

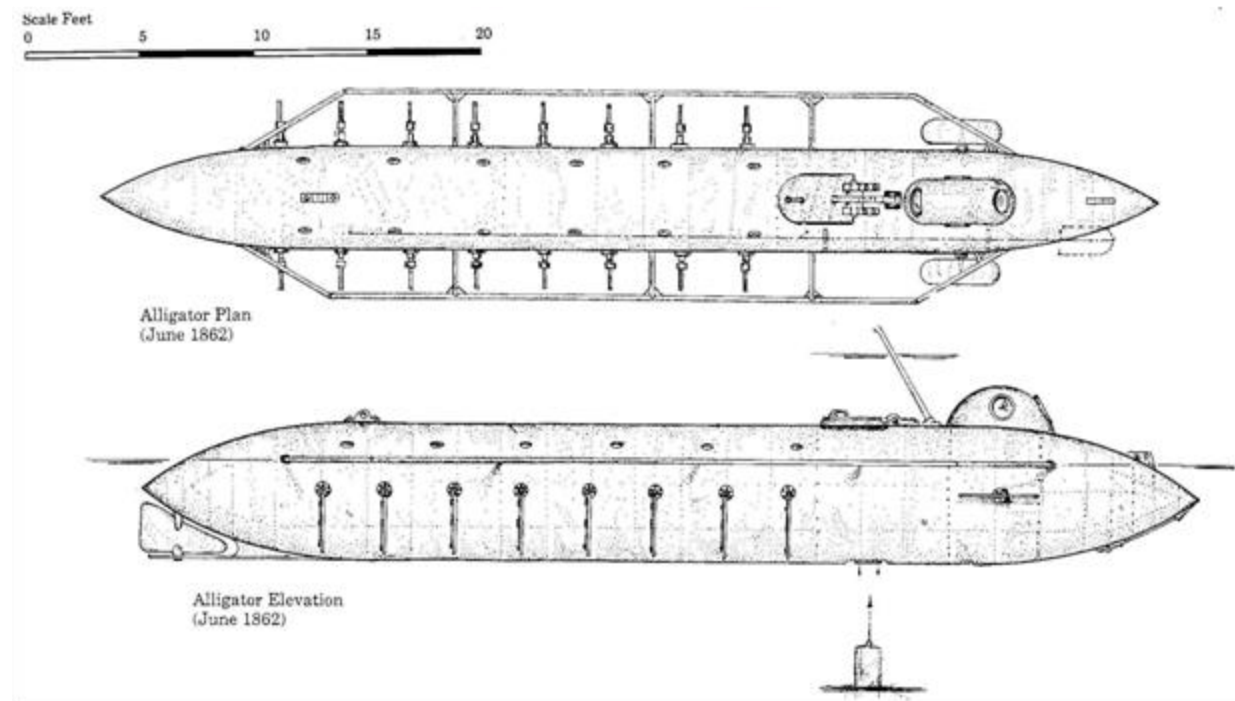
A BRIEF HISTORY OF SUBMARINE AIR QUALITY

W. Mazurek

AUSTRALIA

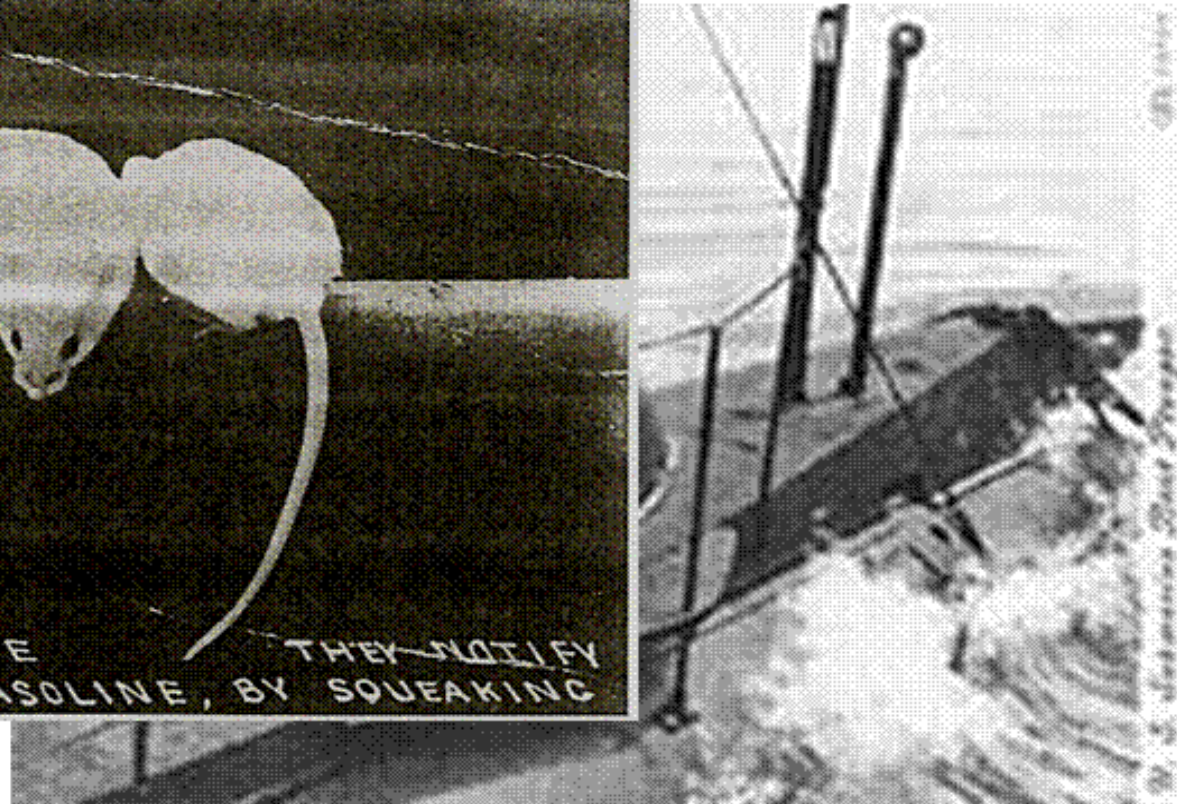
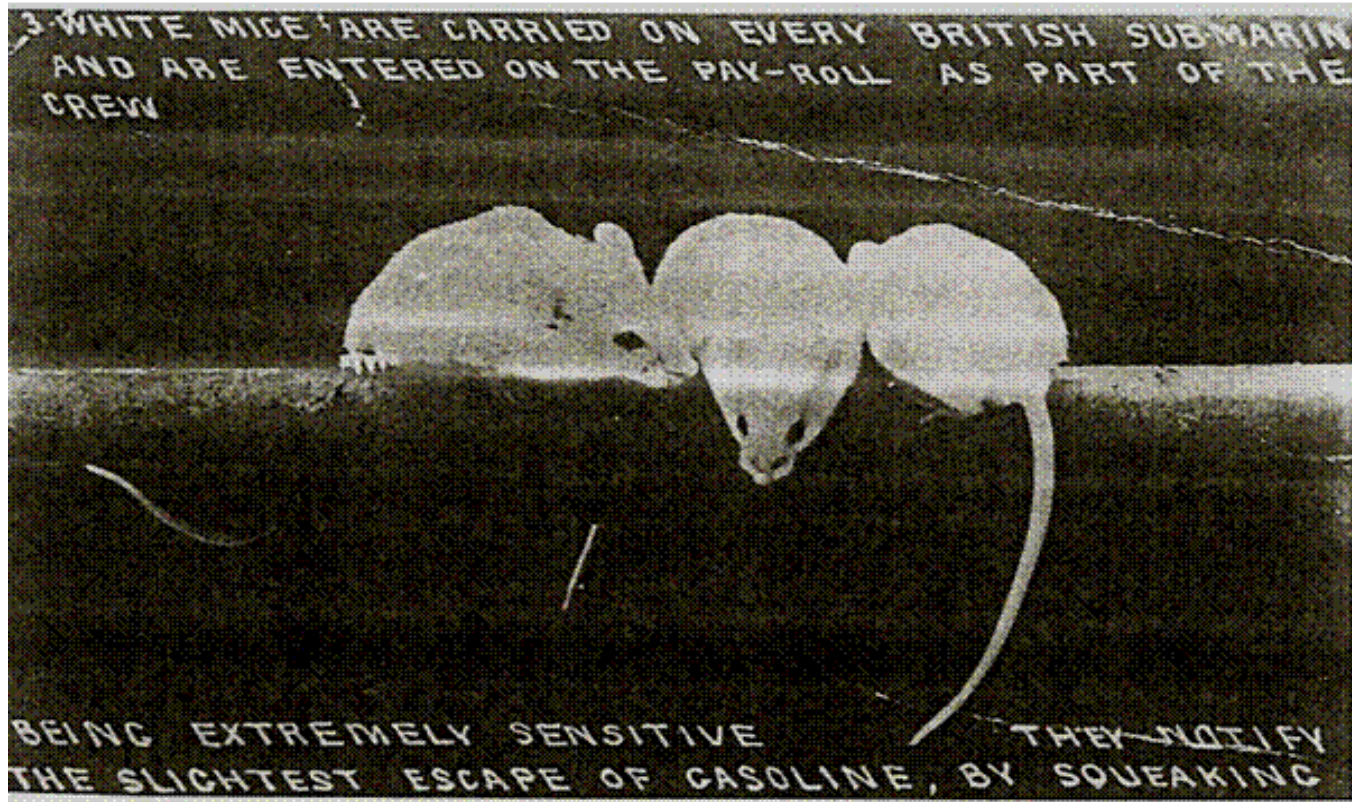
ALLIGATOR
Circa. 1863
Man-powered Submarine
US Civil War
Crew 20(?)

Lime CO₂ Removal System



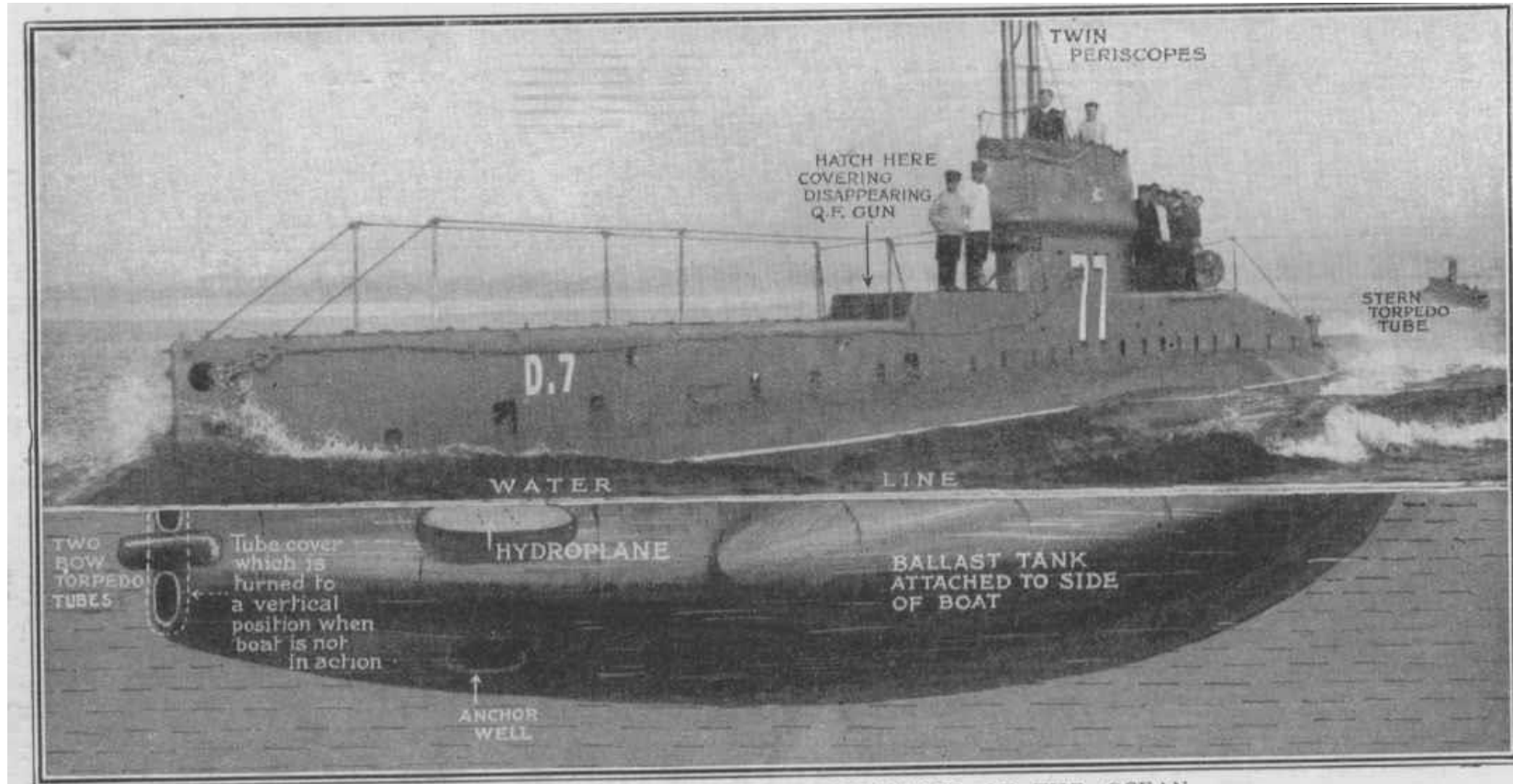
EARLY SUBMARINE AIR MONITORING SYSTEM

circa 1904 (Post card)



RN WWI, D-Class Submarine

(crew=18, 500 tons disp.)



ONE OF BRITAIN'S DEADLY MOSQUITOES OF THE OCEAN.

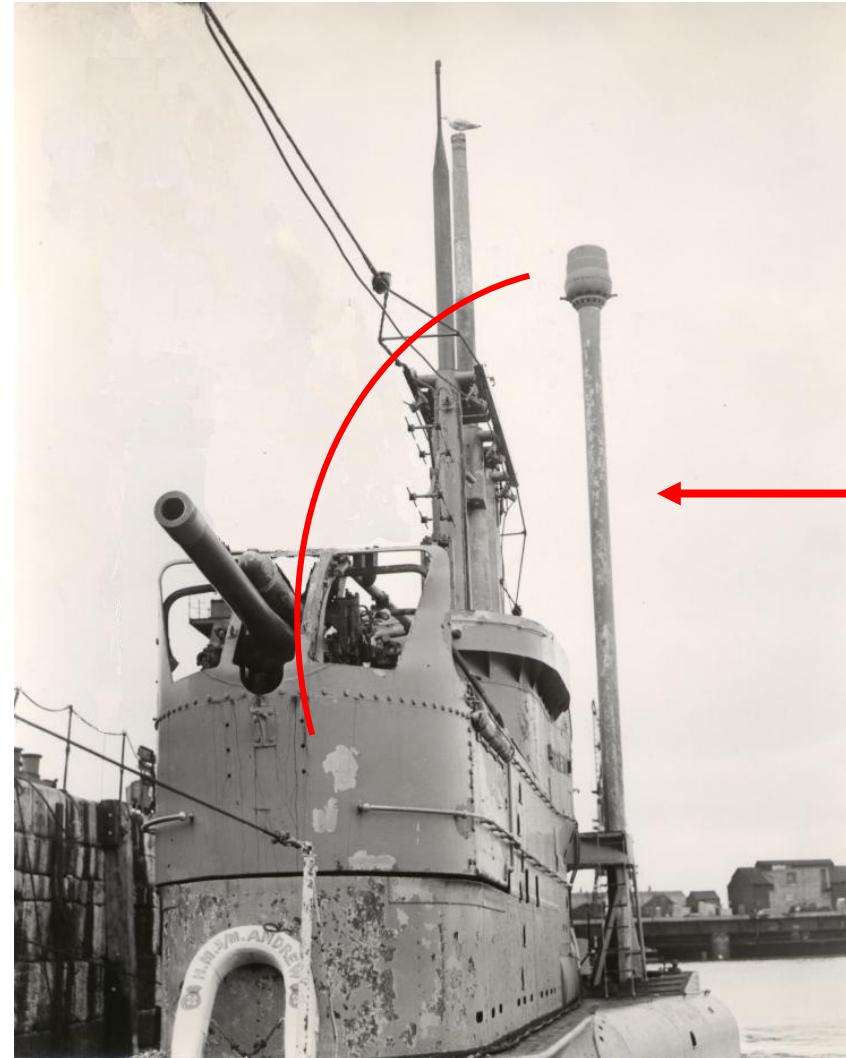
This is one of the D class of submarines, of which the British Admiralty had eight at the opening of the war. All these, along with nine boats of the E class, were on guard in the neck of the bottle that held the German Fleet while the British Expeditionary Force was being transported to France. "The patrol was maintained night and day," in the words of Commodore Keyes's despatch. These boats are of 550 to 600 tons displacement, with a speed of 15 knots above water and 10 knots submerged; they carry three 18 in. torpedo tubes, a 12-pounder gun on a disappearing mount, and a crew of 20 officers and men. The lettering on the picture is explanatory.

WWII SUBMARINES:

Essentially Semi-submersibles with a Keel and no Snorkel



DUTCH FOLDING SNORKEL



SNORKEL

DUTCH FOLDING SNORKEL

(MUSEUM, DEN HELDER)

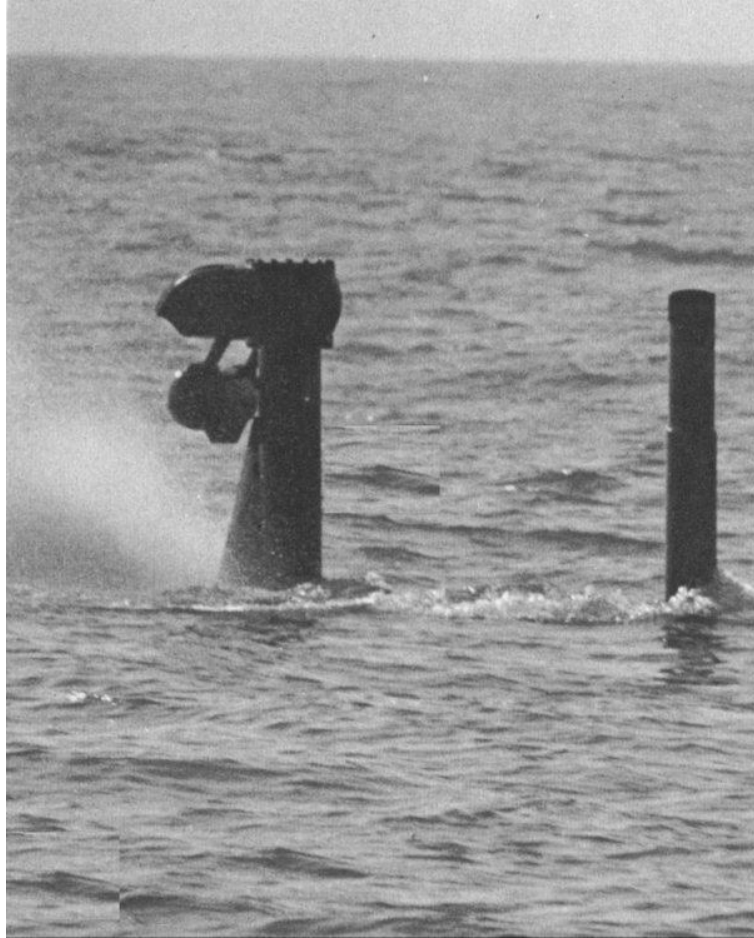


THE ORIGINAL SNORKEL

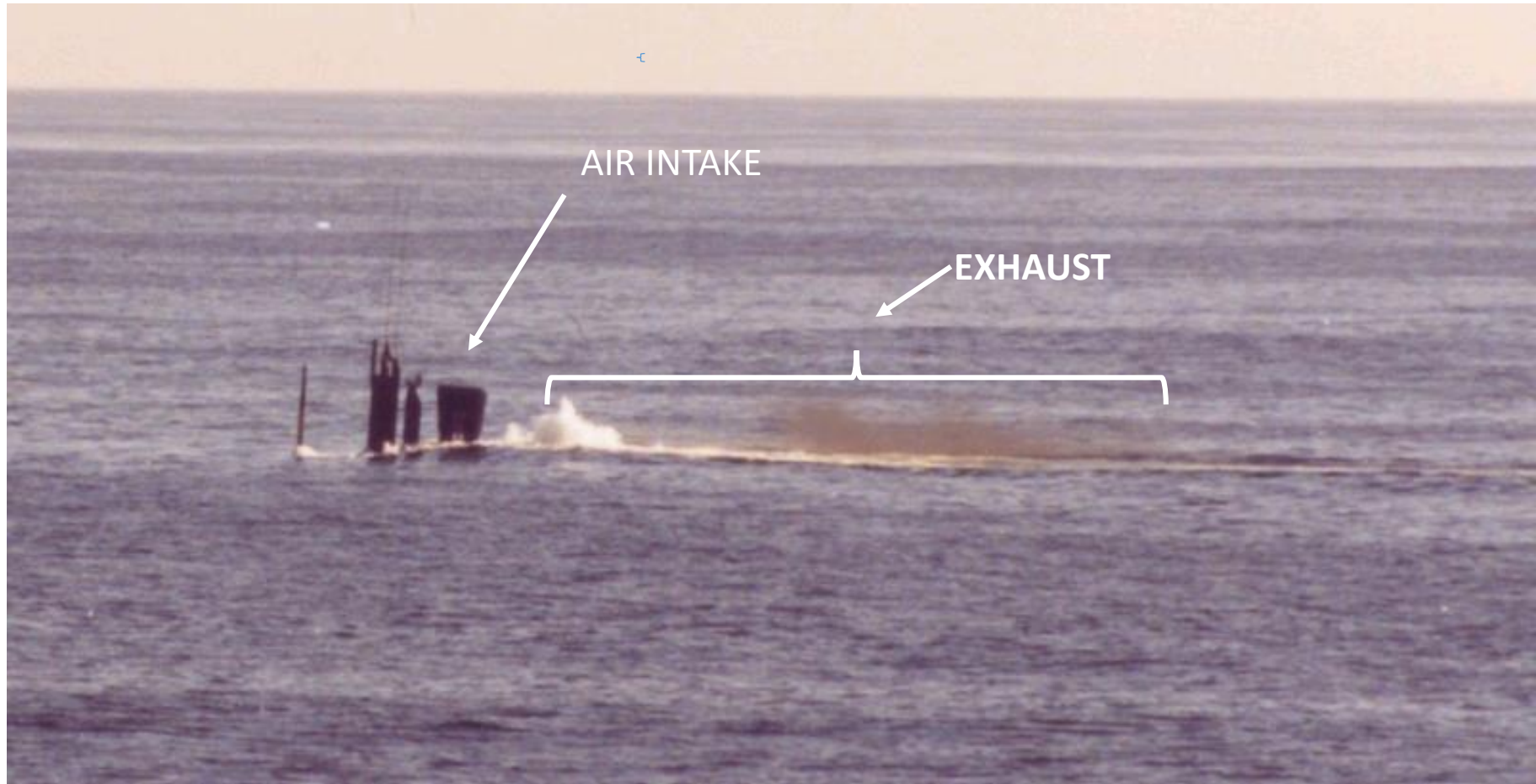


Snorkelling

RN EXPERIMENTAL SNORKELS 1950s



SNORKELLING SUBMARINE



EFFECTS OF HIGH CARBON DIOXIDE LEVELS (WWII)

- Capt. W.O. Shelford, RN “Subsunk – The story of submarine escape”, (Harrap, 1960)
- “the brain is being affected before the body is seriously incommoded, so judgement and alertness become blurred and distorted without the crew being aware of their condition”

1945

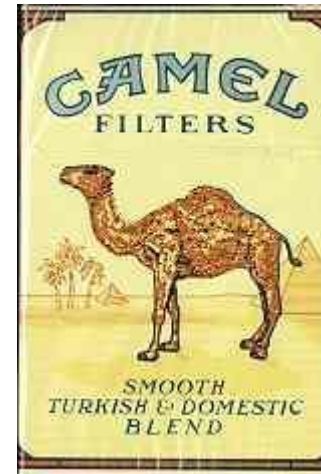
- **ROYAL NAVY BR1326/45: AIR QUALITY**
 - OXYGEN 18%
 - CARBON DIOXIDE 3%
 - NO INSTRUMENTATION

- **GERMAN and ITALIAN NAVY**
 - MONITORING
 - OXYGEN
 - CARBON DIOXIDE
 - HUMIDITY

EARLY GAS DETECTORS



**HYDROCARBON/CARBON MONOXIDE
SENSOR
(1904)**



**OXYGEN SENSOR
(WWII)**

1947

- ROYAL NAVY AIR QUALITY TRIAL
 - OXYGEN
 - PARAMAGNETIC PAULING OXYGEN ANALYSER
 - CARBON DIOXIDE
 - THERMAL CONDUCTIVITY, CAMBRIDGE INSTRUMENT Co
 - CARBON MONOXIDE
 - CHEMICAL CARBON MONOXIDE INDICATOR, FARNBOROUGH

AIR PURIFICATION DIESEL-ELECTRIC SUBMARINES (ie RN OBERON CLASS, 1960s-1980s)

- OXYGEN: CHLORATE CANDLES
- CARBON DIOXIDE: SODA LIME
- CARBON MONOXIDE/ HYDROGEN: PALLADIUM COATED ALUMINA, (HEATED) CATALYST

AIR PURIFICATION IN NUCLEAR-POWERED SUBMARINES

- OXYGEN: ELECTROLYSIS OF WATER
- CARBON DIOXIDE: MONOETHANOLAMINE (MEA) / MOLEULAR SIEVE
–REGENERATIVE SYSTEM
- CARBON MONOXIDE/HYDROGEN: HIGH TEMPERATURE CATALYST
HOPCALITE (MANGANESE DIOXIDE/ COPPER OXIDE (3:1))

NUCLEAR POWERED SUBMARINES
AIR PURIFICATION PROBLEMS
1950s

“The Rickover Effect”

Theodore Rockwell, Naval Institute Press (1992) pp218-224.
The Submarine Atmosphere Problem

The Nautilus had just returned from her dramatic eighty-four-hour, thirteen-hundred-mile submerged shakedown cruise to San Juan, and Ebersole had a problem. His voice had an urgent, serious quality to it as he said, "Admiral, this is Ebersole. The air quality on the submarines is terrible. If we don't do something about it before we go to sea again, we'll never be able to stay submerged for very long."

Rickover asked, "Why? What's wrong?"

"The carbon dioxide scrubbers don't work, and the carbon monoxide burners keep exploding and catching fire. It just isn't habitable.

Ebersole was the Medical Officer of Nautilus

ADM Rickover : credited with the development of nuclear-powered submarines for the USN

NO MORE LOOSE FILLINGS OR SLOW EMBALMING; HOW NAVAL SCIENCE HELPED SUBMARINERS BREATHE EASY

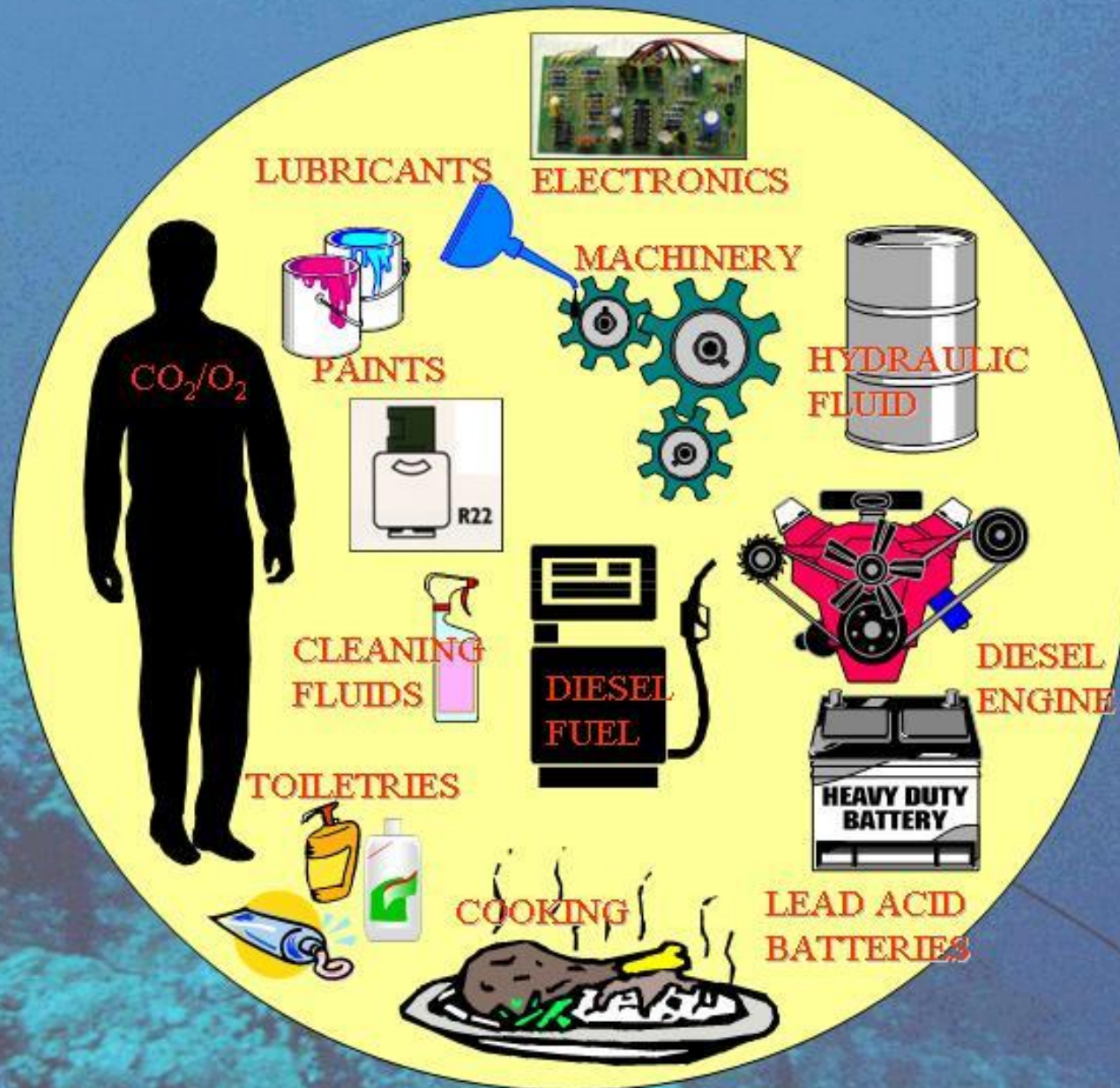
Jeffrey R. Wyatt; UNDERSEA WARFARE, WINTER 2001

“A retired skipper told me once that early in his career he was aboard a ship (1960s) a large refrigerant leak *occurred*. As the refrigerant decomposed, it produced hydrochloric acid. This not only produced significant corrosion throughout the boat, but at the end of the patrol many of the crew (including himself) needed all the fillings in their teeth replaced.”

In addition, formaldehyde and phosgene were generated by the hopcalite catalytic “burner”

Jeffrey R. Wyatt (Chemistry Division, U. S. Naval Research Laboratory Washington, DC) Forty Years of Air Monitoring on American Nuclear Submarines, Third Submarine Atmosphere Purification and Monitoring Conference, Toronto Canada, October 11, 2000,

SUBMARINE ENVIRONMENT



1950s

NUCLEAR-POWERED SUBMARINES

- 1954 NAUTILUS
 - PROTOTYPE ATMOSPHERE ANALYSER INSTALLED (MK II)
 - SAMPLES FROM 8 LOCATIONS
 - CARBON DIOXIDE (IR)
 - CARBON MONOXIDE (IR)
 - OXYGEN (PARAMAGNETIC)
 - HYDROGEN (THERMAL CONDUCTIVITY)
 - HYDROCARBONS (IR)
 - FREON (LATER VERSION)
- INSTRUMENTATION TOO COMPLEX AND UNRELIABLE

1980s

NUCLEAR-POWERED SUBMARINES

- CAMS I: MASS SPECTROMETER (MAGNETIC ANALYSER), fixed target compounds based on m/z
 - RELIABLE
- CAMS II: MASS SPECTROMETER (MAGNETIC ANALYSER), Extended mass range, software selected target compounds

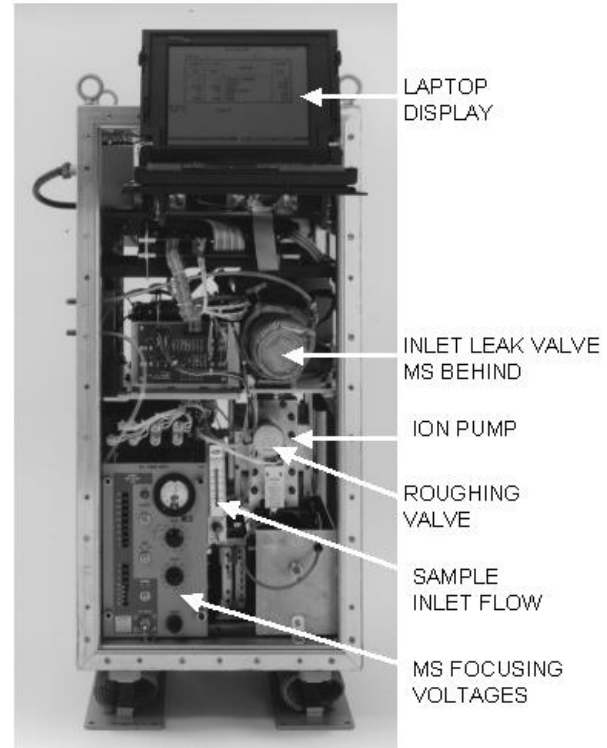
CAMS II capable of monitoring 32 CPDS

RN CAMS

- Early Royal Navy nuclear powered submarines were fitted with an air monitoring system consisting of:
 - Gas chromatograph with 4 separate packed columns for monitoring:
 - hydrogen,
 - oxygen,
 - carbon dioxide and
 - carbon monoxide.
 -
 - Like the early monitors in the US submarines, it also suffered from reliability problems and in 1980 it was replaced with a British version of the US Navy CAMS.
- British CAMS used a quadrupole analyser rather than a magnetic analyser. The quadrupole analysers were more susceptible to drift off calibration. For various reasons the British CAMS proved to be far less reliable than the US equivalent.

MINI-CAMS

designed for diesel-electric submarines



CAMS II 32 CPDS

Instrument Reliability Problems

- Not necessarily due to the technology.
- Installation and maintenance procedures that can lead to these problems.
- The complex and often hostile environment is a challenge to any air monitoring technology.
- There is also is a requirement for continuous operation for 90 days without factory support or calibration.

ANY QUESTIONS ?

