of contaminants. Future prospects in gas detection involve identifying crucial gases such as NO (nitric oxide), NO_2 (nitrogen dioxide), chlorine, and Otto fuel, and exploring advanced technologies including Laser Absorption Spectroscopy (LAS), Chemiluminescence, UV-Vis Spectroscopy, FTIR (Fourier Transform Infrared Spectroscopy), and UV LEDs.

System automation plays a pivotal role in data analysis, offering insights into dangerous gas levels, refining operational procedures, and optimising maintenance schedules. Feedback mechanisms provide insights into critical systems and processes, facilitating fault detection and maintenance tasks. Strategic positioning of gas sensors enhances the efficiency of ongoing processes, while comprehensive atmosphere control integrates monitoring with real-time feedback to manage onboard equipment effectively.

In conclusion, the integrated atmosphere monitoring system addresses historical challenges, providing accurate data for informed decision-making, reduced maintenance costs, and minimal system downtime. As submarines continue to evolve, the adaptable system allows for upgrades to capabilities, ensuring relevance throughout the lifespan of the platform.

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PRESENTATION 16

RETAINING CORPORATE KNOWLEDGE & EMBRACING LESSONS FROM THE PAST, TO ENHANCE FUTURE SUBMARINE AIR PURIFICATION AND MONITORING DESIGN

Tina Goodall

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In order to operate a safe Submarine, there is a requirement to deliver considered Air purification (AP) and Atmosphere monitoring (AM) systems throughout the life of the platform. If this requirement is not managed adequately, there is a credible risk which may result in the potential loss of a submarine, adverse health effects, and/or death/harm to a large portion of her crew.

Designers and engineers must not only understand sources of contamination but must also work in unison with scientists to understand synergistic effects of chemical and mechanical interactions, and potential hazards that may result within the sealed atmosphere.

The overriding aim of any atmosphere management system must be to **promote the wellbeing** of the crew by the provision of a **safe breathable atmosphere** which does not harm the crew or the fabric of the enclosed environment of which they are operating in. This along with the requirement of maintaining operational capability should be the primary focus of the AP and AM design.

Historically, the layout of the AP & AM design will have been well thought out and researched by our predecessors, and we must understand the benefits and disadvantages of all systems and designs and retain corporate knowledge of these decisions. We must also use this data prior to setting a statement of requirement for future designs, and before any new design phase is agreed. This knowledge will enable the designers, engineers and scientists to evaluate why AP & AM systems are located as they are, and permit Suitable Qualified and experienced personnel (SQEP) to review if the decisions previously made, are relevant to future designs. Submarine designers must also be mindful of operator experience, and when designing new systems, navies should be engaging with industry partners to look for new technologies to further enhance capability and remove known hazards where practicable.

Understanding and appreciating existing submarine AP & AM design cannot be underestimated in the safe delivery and operation of a submarine. Any changes to a submarine's existing AP system must be fully reviewed prior to design encapsulation, in order to ensure that the change will not introduce new and/or, previously unrecognised hazards or remove other desired AP removal capabilities.

Where we have lost corporate knowledge, we should as a community reach out to other sealed atmosphere sectors and operating navies and try to understand common issues and how and why decisions were made in the past. Corporate and specialist sector knowledge is key in the delivery of a ‘safe’ submarine, and this paper will discuss some of the author’s experiences and observations in AP and AM design, and reference where sometimes things have been overlooked to the detriment of good atmosphere management. The author will also reflect on how we can all learn lessons for the future by acknowledging our past.

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PRESENTATION 17

CEPEDA

R. Jolly

It will cover our history, a brief overview of legacy equipment, our growth, and CEPEDA moving forward.

CEPEDA is pleased to present at SAMAP 2024 as a 100% Navy contractor and small business dedicated to supporting the Navy and shipyards for over 45 years. CEPEDA specialises in engineering design, problem solving, fleet support and high quality manufacturing. These turnkey manufacturing services consist of Navy approved welding, machining capabilities, electrical, fabrication, product qualification, and testing services. CEPEDA fully transitioned to a new facility in 2020 to support growth in the industry and has capacity to continue growing to support shipbuilding targets. CEPEDA began with legacy CO_2 removal systems, providing life support equipment to all active classes of US Navy submarines and making them the global leader in life support equipment design and manufacture. From there CEPEDA utilised their engineering and manufacturing skill set to expand into a growing portfolio of mission critical products that include missile system support equipment, to heat exchanger systems, and further into hydraulics, Level I parts, and build to print components. CEPEDA also has substantial success reverse engineering and reviving obsolete parts where sources of supply have become scarce or disappeared completely. CEPEDA aims to continue leveraging their engineering and manufacturing capabilities in the future to provide high-quality mission critical components to the US Navy, while also expanding their global customer base to support future programs like AUKUS. As we look beyond 2024 we will seek to grow through internal development and supplier development funding to transform CEPEDA into an agile digital factory capable of quickly providing robust solutions to the unique needs of the submarine industrial base. These may include additive manufacturing, advanced machining, digital radiography and CT, robotics, and other areas to allow for optimisation of workforce and problem solving to the Navy's needs. If there is a complex problem to be solved, or if there is a vendor struggling to provide high-quality, mission critical parts, CEPEDA is here and ready to help.

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LOCATION & TRAVEL

Conference Location

Marinekazerne Amsterdam
Kattenburgerstraat 7
1018 JA Amsterdam

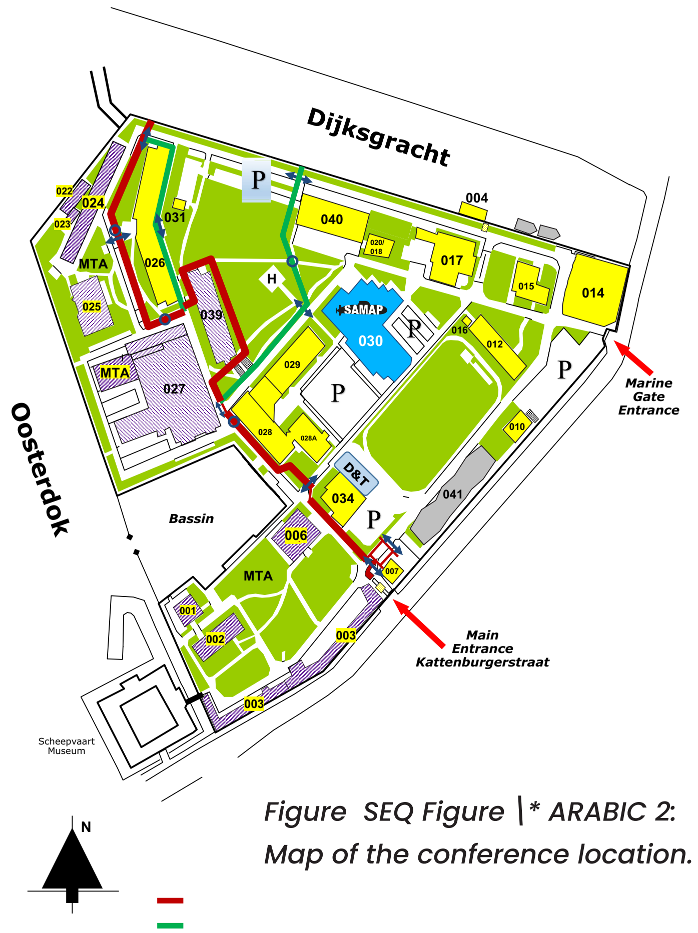

*Figure SEQ Figure * ARABIC 2: Map of the conference location.*

Conference Hotel

The Ibis Amsterdam City Stopera hotel is located in the city centre, a few minutes from the Stopera Opera House, Dam Square, Rembrandtplein and Waterlooplein and less than 2 km from the central railway station. Undercover pay parking is available opposite the hotel.

Address:

Valkenburgerstraat 68
1011 LZ – AMSTERDAM
Tel : (+31)20/5319135
Fax : (+31)20/5319145

Taxi

The taxi system in Amsterdam is quite specific, with designated areas for taxi stands, regulations about where taxis may stop and a strict policy regarding taxi service and licensing. Here are some tips on how to use taxis in the city.

How to Recognise a Taxi? Every taxi in Amsterdam has to have the following: Blue number plates. Furthermore, a price list has to be available from both inside and outside the taxi and a taxi-driver's pass on the dashboard, with photo and name.

Fast Taxis

Only taxis displaying an exemption card may use the tram and bus lanes. This card must be clearly visible, located inside the passenger side of the front windscreen.

Knowledgeable Drivers

Possession of an exemption card is a guarantee that the taxi driver knows the city. Such a card shows that the driver has taken an exam to show their extensive knowledge of the city.

Where to find a taxi

There are official taxi stands at Schiphol Airport as well as throughout the city at stations such as Central Station and the Dam and you do not have to take the first taxi in the queue. Taxis can also be hailed on the street, although there are several no stopping zones. Further, you may call a taxi to pick you up. For a list of taxis in Amsterdam, refer to the Gouden Gids (phone book).

How much is a ride?

Taxi prices are based on the following:

Call	No Charge
Basic Price	Maximum €5.12 (for 4 or more passengers, €8.33)
Price per Kilometre	Maximum €1.94 (for 4 or more passengers, €2.23)
Hold/Stop	Maximum €32.87 per hour

Sample Costs

Here is a sample of average costs for taxi rides to and from common areas of the city. A receipt must always be given when asked.

Schiphol - Amsterdam Center	circa €60
Central Station - Museumplein	circa €25
Leidsplein - Dam	circa €251
Rembrandtplein - Central Station	circa €20
RAI - Dam	circa €25

More Information For more information and a map of taxi locations, download the brochure How to Use Taxis in Amsterdam or go to www.taxi.amsterdam.nl.

Public Transport

During your stay in Amsterdam, a nice way to travel and see as much as possible, public transport is the best way to visit all the sights and admire the city. The GVB, the public transporter of Amsterdam will be your host. 16 tram lines, over 30 bus lines, 5 ferry links and 4 metro lines make up an extensive public transport network with excellent connections, also in the night time.

Tickets & Info

The GVB Tickets & Info desk on the Stationsplein opposite the Central Station can provide you with personal information on all the possibilities offered by public transport in Amsterdam. The desk also sells transport tickets and maps for all Amsterdam bus, tram and metro routes, and offers various attractive excursions.

Schiphol Airport

Schiphol Airport by Train

Train transport to and from Schiphol is convenient, simple and fast, with the Schiphol train station located directly below the main lobby of the airport.

Train tickets
You can purchase domestic train tickets through the yellow ticket machines near the platforms at Schiphol Plaza as well as domestic and international tickets are also purchasable from the ticket offices near the red/white-checked cube at Schiphol Plaza, where you can also ask for train schedules. All tickets, unless when asked for a non-dated ticket, are for use on the day of purchase. Tickets can also be purchased up to a month in advance from a ticket machine or one can ask for non-dated tickets. In the latter example, the ticket needs to be stamped by a conductor or by the yellow ticket machine boxes near the platform before boarding.

Travel Length
The average travel time to Amsterdam Central Station from Schiphol, or vice versa, is 15 minutes. Be sure that you indeed take a train bound for Amsterdam Central Station (Centraal Station, or CS) if that is your destination, as other stops, such as Amsterdam Lelylaan, Amsterdam Sloterdijk, may sound similar. You will know when you have arrived at CS when you see historical church steeples and canals (e.g., the modern office park station is Sloterdijk). In theory, the conductors on all trains to and from Schiphol call out stations in Dutch, English and sometimes other languages.

Information about your train journey
The journey planner on the NS website (see link at the bottom of this page), will provide you with information on the fastest and shortest route between your home address and Schiphol. It also contains the latest travel information, including details of temporary timetable changes.

Direct or change
Many Amsterdam Stations have direct travel to Schiphol, some have only one train change, usually at Amsterdam Sloterdijk and Duivendrecht. If you have to change at one of these stations, your connecting train will depart from another level to the one on which you arrived and timetables make allowance for this.

Night train
If you are departing/arriving at night or in the early morning, the NS night network offers trains once an hour between from Amsterdam CS - Schiphol and vice versa. If it is not possible for you to travel by night train, then the Schiphol Travel Taxi could be the answer.

More Information

For more information, please see the Schiphol website www.schiphol.com or the website of the NS Rail, www.ns.nl.

Schiphol Airport by taxi

Schiphol taxis operate only from the taxi rank outside Schiphol Plaza or from the STA desk. Taxi drivers are not allowed to solicit customers from any other location. Schiphol taxis can take you to any destination in the Netherlands or in neighbouring countries. They will also pick you up from home and take you to the airport.

To calculate your fare for a Schiphol taxi, go to the English pages of www.schiphol.com and select Airport Information> From & To Schiphol> Taxi.

For more information or fares call: + 31 (0)20 653 1000.

Bike Rental

The Yellow Pages lists fifteen bicycle and moped rental companies in Amsterdam. Some also have tandems, kid's bikes, delivery bikes, racing bikes and/or mountain bikes (All-Terrain Bikes).

Figure 3: Overview of the conference location, and other important sites.

IMPORTANT CONTACTS

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IN CASE OF EMERGENCY

Escape route conference location