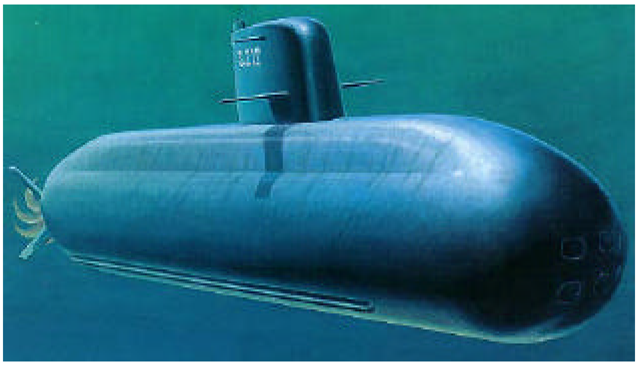
Dräger safety

Confined space monitoring in Submarines

Introduction

The closed atmosphere in a submarine requires frequent monitoring to maintain the quality of the air. This monitoring allows detection of potentially hazardous substances as well as adjustment of the air composition. Routine analysis is conducted in several compartments before submerging and while submerged. A number of modern instrumental techniques are used to provide quantitative assessment of these vital characteristics.



Submariners have always needed atmosphere monitoring instruments, and it's important that the equipment be reliable: On old diesel-electric submarines, there was little you could do to refurbish the atmosphere except for short term, emergency fixes using chemical scrubbing, oxygen candles, or reserve air carried in tanks. The principal method of atmosphere control was surface ventilation, which you had to do anyway to recharge the batteries, so the requirement for atmosphere monitoring was minimal. An old diesel submariners told you could always tell when the oxygen level was getting low when it became difficult to light your cigarettes. That may say as much about how the world has changed since those days as needs to be said.

Not only did oxygen need to be supplied and carbon dioxide removed, but trace contaminants became a concern when submarines stayed submerged for long periods.

Catalytic burners remove many undesirable compounds and odours from the air, but they're only one of the systems that maintain the quality of a submarine's atmosphere. Submarines produce oxygen by electrolysing water - splitting the oxygen from the water it's bonded to. The boats also carry charcoal filters - good for absorbing large spills. And they remove carbon dioxide with a scrubber using soda lime, lithiumhydroxide (LiOH) or the compound monoethanolamine (MEA) e.g., which absorbs the CO2 from the air. The MEA is then treated to drive out the gas, and the latter is compressed and ejected overboard.

But air conditioning (cooling and dehumidifying) requires refrigerants, and these systems occasionally leaked refrigerating gases into the submarine's living spaces. These would build up over time, and, while they were in themselves non-toxic, they would decompose in the burner to produce acidic gases that were both toxic and corrosive.

Atmosphere Monitoring System have to be built and tested to all the rigorous acoustic, EMI, shock and vibration requirements for submarine equipment.

The conventional diesel-electric propulsion submarines are the submarine units more widespread all over the world (about 240 active units in 39 Navies). For years judged as minor importance submarines, apparently overcome and outclassed from the nuclear propulsion submarines, they have evolved technologically in these last years (also with new propulsion AIP systems independent from the air) and they are currently sophisticated and dreadful rivals. The latest German ships use fuel cell technology to supply the electrical propulsion with power. A fuel cell directly generates electrical power out of Oxygen and Hydrogen without any head dissipation and noise. .
Even though they are present in nearly all the Navies of the world, these submarines are built in a restricted number of shipyards. The high cost of the planning and the technical difficulties of realisation feed a flourishing world market of shipbuilding and sale abroad, a non-existent phenomenon for the nuclear propulsion submarines
The leader nations of the export of conventional submarines are Germany (*Type 209, Type 212, Type 214)*, France (*Daphnè, Agosta, Scorpene*) and the Russia (*Kilo*). Other nations as Italy, Sweden, Japan, build their own submarines for an exclusive and not commercial use.
Currently, the export market is differentiated. The shipyards (and the Governments), besides selling the units already complete, yield sometimes the only planning of the submarines, and the shipbuilding or the final assembly is achieved by the buying Nation. This is, for example, the event of the supply of the three *Agosta 90B* to Pakistan (planning and shipbuilding of two examples in France, assembly of the third in Pakistan), of the Brazilian *Tupi* Class and Italian *Type 212A*, planned in Germany and built in Italy at the new shipyards of Fincantieri of Muggiano.
The Great Britain, leader of the building of diesel-electric submarines in the postwar period, has interrupted the building of these units, selling those ones still active to Canada (ex *Ulpholder-class* now *Victoria-class*), whereas the USA, already for decades, have only nuclear submarines.
They are silent and with a low sonar signal: their duty, besides attacking naval surfaced targets, is to patrol the coasts, the naval bases and to clash the nuclear submarines.
According to the NATO designation, these submarines are individuated for the acronym "SSK" (Submarine-Submarine Killer).

Segment

- Ship yards for naval submarines
- Research and salvage submarines
- Industrial submarines

Description of the challenge

Today's submarines can stay submerged under water for weeks. During this time there is no air exchange with the atmosphere. The crew will be exposed all the time to the gas in opposite to an industrial worker, who gets an 8 hours doses and can recover there after. That's why the limits have to be different from the industry. The inside air has to be controlled and regulated to stay breathable, healthy and free of smell. Thus the air is processed and losses are compensated for. Traces of gases must not accumulate or be distributed over the entire ship.

Oxygen
The environmental conditions are artificial. The barometric pressure can change fast in the range from 600 mbar to more than 1400 mbar. The partial pressure of Oxygen is directly related to the barometric pressure inside the ship. Deployed submarine atmospheres undergo fluctuations of partial pressure of oxygen. Such fluctuations must be controlled to insure adequate life support for the crew. Although the partial pressure of oxygen is the critical factor physiologically, the Vol % of oxygen is more critical in propagation of oxygen-supported fire. Oxygen is supplied either from pressurised tanks, an oxygen generator (which can form oxygen from the electrolysis of water or by some other means) or some sort of "oxygen canister". Dräger Safety can offer both, sensor for measurement of Volume percent and partial pressure oxygen.

Carbon dioxide
CO2 is being generated by humans and burners. It is removed by chemical scrubbers which have to be monitored. Safe control of CO2 level is below 0.5 % vol. Polytron IR CO2 can be used to monitor the concentration from 0 to 2000ppm until 30 Vol% CO2.

Hydrogen

Hydrogen H2 is stored onboard and has to be monitored for leaks. H2 also can be generated when charging the batteries. It can form a highly explosive atmosphere. For low concentrations up to 3000 ppm the electrochemical sensor can be used. For 400 ppm up to 4 Vol% (LEL) our combustible sensors are suitable.

CO

Carbon monoxide (CO) is produced on a submarine by three methods only: cooking (the least significant), diesel exhaust, and tobacco smoke (the most significant). A electrochemical CO sensor will detect this.

Cl2, HCl and HF

These gases are toxic and corrosive. Chlorine can be produced as a result of contact between seawater and submarine batteries.
HCl and HF they are generated by decay of halogenated hydrocarbons or fire. All can be monitored with electrochemical sensors of the diffusion and AC-type.

HCN and NOx

Otto Fuel II, a torpedo propellant, is a mixture of three component chemicals: propylene glycol dinitrate, 2-nitrodiphenylamine, and dibutyl sebacate. The nitrated ester produces hydrogen cyanide HCN and NOx when burned. Both can be detected with different electrochemical sensors.

Benzene, Toluene,

Benzene and toluene and other hydrocarbons are off-gassing or leaking compounds of various fuels, solvents, paint, and petroleum products and lubricants. We have no fixed instruments to measure these at low concentrations. DrägerTubes a traditionally being used here.

To protect crew members on disabled submarines from adverse health effects caused by exposure to eight toxic gases, the Chief of the Bureau of Medicine and Surgery, U.S. Navy, requested that the National Research Council (NRC) review the available toxicity data on eight gases: ammonia, carbon monoxide, chlorine, hydrogen chloride, hydrogen cyanide, hydrogen sulfide, nitrogen dioxide, and sulfur dioxide, and evaluate the scientific validity of the Navy proposed SEALs (**S**ubmarine **E**scape **A**ction **L**evel).
Source: http://books.nap.edu/books/0309082943/html/5.html#pagetop

	SEALs (ppm)[a]		Recommended SEALs (ppm)[b]	
Gas	SEAL 1	SEAL 2	SEAL 1	SEAL 2
Ammonia	25	75	75	125
Carbon monoxide	75	85	125	150
Chlorine	2	5	1	2.5
Hydrogen chloride	2.5	25	20	35
Hydrogen cyanide	1	4.5	10	15
Hydrogen sulfide	10	20	15	30
Nitrogen dioxide	0.5	1	5	10
Sulfur dioxide	3	6	20	30

[a]ppm, parts per million

[b]The subcommittee’s recommended SEALs are for an atmospheric pressure of 1 at 25°C Values obtained for the gases using Dräeger tubes or other measurement devices in a disabled submarine might need to be corrected to an atmospheric pressure of 1 and 25°C.

Chlorofluorocarbons CFC and Hydrofluorocarbons HCF

CFC and HFC are refrigerants that can escape out of air condition systems or dehumidifiers. Formally been used chlorinated fluorocarbons (like R12) are being replaced by hydrogen fluorocarbons which are not that harmful to the ozone layer of the atmosphere. The established exposure guidance levels are taken over for the new surrogates. HFC-236fa and HFC-404a (replacing CFC-12 and CFC-114) have

	a hour limit of	2000 ppm and
	a 24 h limit of	1000 ppm and
	a 90 days limit of	100 ppm.

For HFC-23 the same limits apply. It is generated when HFC 236fa is passed through a submarine's carbon monoxide and hydrogen burner. No fixed instrumentation from Dräger Safety available to do the job.

Solution from Dräger

Name	Formula	Source	Task	common Threshold	Transmitter	Sensor
Carbon dioxide	CO2	breathing air, fire extinguisher	breathing air control	5000 ppm	Polytron IR CO2	
Oxygen	O_2	storage and generator	breathing air control and leak detection	19 Vol % or 200 mbar	Polytron EC	6809630 6809720
Carbon monoxide	CO	fire, exhaust	toxic threshold	30 ppm	Polytron EC	6809605
Hydrogen	H2	storage and battery	leak detection		Polytron EC Polytron Ex/SE Ex	6809685 LC
Chlorine	Cl2	electrolytic generation	toxic threshold and corrosion protection	0,1 ppm	Polytron EC	6809665
Nitric oxides	NOx	exhaust	toxic threshold	5 ppm	Polytron EC	6809625 6809655
Hydrogen cyanide	HCN	exhaust	toxic threshold	10 ppm	Polytron EC	6809650
Sulfur dioxide	SO2	acid from batteries	toxic threshold	2 ppm	Polytron EC	6809660
Hydrogen fluoride Hydrogen chloride	HF HCl	decomposit and off-gassing	corrosion protection toxic threshold	3 ppm	Polytron EC	6809640 6810595

Transmitter

Polytron 1
Polytron 2
Polytron XP Tox
Polytron TX
Polytron 3000
Polytron 7000

Ex-Transmitters with pellistors for monitoring LEL:

Polytron SE Ex,
Polytron Ex,
Polytron TX
Polytron 2 XP Ex
Polytron SE Ex LC
Polytron Ex LC

Installation hint

Polytron EC transmitter will need a small drilled hole in the housing to allow for fast pressure tracking and avoid pressure differences between transmitter inside and environment

Advantages of the Dräger Solution

Industry approved equipment
Build in pressure release system allows extreme dynamic changes without harm or interference.
Compensated environmental conditions
Ease of maintenance
Naval approval for Polytron family from: Det Norske Veritas and Lloyd's Register
Polytron 1, Polytron L, Polytron Ex und Ex-R, Polytron SE Ex
Polytron 2 Offshore und Polytron 2 IR

Restrictions

Cross-talk of dynamic partial pressure change on Volume Percent measurement with O_2 LS 6809630
H2 cross-sensitivity of electrochemical sensors
Pressure release hole in the transmitter body for pressure release

Appendix

Dräger Review 87 8/2001
Monitoring of the submarine atmosphere composition

http://www.chemistry.usna.edu/plebechem/112pdf/subair02.pdf

http://www.chinfo.navy.mil/navpalib/cno/n87/usw/issue_10/breathe.html

List of world-wide diesel subs:
http://www.empire.net/~xmp/diesels.htm

http://lab.nap.edu/nap-cgi/discover.cgi?term=submarine&restric=NAP

Review of Submarine Escape Action Levels for Selected Chemicals ISBN 0-309-08294-3

Submarine Exposure Guidance Levels for Selected Hydrofluorocarbons: HFC-236fa, HFC-23,and HFC-404a ISBN 0-309-07084-8

Drawings & Pictures