TRANSITION FROM OBERON TO COLLINS CLASS SUBMARINES: AIR QUALITY ISSUES

and

LESSONS LEARNED

W. Mazurek
AUSTRALIA

OBERON CLASS SUBMARINE
Semi-submersible
WWII technology

Commissioned 1960-2000
Total of 27 built

HMAS OTAMA
decommissioned 2000

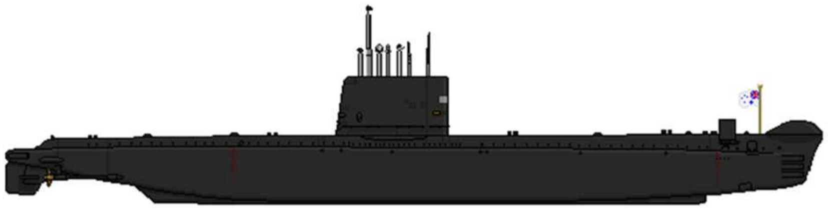
Builder: Four UK shipyards
Length 295.2 ft (90.0 m)
Beam 26.5 ft (8.1 m)
Draught 18 ft (5.5 m)
Displacement Surfaced: 2,030 t (2,000tons)
Submerged: 2,410 t (2,370 tons)
Complement 70

AUSTRALIAN COLLINS CLASS SUBMARINE
Submersible
AIP - ready

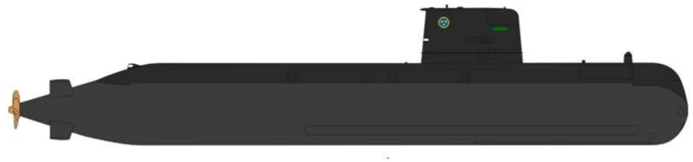
COLLINS
Commissioned 1996-2003
Total 6 built

Builder: Australian Submarine Corporation, Osborne, South Australia
Length: 77,42 meters (254 feet)
Beam: 7,8 meters (26 ft)
Draft: 7 meters (23 ft)
Displacement: 3100 tons (surfaced) / 3400 tons (submerged)
Complement: >58

OBERON

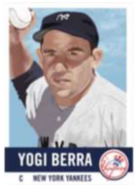


COLLINS

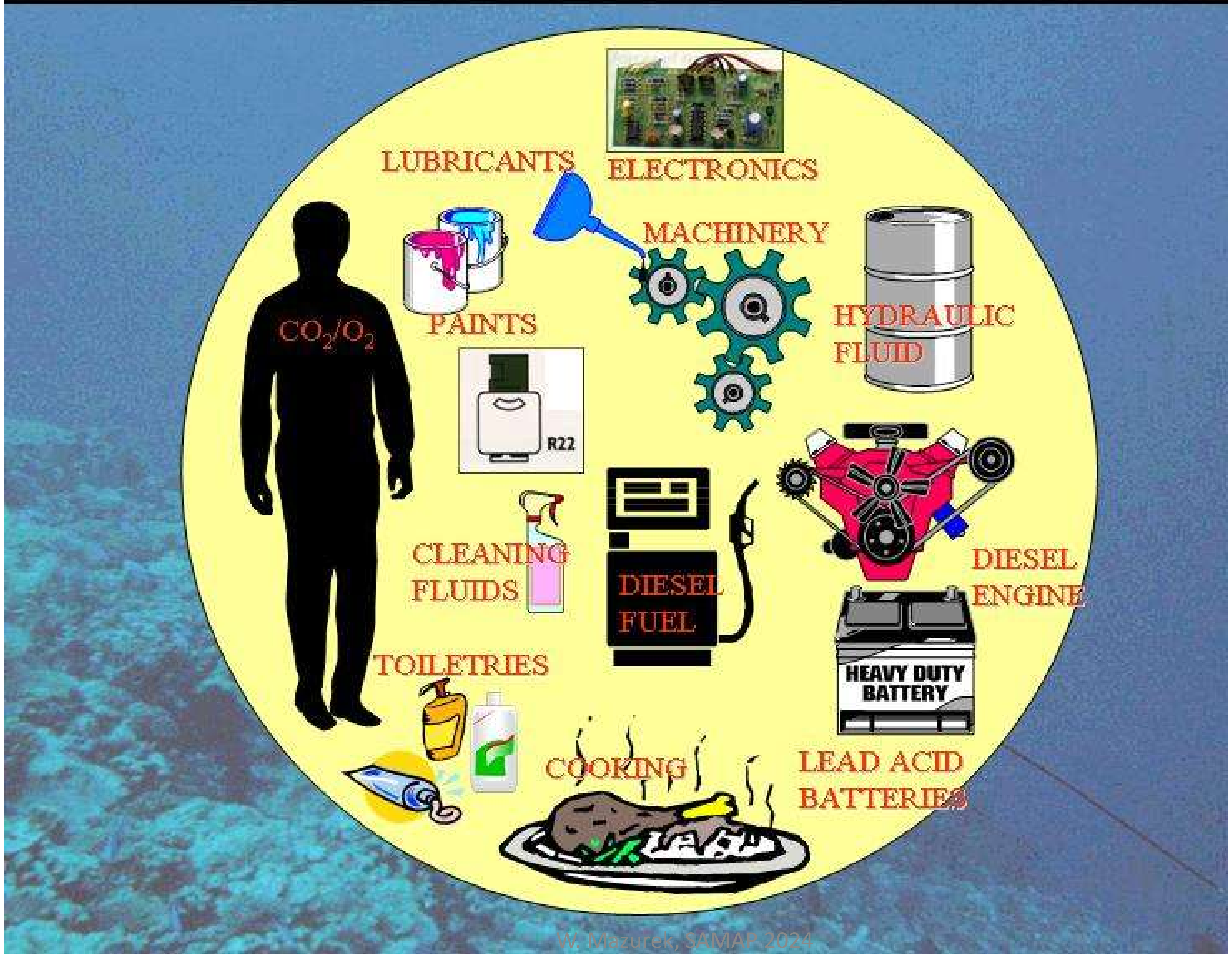


‘IN THEORY, PRACTICE AND THEORY SHOULD BE THE SAME;
IN PRACTICE, THEY ARE NOT !’

YOGI BERRA



SUBMARINE ENVIRONMENT



SMELL THE DIESEL !
Basic Differences in Air Quality Factors

BOTH CLASSES OF SUBMARINES DEPLOY SIMILAR TECHNOLOGY ALTHOUGH THE DESIGNS ARE DIFFERENT

Oberon	**Collins**
Fuel tanks vented internally	Propulsion compartment isolated
Deep fat fryers	No deep fat frying
Oxygen and Carbon dioxide control	Oxygen and Carbon dioxide control
and monitoring (incl. CO) by colorimetric tubes	Multi-gas real-time monitoring
Short dive times	Extended dive times
Smoking	Limited Smoking

The Characteristic Submarine Odour

Diesel fuel vapour/cooking oil emissions

SUBMARINER ATTITUDES TO OH&S:

A MIXTURE OF SUBMARINER CULTURE AND CIVILIAN WORKPLACE PRACTICES

DURING THE TRANSITION FROM OBERON TO COLLINS:

BOTH SUBMARINE CULTURE AND CIVILIAN WORKPLACE PRACTICES CHANGED – ACCELERATED BY SUBMARINER GENERATIONAL DIFFERENCES AND EVOLVING SOCIAL ATTITUDES TOWARDS HEALTH

HUMAN EXPOSURE LIMITS

DERMAL: paucity of data

The contribution of dermal exposure to the total body burden has probably been underestimated.

Fortunately, the wearing of chemical resistant gloves (ie. Nitrile rubber) has become a common practice in the workplace (eg. Car mechanics)

THE PHILOSOPHY OF SUBMARINE AIR QUALITY

1. HEALTH-BASED
   - ACUTE HEALTH EFFECTS
   - CHRONIC HEALTH EFFECTS

2. COGNITIVE EFFECTS (eg. Carbon Dioxide, Oxygen)

3. EQUIPMENT-BASED
   - INDICATORS OF EQUIPMENT MALFUNCTION (Leaks, Overheating, Fire)

4. FIRE MANAGEMENT (Alerts, Propagation, Air Clearance)

EXPOSURE LIMITS

AIR

OH&S WORKPLACE STANDARDS

US
- **A**merican **C**onference of **G**overnment and **I**ndustrial **H**ygienists
- **O**ccupational **S**afety and **H**ealth **A**dministration
- **N**ational **I**nstitute for **O**ccupational **S**afety and **H**ealth

World **H**ealth **O**rganisation
EC Scientific **C**ommittee on **O**ccupational **E**xposure **L**imits

Harmonisation of Occupational Exposure limits organized by the Directorate General of Labour in the Netherlands and the Commission of the European Communities, The Hague, Netherlands.1989

SUBMARINES: continuous exposure (for the duration of deployment)

AIR MONITORING

OBERON

COLORIMETRIC TUBE (eg. Draegar)

Carbon dioxide
Carbon monoxide
Oxygen
Hydrogen

COLLINS

49 Gas sensors (continuous monitoring) in fixed locations

Carbon dioxide
Carbon monoxide
Oxygen
Hydrogen
Chlorine
Hydrogen cyanide
Hydrogen sulfide
Aerosols
Hydrocarbons
Otto fuel*
MEA *

*portable

OXYGEN GENERATION

Self-contained Sodium Chlorate Oxygen Candle, 15 kg, 3000 L/O_2 over 35min

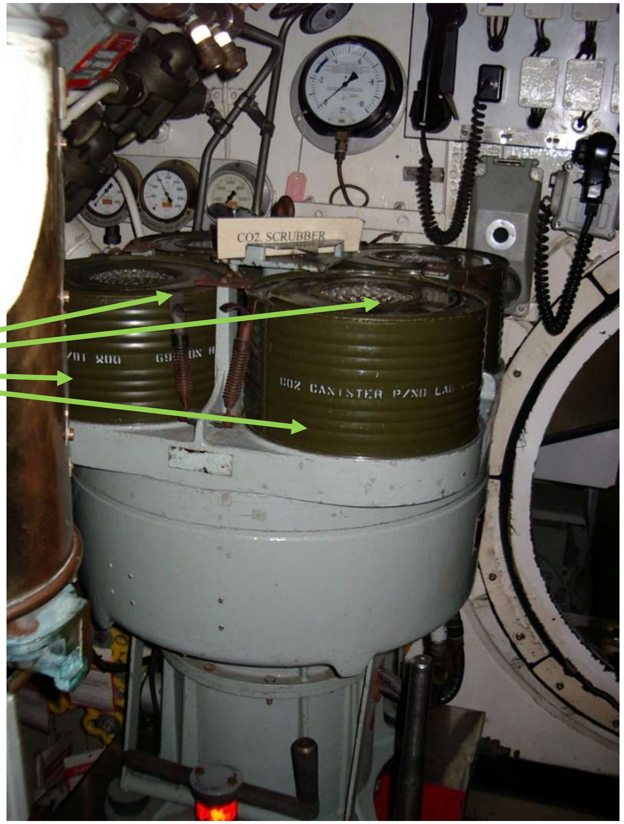
OBERON
COLLINS

OXYGEN CANDLES

AIP → LIQUID OXYGEN (LOX)

OBERON
CARBON DIOXIDE ABSORPTION UNIT (cdau)

SODALIME
CANISTERS (4)

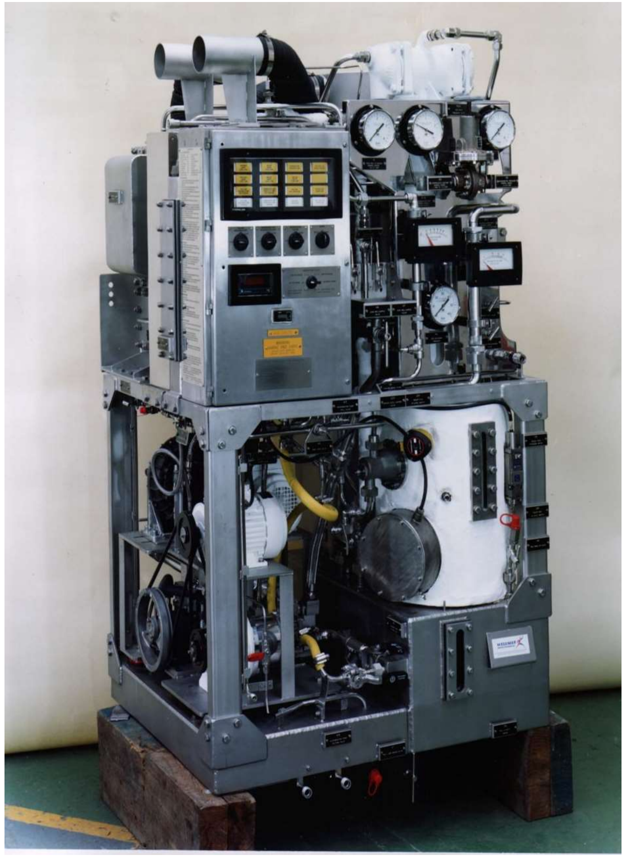


COLLINS
SODALIME CANISTER (4l)
10 CANISTERS IN CARBON DIOXIDE ABSORPTION UNIT

AIR FLOW

COLLINS MEA SCRUBBER

- Manual controls
- Newer version microprocessor controlled
- Potential for leakage, spillage during MEA transfer
- CO2 compressor oil sump contamination



The Relocatable SLCDAU (RSLCDAU) Concept

The relocatable SLCDAU concept has developed by DSTO. It involves single electric fan connected to a canister of sorbent. The fan is a Commercial Off The Shelf (COTS) inexpensive radial fan fitted to the lid of the canister. Fans are available for various voltage supplies (240v, 110 v, 24 v). The air flow rate through the canister is equal to that in the traditional SLCDAU. A low noise fan is selected. The fan and canister can be located wherever there is electrical power.

Advantages of the RSLCDAU

High level of redundancy (not dependent on one fan)

A. Canisters can be located in areas of high CO_2 concentrations (where the sorbent is more efficient)

B. Ventilation through trunking not required.

C. Can be used to supplement existing CO_2 removal

D. When not in use space occupied by fans is small

E. Very low cost

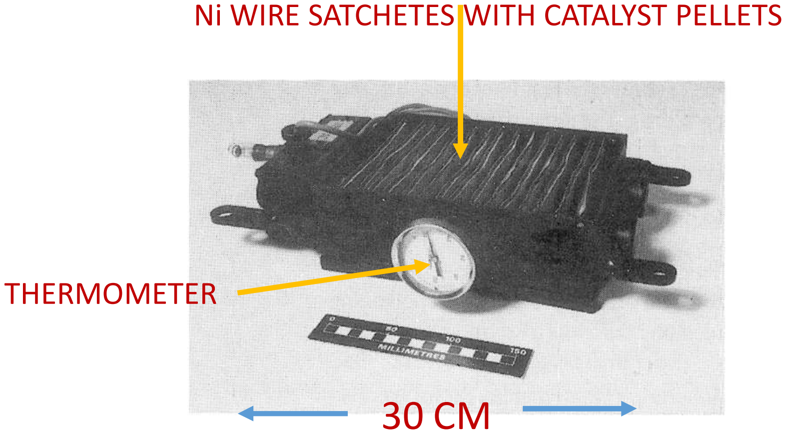
115V computer cooling fan

Standard 4.2 l MP soda lime canister

RELOCATABLE SLCDAU CONCEPT, PJ Hanhela, T-H Gan and W Mazurek
Maritime Platforms Division, DSTO, Department of Defence, 506 Lorimer St, Fisherman's Bend, Melbourne, Vic. 3207 Australia. SAMAP 2007, Amsterdam.

CO/H_2 OXIDATION CATALYSTS

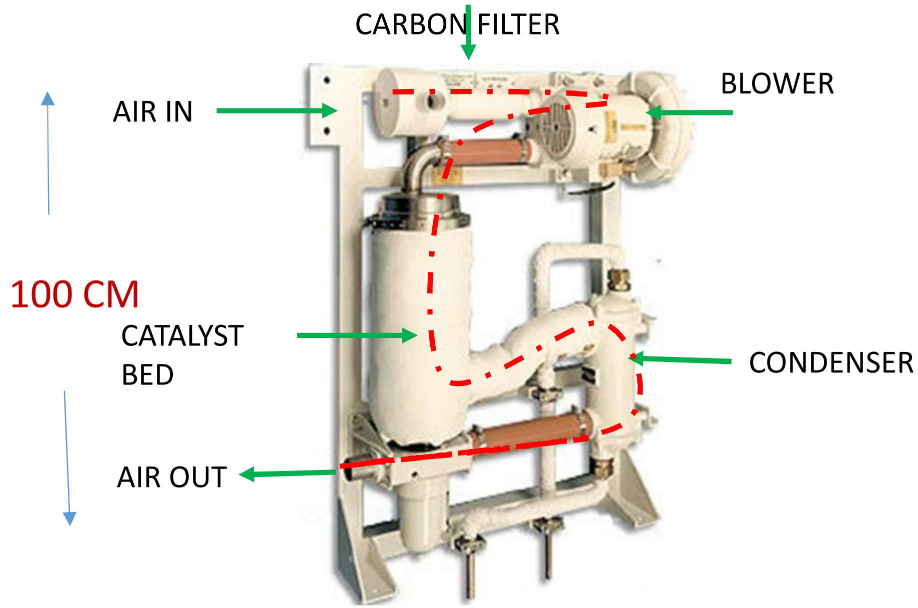
OBERON



CO/H_2 Burner (oxidation catalyst) Pd/Al_2O_3

DISTRIBUTED THROUGHOUT THE SUBMARINE

COLLINS



Atmosphere Control International, Corac Plc
(Formerly , Wellman, CJB)
Low Temp Cat. Pt/Pd on Tin Oxide + Activated Charcoal Filter
ENGINE ROOM

DIESEL EXHAUST EXPOSURE : WORKPLACE AND ENVIRONMENTAL
Rapid change in US exhaust emission legislation

1974 US EPA introduced emission standards for heavy duty diesel engines targeting carbon monoxide, nitrogen oxides and hydrocarbons under the Clean Air Act (1970)

1985 Separate emission limits were introduced for nitrogen oxides and hydrocarbons

1988 Diesel particulates were added

1990 US Congress legislates further reduction in emissions of hydrocarbons, carbon monoxide, nitrogen oxides and particulates.

1997 EPA sets emission standards for diesel locomotives and locomotive engines.

1998 EPA issues more stringent emission standards for diesel engines in non-road applications.

1999 EPA regulates emissions in large marine diesel engines.

2004 EPA finalises further restrictions on diesel engine emissions in non-road applications by 90%.

2007 EPA regulates emission of air toxins (eg benzene) from mobile

2016 US Mine Safety and Health Administration (MSHA) regulates occupational exposure to diesel exhaust in underground coal mines.

SUBMARINE DIESEL EXHAUST RE-ENTRAINMENT

1947 **Carbon monoxide** was initially identified as the most toxic component and first subject to monitoring on a RN submarine in 1947 (Ellis) with the exclusion of the other exhaust components of lesser known toxicity at the time.

The major source of exposure was the re-entrainment through the snorkel **'getting your own back'**. Fugitive engine emissions also contributed. At the time carbon monoxide could be measured with a Chemical Carbon Monoxide Indicator Mark III from the Royal Aircraft Establishment (probably intended for use with single-engine aircraft).

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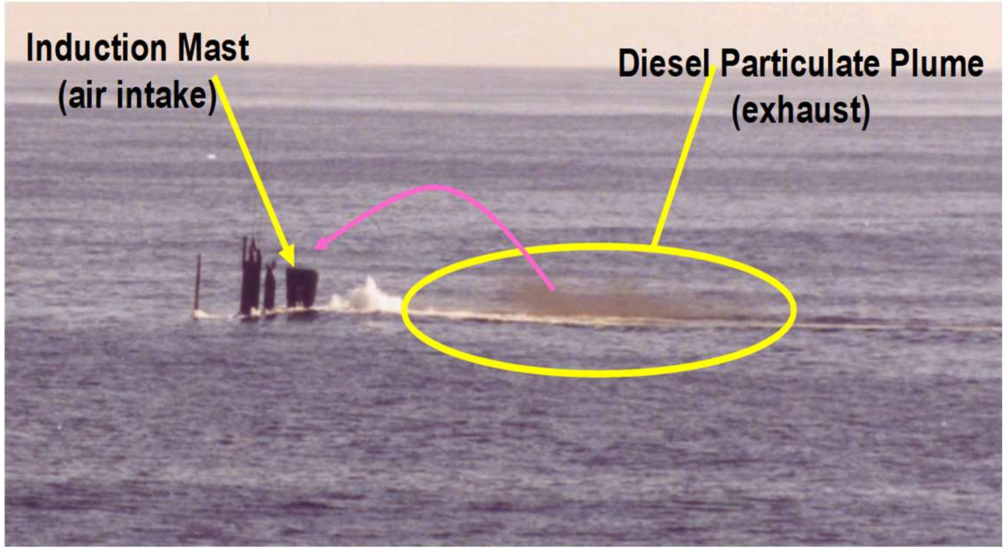
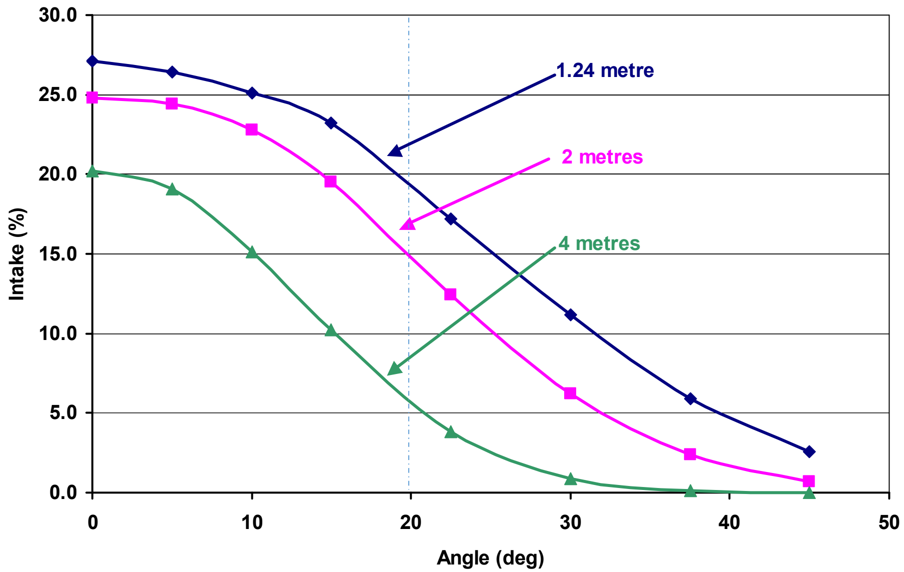
Ellis FP (1947) Environmental factors affecting the health and efficiency of personnel during prolonged periods submerged in submarines fitted with the snort. Medical Research Council, Royal Naval Personnel Research Committee report, R.N.P. 47/402

DIESEL EXHAUST RE-ENTRAINMENT
'Getting your own back'



MODELLING ‘GETTING YOUR OWN BACK’

DIESEL EXHAUST RE-ENTRAINMENT DURING SNORKELING



Computational Fluid Dynamics calculations for dispersal and intake of diesel exhaust emissions during snorting in a model system. The wind direction (angle) is with respect to the longitudinal axis of the submarine (0 (deg) being a tail wind).

W. Mazurek, T.H. Gan, G.I. Gamble and S.R. Kennett , Plume Modelling of Diesel Exhaust Emission Intake through the Induction Mast in Submarines” UDT, 2004, Nov, .Hawaii,

TABACCO SMOKING ONBOARD

OBERON

FEW RESTRICTIONS

COLLINS

DEVISIVE

DESIRE TO ELIMINATE THE PRACTICE

ANTICIPATED AFFECT ON CREW RETENTION,
RESTICTED TO ENGINE ROOM DURING ENGINE OPERATION (2014)

Australian workplace restrictions on smoking:

1. Occupational Safety and Health Regulations 1996 prohibit employers, employees and self-employed persons smoking **in enclosed workplaces**

2. Tobacco Products Control Act **2006** – Smoking in enclosed **public places**

SMOKING IN SUMARINES

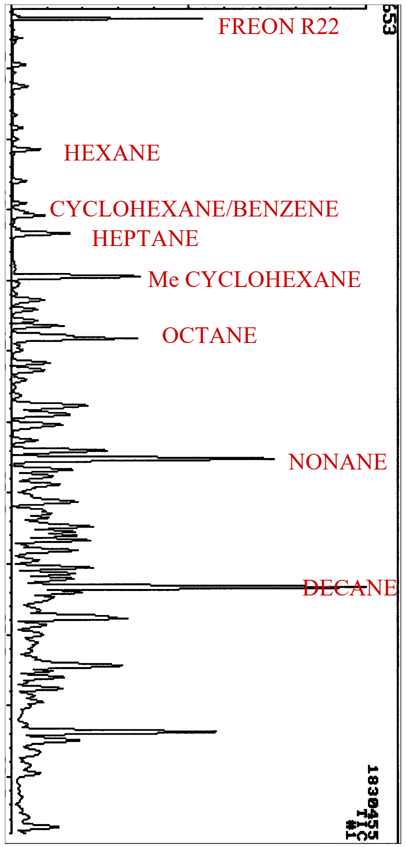
ROYAL NAVY: 2021, Tobacco Free policy, [1].

USN: 2010, smoking ban aboard submarines[2]

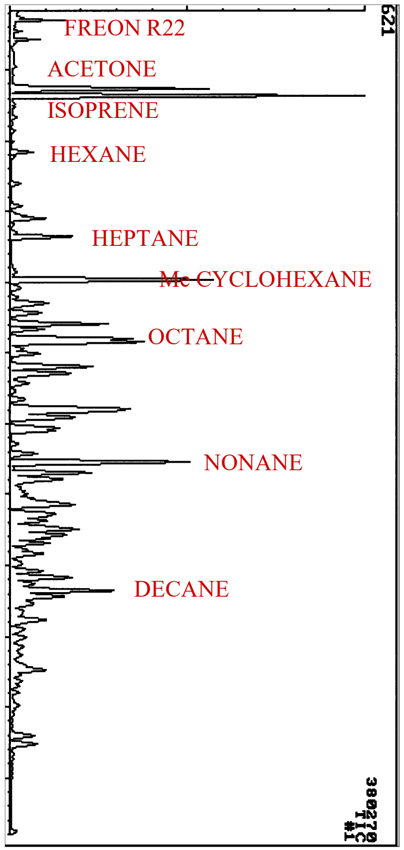
1. https://www.royalnavy.mod.uk/navyfit/health-and-wellbeing/smoking-reduction
2. Banning Cigarette Smoking on US Navy Submarines: A Case Study
Harry A. Lando, Mark. E. Michaud, Walker S.C. Poston , Sara A. Jahnke, Larry Williams, and Christopher K. Haddock, https://doi.org/10.1136/tobaccocontrol-2014-051624, Tob. Control 24 188-92 (2015)

BREATH CHROMATOGRAMS

SUBMARINE AIR



SUBMARINER’S BREATH



CONCENTRATION →

SAMAP 2009

EXHALED BREATH

FILTER

VALVE

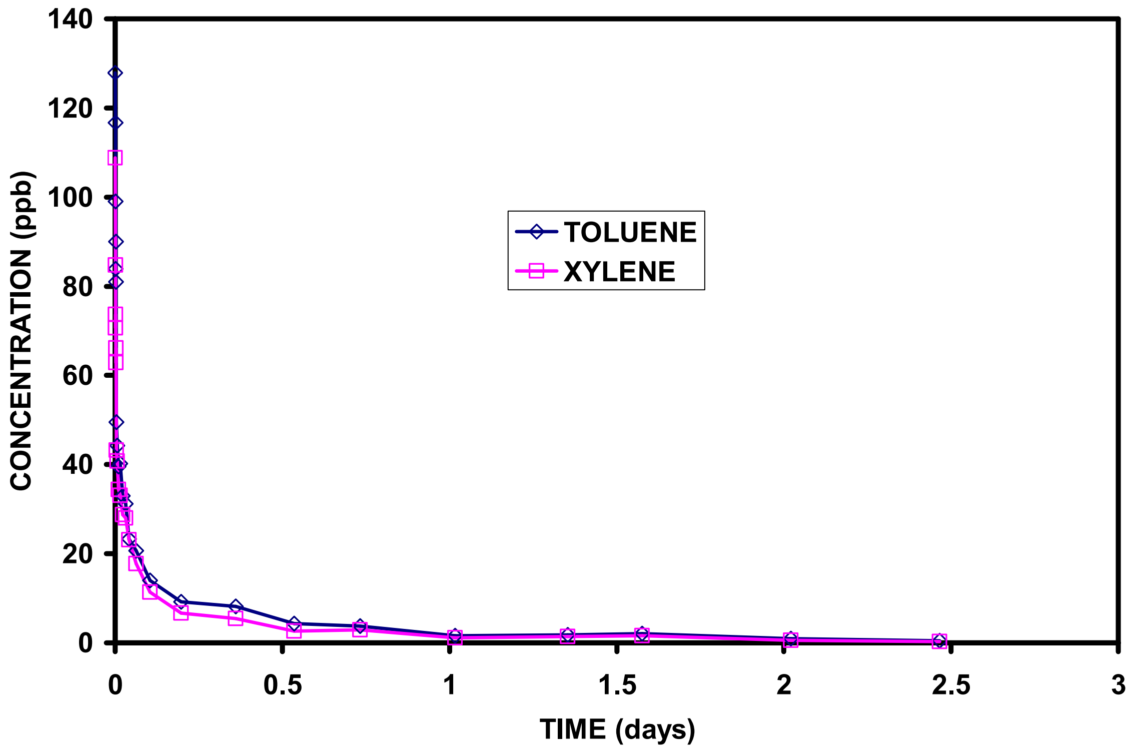
AIR SAMPLING CANISTER

ACTIVATED CARBON FILTER

OBERON : NONE

COLLINS : YES (activated coconut shell charcoal)

EXHALED BREATH



Decay of toluene and xylene in exhaled breath after controlled exposure in a submarine along side. The residual concentration after 2.5 days was 0.5ppb toluene and 0.3ppb xylene.

SAMAP 2009

EARLY USN EXPERIENCE WITH AIR PURIFICATION TECHNOLOGY

Despite the use of proven technology, severe problems arose with the air purification equipment in the early years (USS *Nautilus,* USS *Seawolf*) [1].

The air quality in the submarines was very poor and threatened to jeopardise the advantages of air-independent propulsion. The carbon dioxide scrubbers were not sufficiently effective [2] in removing the atmospheric carbon dioxide and there were leaks of amine solution through the seals around the pump shafts. The catalytic burners would periodically explode and burst into flame as a result of build up of fat and oil emissions from the galley. Refrigerant gases leaked from equipment and were decomposed into acid gases (hydrogen fluoride, hydrogen chloride) resulting in brass fittings turning green and submariners suffering from throat and eye irritation [2]. The acid gases were allegedly causing loose tooth fillings [1]. The extent of the refrigerant leaks was reduced through better seals.

1. Wyatt J (2001) Undersea Warfare, 3:8
2. Rockwell T (1995) The Rickover effect, John Wiley and Sons, New York, p 218

PROPULSION SYSTEMS

1. Naval News Oct .(2023)
2. Naval News January 2024 Navy Forces Maritime Defense Industry, 31 JAN. 2024

DIESEL-ELECTRIC

Traditional

LEAD-ACID BATTERIES

LITHIUM-ION BATTERIES

New Technology

Japan’s 2 Soryu-class, new Taigei class diesel-electric submarines [1]

Italian Navy's future U212 NFS submarines[2]

AIR-INDEPENDENT PROPULSION

HDW Type 212A
Commissioned 2005 -
Germany, Italy

FUEL CELL
H_2/O_2
Ethanol/O_2

STIRLING ENGINE
1970s Sub Tech
Diesel/O_2

Sweden’s Gotland class (2008)
Japan’s Soryu-class Commissioned 2009-

THE NEXT TRANSITION

FROM COLLINS TO SOMETHING LIKE THIS ?

SUGGESTED FURTHER READING

- Rockwell T (1995) The Rickover effect, John Wiley and Sons, New York.
- Mazurek W (1998) Current submarine atmosphere control technology, Life Support Biosph Sci. 5(3):279-85
- Mazurek W (2005) Submarine Atmospheres, The Handbook of Environmental Chemistry , Air Quality in Airplane Cabins and Similar Enclosed Spaces (HEC4,volume 4H) Springer, Ed. Martin Hocking.
- Mazurek W (2015) Key developments in submarine air monitoring and air purification during the past 20 years, SAMAP 2015, Den Helder , The Netherlands.
- Mazurek W (2019) A brief history of submarine air quality, SAMAP 2019, Newcastle, UK.